FINAL REPORT

Total Cost of Transportation analysis of road and highway issues

Phase II
A restudy of Iowa county roads using FY2002 data

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Stephen W. De Vries, P.E.
Iowa County Engineers Association
Service Bureau
501 SW 7th, Suite Q
Des Moines, Iowa 50309

Abstract

A prior project, HR-388, (which was entitled Total Cost of Transportation analysis of road and highway issues), explored the use of a total economic cost basis for evaluation of road based transportation issues. It was conducted as a proof-of-concept effort between 1996 and 2002, with the final report presented in May 2002.

The basic total cost theory developed and tested in HR-388 was:

a) That a road 'system' is more than just the roads and bridges. It also includes and consists of vehicles, human resources, supporting facilities, and enabling institutions.
b) The operation of the overall system produces fixed, distance based, and time based costs from the following sources: road network, vehicles, human resources, accidents, business/economic expenses and socio-environmental impacts.
c) The sum of all fixed, distance, and time costs from all sources is the Total Cost of Transportation
d) The objective of operating and improving the road network is to reduce the distance and time based costs of the total system.

Using data from Iowa's county road network, the TCT theory was explored, tested and shown to be both valid and workable. At a final briefing, county engineers requested that that the study be re-done using current, 2002, data instead of the 1988 data on which HR-388's analyses were built. This was proposed and approved to be performed as TR-477.

TR-477 rebuilt the analytical model using current data, then performed general, system level, county level, and road segment level analyses. The results are presented herein and will be distributed to all county engineers for information and local use.

Key findings included:

a) That the county road network is economically appropriate and adequate for the traffic it serves.
b) That current road use and property tax rates are not set high enough to permit the county road system to be completely self-funded.
c) That about $402 million in level of service upgrades were justifiable in fiscal year 2002.
d) It is possible to obtain consistent results for the entire system, county-by-county, and segment-by-segment.

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Important note :

Because the data tables that present the results of this project are quite large, it was necessary to format them to be printed out on 11x17 sheets. Since binding such pages into an otherwise 8½x11 formatted booklet is cumbersome both for author and reader, they have been bound separately, in a supplemental document. As you read this report, please refer to the supplement to locate and view the tables that the text refers to.

TR-477 Final Report

TOTAL COST of TRANSPORTATION Analysis – Phase II

Evaluation of Iowa Secondary Roads using 2002 data

Introduction

This project is a follow up to a prior research effort, Total Cost of Transportation analysis of road and highway issues, TCT, conducted as HR-388. That project explored evaluation of transportation issues via the total economic cost of travel and transport occurring within a road network. It defined the term 'transportation system' to include all things required to move goods and people: roads, vehicles, human resources, supporting businesses and institutional framework. The economic costs of all such items were identified, expressed as dollars per vehicle mile of travel, then summed into a special spreadsheet to find the least cost (or optimal) road types for various levels of traffic. HR-388 used the resulting tally of costs to test whether or not the data could be used to evaluate transportation issues, help with road improvement decision making, and identify needs. The study concluded that these items were feasible with the TCT methodology and that the theory was valid. In the process, it generated a large number of findings regarding Iowa's county road network.

A two part model of the county roads and their traffic was built to implement and test the TCT theory:

1) a physical model to represent miles and type of road, traffic, activities levels, and speed, and
2) a financial model to express costs in per-VMT figures.

The physical side of the system was represented in a spreadsheet that encapsulated road types, traffic levels, mileage, and speed of travel in a single tabulation. A matching worksheet modeled the economic side of the system, computing the costs arising from the operation of the physical components. Taken together the paired worksheets provided a basis for asking and answering a variety of transportation network management and engineering questions.

Final conclusions from HR-388 were:

- That the overall TCT concept was a valid way in which to frame and evaluate transportation issues.

- That a combination database/spreadsheet model was a viable method for representing the size, scope, activity levels, and economic cost of a road system.
- That the concept was scalable: able to be employed to make general design guide decisions, and to perform evaluations at the system, jurisdiction, project, and road segment levels.
- That the concept could be applied to a variety of activities: paving justification, design exception analysis, comparison of alternates, evaluation of service adequacy, determination of capital upgrade needs, estimation of revenue needs, forecasting future system size/composition/activity, judging transfer of jurisdiction proposals, and studying whether to maintain or close low volume facilities.

TR-477 Objectives

Work on the HR-388 study began in 1996 and reached completion in 2002, with the final report presented in May 2002. As a result, the source data obtained from 1996 through 1998, while adequate for developing and testing the TCT concept, was out of date. This meant that the detailed analysis sections were only valid for showing how TCT might be applied – not for drawing relevant, current conclusions -- because their results were obsolete. County engineers attending a final briefing found this frustrating and asked if the study could be redone using fresh data so that 'present day' results could be made available. Since some of the original funding remained unused, this was proposed to and approved by the Iowa Highway Research Board, resulting in this project, TR-477.

The objective set forth for the Phase II study was: "To use the Total Cost of Transportation methods developed in HR-388 to conduct a current assessment of county road adequacy, budget needs, and improvement needs." -- on both a statewide and county-by-county basis.

TR-477 Preparation

Before a Phase II study could be performed, all source data had to be either recollected or re-verified. The following actions were taken to renew the data in the TCT model:

- 2002 road and bridge data was obtained from the Iowa Department of Transportation. This included 154,083 county road-segment and 19,554 bridge records. This information was processed into the format needed for TCT modeling and cleaned up to eliminate data problems.
- A recheck of ALAS data showed that accident rates had remained about the same as for the HR-388 study.
- 2001 vehicle and driver data was downloaded from the Iowa DOT's Motor Vehicle Division
- FY 2002 County Engineer Annual Report data was combined with FM letting reports, tallies of Federal Aid allocations to counties, and DOT Road-Use-Tax estimates to compute updated road and bridge costs.
- Additional research and estimating was done to develop a refined 'speed-of-travel' estimate for all combination of road types and traffic counts.

TCT Model reconstruction

After the data had been gathered, processed and organized, it was used in the rebuilding of both the TCT physical and economic models of the Iowa county road network via a multi-step process:

a) DATABASE WORK

   The basic road data obtained from the DOT came in the form of an Access database. This information was processed, via a number of queries, to prepare it for analysis:

   a. DOT type-of-surface codes were reduced to TCT surface categories. **Table 1** shows how DOT codes were mapped to TCT surface classes.
   b. This data was then combined with pavement width, shoulder data, and structural indices to compute "Level of Service", LOS, scores for each road segment.
   c. The LOS scores were mapped into values ranges corresponding to 14 pre-defined Levels of Service and each road segment was assigned an appropriate LOS index number. **Table 2** shows the 14 LOS categories and their LOS score ranges.

d. Each road segment was assigned to one of 24 logarithmically defined traffic ranges, which covered AADT figures from 1 vehicle per day up to 109,650 vpd. Since the highest recorded county traffic level was 14,500, only 19 traffic bands were actually needed. **Table 3** contains the data used to assign traffic bands to the road segments.

e. Bridge data was reduced to square feet of bridge deck per mile and appended to pertinent roadway records.

f. Additional, derived figures, such as total annual VMT and estimated traffic in 5 years and 20 years were computed and appended to the records.

g. After the database preparations were complete, a cross-tabulation was performed to find the miles of road associated with each combination of roadway type, (also called Level of Service, or LOS), and Traffic band. This divided the 89,689 mile county road network into 266 (14 LOS x 19 T-bands) separate mileage figures. These results then formed the Physical model spreadsheet.

h. **Table 4** presents the physical model: the number in each cell represents the number of miles of roadway that have a particular level of service and fall into a particular traffic band. Collectively, the 266 main cells show the system's size, characteristics, and activity. Related tables also link typical speed of travel, vehicle mix, accident rates, and trip purposes to each LOS/T-band combination.

i. Average speed of travel figures were re-estimated for each LOS/T-band combination. See **Table 5**

b) COST MODEL RECONSTRUCTION

Various sources of roadway cost information were combined to rebuild an accurate tally of all expenditures made for secondary roads in FY 02.

a. All cost data -- from all the sources in the preparation section -- were combined into a master cost sheet, then distributed into TCT expense categories. From this, estimates of Administration, Engineering, Operations, Maintenance, Repair, and Depreciation (or reconstruction) were prepared and transferred to the Road Costs sub-page of the cost model worksheet.

b. The Depreciation data was cross referenced with the physical parameters of the various levels of service to compute original capital costs, rates of depreciation, and current net value of road/bridge assets.

c. Asset values were then used to compute "cost-of-capital" figures for each LOS

d. All road costs were then totaled to compute a cost per mile per year for each LOS, then converted to a per-VMT basis for each LOS/T-band combination.

e. Vehicle costs per VMT were computed, starting from the overall mix of vehicle types in the motor vehicle fleet and determining per VMT figures for each LOS in each traffic band.

f. Cost of paid labor time consumed while people travel in vehicles was computed from available statewide wage rate data, information of trip purposes, and average speeds of travel. Accident costs were reused as-is from the HR-388 cost tables.

g. Business/Economic, Social/Environmental, and Offset items were also reused from the HR-388 cost tables.

h. **Tables 6a through 6h** present the cost per VMT for each of the major cost sources:

6a = Per VMT cost of Road/Bridge network including capital costs
6b = Per VMT cost of operating a motor vehicle
6c = Per VMT cost of paid time consumed while people are in vehicles
6d = Per VMT costs of accidents
6e = Per VMT business and economic costs
6f = Per VMT social and environmental costs
6g = Per VMT offsets, or reductions, in other societal costs due to use of road transport
6h = Total per VMT cost of travel in each LOS / Traffic band combination.

c) COST TO UPGRADE ESTIMATES

Based on first costs estimated in estimating capital costs and using construction figures obtained from the DOT's 2002 re-run of the Quadrennial Needs Study, the costs to upgrade, (and in some cases to downgrade), roads from one service level to another were computed. Since the depreciation figures included the cost model already cover the funding needed to periodically renew each roadway, the upgrade figures represent the extra capital needed when it becomes necessary to improve rather than just maintain a given LOS. **Table 7** shows the cost figures, per mile of roadway, representing this incremental cost figure.

d) IDENTIFICATION OF OPTIMAL LEVEL OF SERVICE FOR EACH TRAFFIC BAND

A search was performed to locate the LOS in each Traffic Band that exhibited the <u>least</u> cost per VMT. This identified an 'optimal' Level of Service for each band. Then, by subtracting the least cost amount from the per-VMT costs in each LOS in the traffic range, the net cost savings, per VMT, from converting a roadway from non-optimal to optimal was computed. The present worth any savings achieved by such a change, (based on a 20 year evaluation period), was then divided by the incremental cost to see if the change would be justified. These results were called Savings* to Cost ratios.

* The net $\text{savings}_{\text{per mile}}$ were computed via the following formulas: [Per VMT savings] x [Avg Traffic count of T-Band] x [365] = [YearlySavings]; Present Worth, (of YearlySavings) = $PW_{20\ \text{Years}}\,[\text{Yearly Savings}]^{i=8\%APR}$

Table 8a shows the per VMT savings calculated for upgrading, or downgrading, any non-optimal road segment to the least cost LOS in each traffic band. **Table 8b** shows the corresponding cost of adjustment, in $dollars per mile, to convert road segments from a non-optimal LOS to the optimal one.

Table 8a's results suggest that gravel is the best level of service to provide for traffic levels up to 53 per day and that pavement becomes justified at around 580 vehicles per day. In between, the model seems to recommend hard surfacing – a waterproof surface over a granular base. The physical model shows that actual road types now serving the 53 to 580 vpd traffic range are a mixture of gravel, hard surface, and pavement surfaces– suggesting that engineers have not found it difficult to decide how to best serve this traffic range. The model seems to imply that it would be better to hard surface gravel roads earlier than is done in current practice, but to do so with less grading and widening. This would provide the public with much of the benefits achieved through complete re-grading and paving, and postpone those more expensive options until traffic volumes were in the +500 vpd range.

EVALUATON OF SAVINGS TO COST RATIOS

Each of the 266 LOS vs. Traffic Band combinations defined in setting up the physical model were classified according to their relationship with the optimal Level-of-Service in their T-band and the magnitude of their Savings to Cost (S/C) ratios:

a. Combinations that had a S/C ration of 1.00 or less were labeled '**Adequate**' -- meaning that even though they weren't optimal, they were close enough to it that upgrading them would not be cost effective.

b. Combinations where the LOS exceeded optimal and the S/C ratio, of downgrading to optimal, was greater than 1.00 were labeled as '**Exceeds Current Needs**'. Road segments in these categories exhibit a higher fixed cost than is really appropriate for current traffic levels. This does not necessarily mean that they should be downgraded, though. In most cases they've been designed to serve a traffic level that will be realized a few years into the future.

c. Combinations where the LOS fell below optimal and the S/C ratio, of upgrading, exceeded 1.00 were identified as needing to be improved. Those with S/C ratios between 1.01 and 4.99 were labeled as '**Upgrade warranted**' and those with S/C ratios of 5.00 and above were labeled '**Upgade Urgent**'.

d. **Table 9** shows the Savings to Cost ratio, for adjusting a section of road to optimal, of each LOS / Traffic band combination. Each cell has been color coded to show whether it is Adequate, Exceeds Current Needs, Upgrade warranted, or Upgrade Urgent.

Analysis and Results

The following sections present and discuss the findings extracted from the TCT physical and costs model after they had been set up and the LOS/T-band combinations classified. The analysis commences with generalized observations regarding the overall Road/Vehicle based transportation system. It then progresses towards greater detail for three lower levels: the statewide county road network, the status of individual counties, and finally specific road segments. The goal of this section is to demonstrate what information may be drawn out of a TCT based model of a transportation system and to evaluate Iowa's county road network.

GENERAL SYSTEM LEVEL

The Total Cost of Transportation theory, as developed in HR-388, views the transportation system as consisting of everything required to move goods and people. It thus views the system as being made up of not only roads and bridges but also vehicles, vehicle sales and support, human resource time, laws, institutions (such as the auto insurance industry, and auxiliary facilities. The theory further holds that the sum of all things consumed or given up in moving goods and people, denominated in dollars, is the total cost of transportation. The economic objective of building and operating highways is to minimize the total cost – by shortening travel distances, decreasing travel time requirements, and improving safety.

The TCT physical and cost models facilitate the study and comparison of the various source costs within the transportation system and enable identification of ways to work towards the least cost configuration. The remains paragraphs of this sub-section explore what can be learned from the model about the entire system.

Magnitude and relationship of major cost elements

Table 10a shows the computed total costs per year for the general system. Contributions for roads, vehicles, paid time, accidents, economic, socio-environmental, and offsets are listed, and summed, for all Levels-of-service. Each column of costs are then totaled.

The overall grand total amounts to $7.120 Billion per year, or about $19,755,000 per day. (which works out to about $1.42 per VMT.) About 53% of the cost derives directly from the sales, operation, maintenance, and storage of vehicles. Another 29% comes from the cost of wages paid to people as they drive or travel, with accidents adding another 3.5%. The road network completes the cost picture at about 14.5% (Roughly 16% minus a 1.5% cost offset). The Economic and Socio-environmental costs for secondary roads not accounted for in the cost of construction are almost negligible.

Of the total roadway cost, only $477 Million, (6.6%), is actually from direct expenditures made by road departments. The remaining three fifths comes from the cost of capital invested in the system, the legal/financial institutional framework in which it exists and auxiliary items.

Vehicle operations and the cost of paid time represent the two largest costs. If the objective of building roads is to reduce or minimize the total cost, then the incremental cost of improving a road must be offset by the savings achieved through reduction of the vehicle and paid time components. Thus road improvements a) need to reduce travel distances – by offering drivers the shortest, most direct routes possible and b) by enabling sufficient speeds to keep paid travel time costs down. At the county level, therefore, the cost model endorses provision of an extensive network that will provide direct routes for almost every conceivable trip. When enough trips concentrate upon a particular route, then it becomes important to enable a speed of travel that will keep the paid time cost component down. This is what justifies improving the level of service. A resultant observation is that if, as is sometimes argued, an attempt was made to reduce the overall size of the road network by closing little used segments – something that would tend to increase travel distances – it would need to be accompanied by surface upgrades on other routes to provide an offsetting savings in travel time costs.

The annual amount currently spent on improving the road system is about $22 Million, (over and about that spent to maintain and repair things), -- or about 0.30% of the general system total. Since, as will be seen in the next main section, it appears that the county road system is mostly adequate for the traffic carried, it appears that this modest annual increment in service level has proven relatively effective at helping keep general TCT costs down.

<u>AOEMRD costs vs. Upgrade costs</u>

In determining and allocating road/bridge network costs, TR-477 identified seven major cost categories. Of these, six relate to system operation and preservation. They represent the cost of maintaining the roads and bridges in a 'steady state' condition. The seventh one pertains to the expense of making service level improvements when/where appropriate.

The first six are as follows:

A : Administration – covers the costs involved in operating and managing a road system

E : Engineering – covers the cost of technical work, design, and construction management.

O : Operations – includes the expenses incurred in keeping the system in operation – i.e electricity for lights, and the cost of sand & salt spread for winter traction.

M : Maintenance – funds expended to keep assets from deteriorating – such as painting steel.

R : Repairs – funds expended to patch and restore sub-sections of otherwise sound assets.

D : Depreciation – those funds expended to restore a deteriorated asset back to "as-good-as-when-first constructed" status.

The AEOMRD figures can be estimated accurately and uniformly – and will typically not change much from year to year. Thus, they might be useful in determining how much road-use and other tax monies ought to be spent by each county per year to keep their existing system in shape. The AEOMRD figures do not, however help evaluate the adequacy of that system or help identify where it ought to be improved. Thus, the determination of Savings to Cost ratios for various Level-of-Service changes is needed to determine where improvement funds, (the seventh cost category), ought to be spent. In general, the goal will be to expend the money where it will most reduce vehicle operation, paid time, and accident costs

Table 10b shows the computed AEOMRD figures for the county road network. Traffic bands 3, 4, and 5 show a localized maximum for low volume service – which no doubt reflects the cost of keeping granular surfaced roads rocked. A similar increase across the traffic bands most often served by pavement probably reflects a combination of winter sand/salt applications and the cost of periodically reconstructing the pavement.

Design implications of the TCT model

Because the TCT model helps identify an 'optimal' Level-of-Service for each traffic band, it can help with the determination of guidelines as to what level of improvement is warranted on any given road. **Table 10c** shows the traffic count range for which each Level-of-Service was found, by the model, to be optimal. Because the same LOS is often appropriate for several side-by-side traffic bands, the entire range of traffic of county road traffic volumes appears to be best served by just seven specific LOS categories. A general inference that could be made from these results is that, when making an upgrade, it's best to improve to the highest category of the target LOS type. It suggests that one overbuild a bit, so as to not have to reinvest again soon.

Traffic counting & estimating concerns – a special note

Since the results of the TCT model or any other method of calculating road needs depends heavily on traffic count data, it is important that it be as accurate as possible. And, to whatever degree it falls short of that goal, it should at least be of a uniform level of precision statewide.

In the process of preparing this study, however, the author found problems in both uniformity and perhaps how much confidence may be placed in traffic count and growth rate figures contained in the DOT base records. This came to light when 1988 data, obtained for the HR388 project, was compared to the 2002 information used for this one. **Table 10d** shows that the four-year change in traffic counts implies that there are both positive and negative traffic count trends around the state. The growth rate factors estimated by the DOT and stored within the base records, in contrast, show only positive growth rates. In other words, recorded growth rates are inconsistent with the reported change in traffic counts. Further, there is considerable variance in traffic growth both within the column showing derived growth factors, (second column from the right), and between the two growth rate figures for any one county. It appears that it would be advisable to expend some extra money to improve the accuracy and internal consistency of traffic count data for secondary roads.

ROAD NETWORK LEVEL

This section explores what can be learned from the use of TCT about the statewide network of county roads. Such information will not have application in the day to day operation of any one county but may prove useful in informing elected officials and educating the public about the role of county roads.

Service analysis

Table 11a displays, via color coding, which LOS / Traffic band combinations, and hence the miles of road within them, fall into the four service categories of Adequate, Exceeds Current Need, Upgrade warranted, and Upgrade Urgent.

- The greatest portion of system miles fall within the "Adequate" zone, and the percentage of miles within each traffic band that are so labeled is very high except in bands 8 & 9, (116 to 260 vpd). The cost figures developed in the model suggest that the miles in T-bands 8-9 ought to be upgraded from granular to hard surface. The fact that so many aren't reflects the tendency of road designers to stay with gravel until a full paving upgrade becomes justified. This is sometimes by deliberate choice and sometimes because limited funds prevent making improvements at an earlier stage.
- Most miles that fall into the Exceeds Need category are in the very lowest traffic bands, where it's hard to provide any service at all without exceeding that which the traffic justifies. Most "Exceeds need' segments appear to be granular surfaced not paved.

The mini-summary at the bottom of **Table 11a**, shows system miles summed into each of the four service categories, then totaled at the bottom. This data appears to indicate that the current county road network 'fits' the traffic it serves quite well. Overall, the network rates 96.27% Adequate. Just 0.87% of the mileage falls into the Exceeds Current Need category and only 2.86% appears to need improvement. TCT methods, therefore, suggest that the county road network is appropriate in both size and complexion.

Annual budget and capital needs

Table 11b shows the results of multiplying AEOMRD per VMT costs times traffic counts and mileages. The computed totals amount to $455 Million per year, which corresponds well the actual amount of $477 Million per year less $22 Million spent on system upgrades. Most of the system cost lies in the traffic ranges under 200 vehicles per day. About 60% of all expense comes from maintaining the granular and earth surfaced parts of the network.

Cost of optimizing service

Table 11c shows a tally of estimated upgrade costs, broken down by Level-of-Service and Service Category. In all, the tally shows that a total of $9.933 Billion could be spent -- if an attempt was made to fully optimize the entire system. However, costs that fall in the Exceeds Need and Adequate categories can be ignored, since they would not bring sufficient savings to justify being expended. This leaves $404 million of upgrade needs in the Upgrade Warranted and Urgent groups. This is a substantial number but amounts to only $4 Million per county – or roughly $400,000 per year if financed over a ten year period. So, while the need is substantial, it isn't completely beyond Iowa's means. Currently, we appear to be expending $22 million per year for system upgrades, so a doubling of commitment would appear to be sufficient to enable such a ten-year program. Another way to look at things would be to say, roughly speaking, that the data supports the idea that capital improvements ought to be budget at about 9-10% of the AEOMRD needs – but it must also be recognized that upgrade needs vary widely from county to county.

<u>Revenue generation vs. costs.</u>

In **Table 11d**, an effort has been made to compare the Road Use + Property tax generation capabilities of the Secondary Roads network to the cost of serving the traffic that uses it. The annual cost column shows the cost of each LOS, as computed from the model. The VMT column was multiplied by $0.045 per VMT to estimate the total amount of State and Federal road taxes generated by each mile of travel. Property taxes were apportioned on a per mile basis, then combineded with the Road tax revenues to compute total revenue generation by Level-of-Service. Net figures, (revenues – expense), and cumulative net totals were then computed and compared to system miles.

The table was then divided into three sections with color coding:

a. – Green – the roads that produce more revenue than they cost to operate.
b. – Yellow – roads that cost more than they generate but whose 'losses' are covered by the excess from the 'a' group
c. – Orange – additional roads which cost more than they produce in tax revenue.

The revenue positive roads comprise the top 17%, ('a'-group) of the overall network. They produce enough revenue that they finance the cost of another 7%, (the 'b'-group), resulting in 24% of the system being revenue adequate. That means that the remaining 76%, the ('c'-group) costs more to operate than it produces in revenue. As a result, the county road system consumes roughly $87 Million more dollars per year than it generates. The difference is financed with funds generated on the state system, (which is almost completely revenue positive), and city streets.

This situation does not indicate that county roads are overbuilt, however. It merely shows that Iowa has not been politically inclined to set road taxes high enough to make county roads self-funding. For example, the limit on the amount of funds that can be transferred from the Rural Basic account has been $3.00375 for many years. If that limit had been adjusted for inflation, say at 2.5% per year, it might now be $4.92199 per $1000. Had this been done, the property tax contribution alone would be about $90 Million more per year, covering the current shortfall completely. Alternately, the same could have been done with the State fuel tax – with similar results. Also, the ethanol gas tax subsidy causes gas tax revenue to fall short of full potential.

COUNTY LEVEL

The results presented at this level show data for each of the 99 counties in Iowa. This permits comparing them against each other to find similarities, differences, and shared issues. Such information shows relative needs, service adequacy and suggests budget levels. While it might someday be possible to use the results to decide funding allocations, the model would first need further refinement.

Service adequacy classification and rankings

The first area of county-by-county investigation was to compare their service adequacies. This was done by creating a special database table that linked each LOS / Traffic band category to a status of "Adequate", "Exceeds Current Needs", "Upgrade warranted", and "Upgrade urgent". A consolidating query then generated a table of all road segments showing their length, county, and status. A cross tabulation was made of the consolidation query results to compute how many miles of each county's network fall into the four service adequacy categories. **Table 12a** shows the results of this effort.

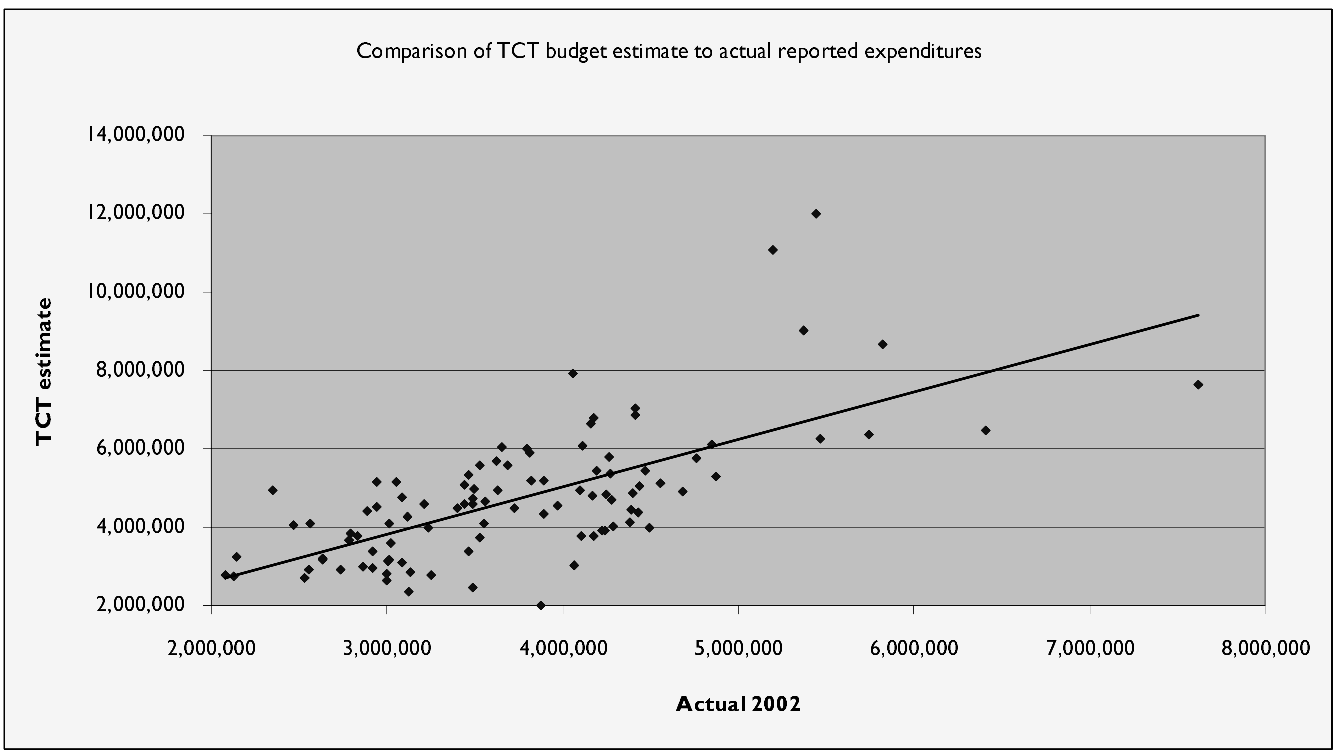
The data shows that service is generally good: statewide, 97.06 percent of county road miles fell into the "Adequate" category. (and Delaware County comes the closest of any to providing average service.) When the table was sorted from lowest percent adequate to highest, the ten counties with the lowest percentages of adequate miles were: Johnson, Des Moines, Linn, Warren, Lee, Wapello, Henry, Marion, Scott and Dubuque. All of these counties are in eastern Iowa or adjacent to the Des Moines metro area and probably have had traffic grow faster than they have been able to keep up with. The ten with the highest percentages were: Worth, Osceola, Taylor, Humboldt, Greene, Cass, Adams, Floyd, and Decatur. These counties are typically rural, with stable or perhaps even declining populations. This appears to have enabled them to reach a good match between traffic and level of service provided.

Although all counties have maintenance and reconstruction needs proportional to the size and composition of their road networks, upgrade needs vary widely. Since TCT identifies needs as being where a road must be upgraded to a higher level of service in order to reduce total system cost, the counties with the lowest percent of adequate miles are the ones with the greatest upgrade needs, and vice versa. If one were to set a goal of having all counties having no more that 4% of their system in the Upgrade categories, one would find themselves distributing upgrade funds to only 25 of them, as that would essentially define three quarters of the counties as needing only to maintain what they already have. This is yet another indication that counties road networks are very well adapted to the traffic they serve.

The percentage of miles deemed to Exceed Current Needs is relatively small. The statewide average is only 0.85% and the highest is just 2.99%. The presence of Exceeds Needs miles seems to be erratic, with both wealthy urban counties and some less affluent rural counties in the top 10 of this group.

Annual budget needs

An attempt was made to use the TCT model to predict how much money ought to be spent by each county per year to manage and maintain its secondary roads. **Table 12b** shows the analysis. The AEOMRD cost figures were multiplied times the mileages and traffic counts of each LOS / Traffic band in each county. The results were totaled to compute an estimate of annual expenditure needed to sustain the roads in a steady state condition. These figures were then compared to the actual amounts expended in each county in FY 2002. As can be seen for the chart below, there was some correlation, but the dispersed data points suggest more work will be needed in this area.



The TCT results are also being used to assist with a study of county road-use-tax allocation methods being conducted by the "Secondary Road Fund Distribution Advisory Committee" – a body charged with this duty by the state legislature. Better correlations have been found between TCT data and long term averages of past allocation factors, so investigation will continue in this area.

Upgrade needs

The first sub-section under the County Level heading explored how many miles were adequate and how many needed to be upgraded. This part explores how much money would be needed by each county to make the upgrades. In **Table 12c**, the Roads column shows how much capital improvement funds the TCT model suggests are needed to move lower LOS roads up to their traffic band optimums. The bridges column also shows an estimate of how much additional money may be needed as bridges are widened and lengthened to fit the higher Levels of Services of their roads. In reviewing these upgrade cost figures, it is important to remember that they represent only that part of cost required to build a replacement facility to a higher standard than the old one. Thus they must be added to the cost of replacing the old item "as-is" to get a total estimated cost for project budgeting purposes.

ROAD SEGMENT LEVEL

The final area of investigation in the Phase II study, was to identify actual, individual road segments and list them for review. This was done to test the model's scalability, (how able it is to serve both overall system assessments as well as to help identify individual road segments by need or other classification.) To do this, update queries were designed tag each road segment with a target optimal LOS, cost to upgrade to that LOS, an estimate of potential 20 year savings from doing so, and the resulting Savings to Cost ratios. Once this was completed, it became possible to extract lists of specific road segments and extract cross tabulations.

While the data from this section is presented in the form of tables, there would be a lot of merit in generating color coded maps to report findings. This option wasn't explored in this study, but would be a logical, easier to understand way to present results. With the availability of modern electronic mapping tools, one could compress thousands of data points into color coded county outline maps or maps of each county with the road segments highlighted according to their status.

Road miles needing upgrade by road class

The first table in this section, **Table 13a**, is a cross tab that shows how many miles needing upgrade are from Local, FM, FM/FAS, and FAS+ route classes. Some 45 percent of the upgrade candidate mileage is local, 37 is classified as FM. Another 14 percent is both FM and Federal Aid, with the remainder being roads of still higher classification. Since the higher class roads typically carry more traffic, this table suggests that counties have prioritized upgrading service in such corridors over doing so in lower traffic areas. This approach is consistent with the TCT principle of investing dollars where they will be most effective at reducing total system costs.

Segments in Upgrade Urgent category

Table 13b shows the road segments classified as Upgrade Urgent through their Savings to Cost ratios. They were selected for inclusion in this list because their S/C ratio exceeds 5.0. They exhibit the greatest mismatches between Level-of-Service and traffic counts in the entire 154,000+ record database. Some of them will, upon investigation prove to actually be OK – having gotten into this category because their base record data is incorrect. The rest should legitimately be top candidates for upgrade. The road segments are identified via a text label that includes county ID, Township, Range, Section, and Road Segment ID number. For example, the road "C01-T075R32S13-RS05" would be segment 5 in Section 13-75-32 in County 01, (Adair County). If one checks a county map, ones find that this segment is located just southwest of Greenfield, Iowa. Intergraph and AutoCAD formatted maps containing every single road ID can be downloaded from the Iowa DOT's website to facilitate cross-referencing between the table and map

Segments in Upgrade warranted category

Table 13c lists all county road segments that warranted upgrading and had a Savings to Cost ratio between 2.00 and 5.00. This amounted to 1611 segments and fills 23 pages of 11x17 print out. Some counties have only a few segments in the listing, while others ended up with tallies covering up to two full tabloid size pages. The listing shows Route, System Class, Width, Length, Traffic count, Cost to upgrade, current LOS, target LOS, and Savings to Cost ratio.

Segments that might warrant downgrading

The last analysis of this study was to explore whether or not there are any roads that merit serious consideration of having an LOS downgrade. A surprisingly large number of such candidates emerged from a query that looked for road segments where the existing LOS is more than five steps higher than optimal. **Table 13d** lists the ones that were found. As with the Upgrade Urgent category, some will be included in this group because their base record data is wrong, while others will be legitimate candidates for change.

Applications

The TCT theory and model can be used in a variety of ways. It might be employed to perform system administration tasks such as evaluating service levels and assigning road classifications. It can help in the selection of future projects by identifying roads and bridges that need to be upgraded. The results could be used to allocate system maintenance funding or capital upgrade funding. It can also predict how much money the system needs and facilitate educating the public about the value of the road network.

It isn't a tool, however, that would be easy to use on a local level. The work to set up and maintain the background data is the same whether the model is built on a statewide basis or for a single jurisdiction. Thus it would probably have to be housed at a centralized facility and be accessible via the Internet to become widely used.

Conclusions

This second effort at using TCT methodology has demonstrated that:

- The TCT physical and cost models can be refreshed with current data in about two weeks time.
- The model is fully scalable – able to be used on high level, abstract tasks like design guide selection yet also capable of picking out individual road segments.
- It can be used for general investigations, system level analysis, county level tabulations, and road segment level details.

Regarding Iowa county roads, the analyses performed showed that:

- In the overall picture, vehicle and paid time (of drivers and passengers) costs represent 83 percent of the total system's costs.
- The road network contributes 16 percent of the total, of which only 7 percent comes from direct expenditures by road departments. The rest arises from the cost of invested capital and auxiliary items.
- The secondary road system, contrary to popular allegation, is not overbuilt: from TCT's economic cost perspective it is 96.3 percent adequate and probably ought to be improved a bit more.
- Total warranted upgrades total about $404 Million. If implemented over 10 years this implies that $40 Million per year would be required vs. the current level of investment of about $22 Million.
- The DOT's base record traffic count growth rates correlates poorly with actual growth rates computed from the differences between 1988 and 2002 records.
- The county road system does not produce enough road use tax and local property tax revenues to pay the cost of operating it. This does not mean that the system is over built, just that tax rates have been kept too low to permit it to be revenue self-sufficient.