The Application of Groupware Software Systems to Permit Vehicle Routing

Terry D. Leatherwood, P.E.
Tennessee Department of Transportation

ABSTRACT

The development of Interstate and National Highway Systems, within the United States, has caused a transition whereby freight and heavy equipment pieces are frequently transported by truck rather than by rail or barge. This shift in transportation mode distribution has resulted in a sharp increase in the number of overweight and overdimensional permit vehicle movements. Traditionally, State and local governments regulate the movement of these permit vehicles in order to prevent undue stress and damage to the highway system. The movement request is evaluated and, if found to be acceptable, a processing fee is charged and a completed paper "Permit" is issued to the trucking company.

The paper-based methods used to support the above permit issuance process have been overwhelmed by this increased demand. For example, the State of Tennessee has seen average annual increases of almost 9% in the number of permits issued between 1991 and 1997. Unfortunately, the staff resources needed to accommodate this demand have not grown at a comparable rate in most States. In addition, there has been a gradual increase in overall truck weights leading to average annual growth rates of over 14% in permits for vehicles exceeding 667 kN (150,000 lbs.) in total load within the same time frame. This increase in the number of very heavy vehicles has placed a severe burden on the bridge engineers who evaluate these permit vehicles.

To meet this challenge, the Tennessee Department of Transportation, with the assistance of Cambridge Systematics, Inc., has implemented new permit routing software to computerize the permit issuance process. Recognizing that the evaluation of a permit request may require the input of multiple offices (such as the permit office, bridge office, etc.), the new system applies groupware concepts to the flow, storage and processing of permit request data. The system also includes the ability to screen permit requests based upon axle weights/spacings and bridge evaluation features based upon statistical sampling methods. The resulting improvement in operating efficiency has led to increased productivity and allows the Tennessee Department of Transportation to perform adequate regulation of permit vehicles with the limited staff resources available.

THE GROWTH OF PERMIT VEHICLE TRAFFIC

A number of factors have combined to cause a marked growth in permit vehicle traffic in recent years. Some of these factors are the development of just-in-time inventory systems, construction of the modern interstate highway system, and competitive operating costs for heavy trucks. As a result, the movement of freight and heavy equipment is increasingly accomplished by truck rather than by rail or barge. The movement of such oversize and overweight loads is now often considered routine where once it was rare. This growth in permit requests for the State of Tennessee is illustrated in Figure 1 below.

This growth is continuing with the number of permits for fiscal year 1998–99 expected to approach 140,000. Unfortunately, this growth was not accompanied by a corresponding growth in manpower resources within the Tennessee Department of Transportation (TDOT). As a result, the Tennessee Permit and Bridge Inventory offices were in danger of being overwhelmed by the increasing workload. Since increased manpower resources were unlikely to be forthcoming, it soon became apparent that a switch to computer processing of these permit requests was the only hope for improving productivity to match the workload growth.

Development of the new computer system began in 1995 with testing and implementation being completed in 1998. The system is now in production and is used daily within TDOT. The productivity gains made possible by the new system have allowed TDOT to both keep up with the increasing workload and provide better service to the trucking industry.

LESSONS LEARNED DURING THE DEVELOPMENT OF TDOT'S SYSTEM

The system developed and implemented within Tennessee differs markedly from other such systems that have been developed nationwide. This does not stem from a desire on the part of the State of Tennessee to be different. Rather, it stems from our analysis of the permit processing needs specific to Tennessee. As we developed the TDOT system, we learned a number of lessons that may benefit other State DOT's or agencies. These lessons are summarized in the sections following.

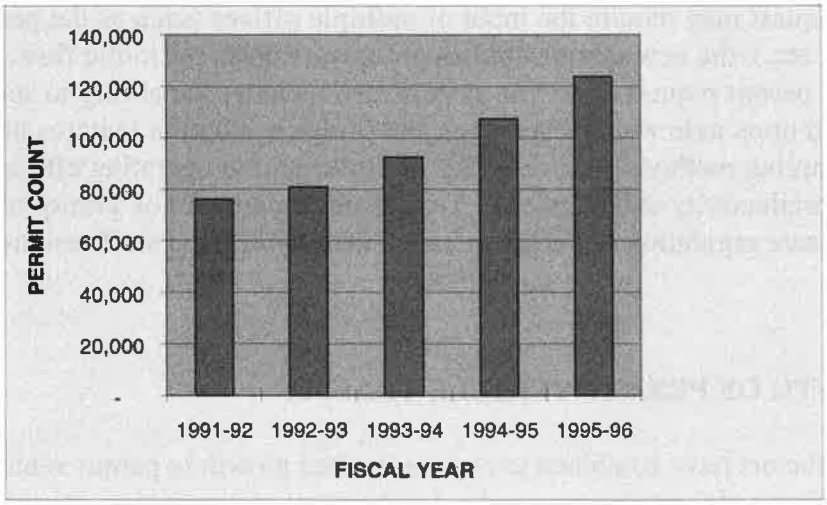


Figure 1: Total permits per fiscal year.

The End Users, on the Front Lines of Permit Processing, Are Valuable Resources: Get and Keep Them Involved in System Development

The Tennessee Department of Transportation is organized using a traditional "Chain-of-command structure. This structure is well suited for most routine activities. However, the processing of permit vehicle requests is one routine activity that cuts across these chains of command. Under our new system, no less than four offices are involved. These would be the Permit Office (which actually issues the permit), the Bridge Inventory Office (which performs bridge analyses), the Information Technology Office (which keeps the computers and local area network functioning) and the Finance Office (which collects permit fees).

To account for this diverse nature, a core development team was selected with representatives from the Permit, Bridge Inventory and Information Technology Offices. In addition, input was solicited from a number of other sources and offices. The development and testing of the system directly involved the end users with their suggestions guiding system development. This resulted in a system that the end users could understand and support. This effort paid dividends when it came time to implement the new system as indicated by the following launch timeline at TDOT.

- 10/08/1998—Training session to introduce the system to external users
- 10/09/1998—First external user installs and configures software
- 10/16/1998—System goes "on line" with first set of permit requests being processed
- 10/23/1998—TDOT approves the 1000th permit request (value approved—$60,000)
- 10/26/1998—Volume exceeds 200 permit requests per day (valued at $12,000)

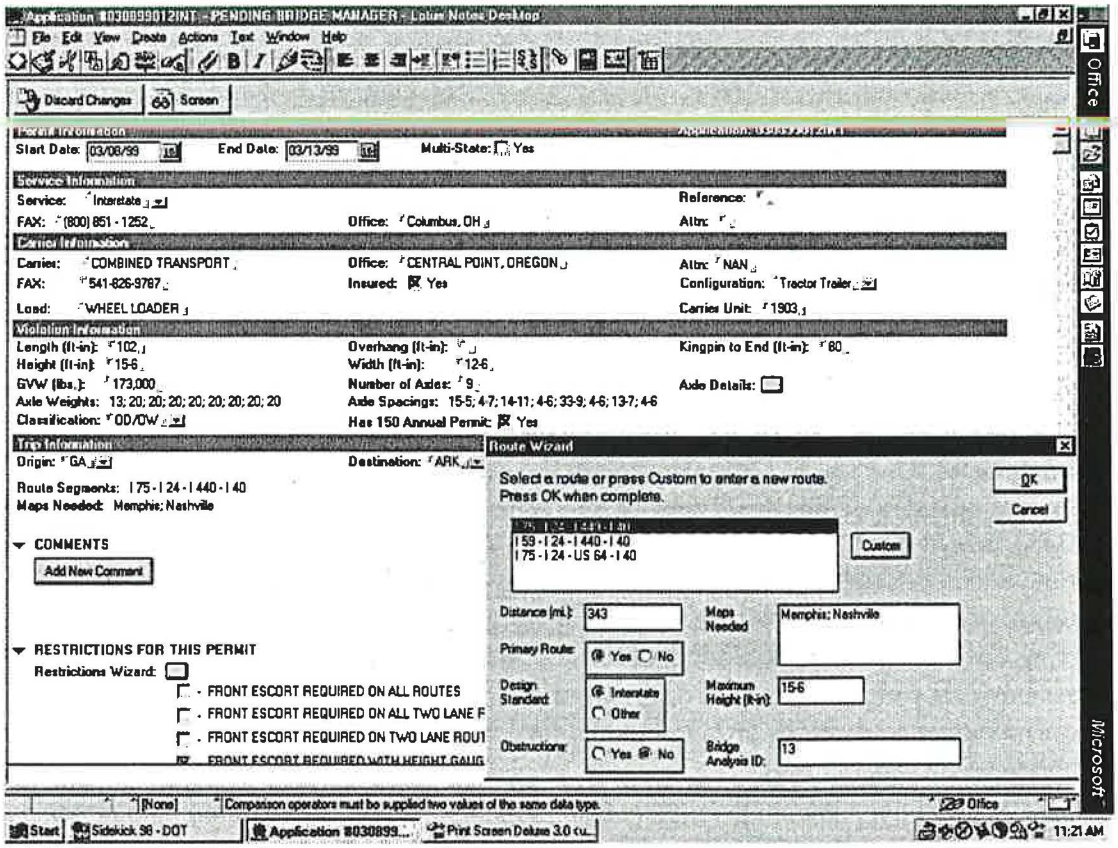
Do Not Automatically Assume That a Geographical Information System (GIS)-Based Map Interface Is Required for Effective Processing of Permit Requests

The design team began the development of the new permit system with a number of preconceived ideas, one of which was that a map based GIS interface was a necessary requirement for the system. Concurrent with the development of the permit system, TDOT was also developing the Tennessee Roadway Information Management System (TRIMS), which does include a GIS. However, TRIMS was still under development at that time and was considered unproven. In addition, GIS systems have often developed a reputation of being difficult to maintain, of being expensive to implement and of requiring cutting edge computer equipment to function at adequate speeds. So rather than just assume that a GIS was required, the team looked at historical patterns of permit vehicle movements to see if the benefits of a GIS interface would warrant the development cost and effort.

The resulting analysis indicated that approximately 75% to 80% of Tennessee's overweight permits were issued for through routes. The primary reason for this is the location of Tennessee on the Nation's highway network. Tennessee is centrally located with respect to the eastern half of the United States and is crisscrossed by a number of interstate and major US highways. Passage through Tennessee is common for traffic moving in both the North–South and East–West directions. Most of these permit movements simply wish to traverse Tennessee as quickly and efficiently as possible, which usually means using an Interstate or US highway route.

The great benefit of a GIS interface is to aid in the analysis of unusual or unique routes. Our conclusion was that the majority of overweight permit vehicles move in predicable patterns in Tennessee and, therefore, the benefits of a GIS system were minimal. Instead, we developed a text-based interface that uses the concept of "Standard" routes. If the Trucking Company simply wishes to traverse the State with their vehicle, they can pick origin and destination locations from a menu system. For example, if a vehicle wished to enter Tennessee from Georgia and exit into Arkansas, then GA would be picked as the origin and ARK would be picked as the destination. A "Route Wizard" is then activated which would list all standard routes going between those two States. The desired route is then selected from the list. Once a standard route is selected, the mileage, analysis bridges and controlling vertical clearances are also automatically identified. See Figure 2 below.

For the 20% to 25% of overweight traffic that cannot use a standard route, the route wizard allows the input of a "Custom" route. A custom route requires the manual checking of mileage, analysis bridges and vertical clearances. In practice, this requires



Permit Information

Start Date: 03/08/99 End Date: 03/13/99 Multi-State: ☐ Yes

Service Information

Service: Interstate

Reference:

FAX: (800) 851 - 1252

Office: Columbus, OH

Attn:

Carrier Information

Carrier: COMBINED TRANSPORT

Office: CENTRAL POINT, OREGON

Attn: NAN

FAX: 541-826-9787

Insured: ☒ Yes

Configuration: Tractor Trailer

Load: WHEEL LOADER

Carrier Unit: 1903

Violation Information

Length (ft-in): 102

Overhang (ft-in):

Kingpin to End (ft-in): 80

Height (ft-in): 15-6

Width (ft-in): 12-6

GVW (lbs.): 173,000

Number of Axles: 9

Axle Details: ☐

Axle Weights: 13; 20; 20; 20; 20; 20; 20; 20; 20

Axle Spacings: 15-5; 4-7; 14-11; 4-6; 33-9; 4-6; 13-7; 4-6

Classification: OD/OW

Has 150 Annual Permit: ☒ Yes

Trip Information

Origin: GA

Destination: ARK

Route Segments: I 75 - I 24 - I 440 - I 40

Maps Needed: Memphis; Nashville

COMMENTS

Add New Comment

RESTRICTIONS FOR THIS PERMIT

Restrictions Wizard: ☐

☐ - FRONT ESCORT REQUIRED ON ALL ROUTES

☐ - FRONT ESCORT REQUIRED ON ALL TWO LANE F

☐ - FRONT ESCORT REQUIRED ON TWO LANE ROUT

☒ - FRONT ESCORT REQUIRED WITH HEIGHT GAUG

Route Wizard

Select a route or press Custom to enter a new route.
Press OK when complete.

I 75 - I 24 - I 440 - I 40
I 59 - I 24 - I 440 - I 40
I 75 - I 24 - US 64 - I 40

OK Cancel Custom

Distance (mi.): 343

Maps Needed: Memphis; Nashville

Primary Route: ● Yes ○ No

Design Standard: ● Interstate ○ Other

Maximum Height (ft-in): 15-6

Obstructions: ○ Yes ● No

Bridge Analysis ID: 13

[None] Comparison operators must be supplied two values of the same data type.

Figure 2: Route Wizard data input screen.

more work on the part of Permit and Bridge Inventory staff. However, it is a manageable level, especially when compared against the overall labor savings to TDOT's staff provided by the new system.

The major benefit of using a text-based approach rather than a GIS-based approach, however, was that it let TDOT reconsider the role of the customer in the process. Avoiding a GIS allowed TDOT to design a system where customers have an incentive to do their own data entry for a new permit request. Carriers may submit permit requests or pick up approved permit documents 22 hours per day every day, although the TDOT office staff only processes these requests during normal business hours. With a GIS, it would have been difficult to provide the appropriate data in a format that would have been acceptable to customers and their existing computer systems. This is especially true given that the movement of graphical data is restricted by the limited available bandwidth of most communication channels.

Clearly, the circumstances of the State of Tennessee may not apply to other highway agencies. Each agency needs to evaluate the typical permit traffic patterns peculiar to their jurisdiction. If one finds, like Tennessee, that permit traffic tends to move in predictable patterns, then a GIS Interface may not be worth the cost and effort. If one finds that permit movements tend to originate or terminate within the State, resulting in many unique route requests, then a GIS Interface may easily be worth the development cost. Do not insist on a GIS Interface simply to be "State of the Art" if the functionality cannot be justified.

Do Not Break the Budget Pursuing the Final 1% of Permit Requests; Rather, Direct Funding to Where It Will Be Most Effective

One common mistake is to design the permit system around the most difficult (worst case) scenario rather than around the most common case. For example, approximately 80% of the permit requests submitted to TDOT consist of vehicles that are not overweight at all. They are merely oversize. Of the ones that are overweight, only a tiny fraction can be considered to be exceptional super loads. For the purposes of this paper, an exceptional super load is defined as any request that exceeds 1334 kN (300,000 lbs.) in total load. Yet many systems ignore the needs of the common permit request by focusing their efforts on trying to accommodate that small fraction of exceptional super loads. Elaborate schemes and algorithms are developed in a vain effort to create a "smart" system that can evaluate multiple detours and find a route capable of safely carrying even the most severe load. The author suggests that the load should be adapted to fit available routes rather than trying to make the routes fit the load.

The system developed by TDOT is designed to focus upon the common permit requests since the real productivity gains can most readily be realized there. It automates the routine activities that consume the majority of man-hours. For example, permit fee calculation was labor intensive under our old paper-based system. The Tennessee legislature feels that the heaviest fees should fall upon those permit requests that most strain the highway system. Therefore, the legislature developed an elaborate fee structure that consists of a 5 cent per ton mile overweight fee plus graduated fees for being overdimensional and for any required engineering analysis. This fee structure has the advantage of discouraging casual abuse of the highway system by outrageously large and heavy loads which may occur if a State uses a simple low flat fee. A disadvantage of the Tennessee fee structure is that the calculation of the fee using pencil, paper and a calculator is time intensive and prone to error. Our new system automates the fee calculation, which has resulted in real productivity gains.

As for the exceptional super loads, we simply accept the fact that there will be a small set of unusual permit requests that will not fit our system. As a practical matter, these loads will always require special handling and an in-depth engineering analysis. Of the 40,000+ permit requests that have been received since the switch to the new system was completed, only 14 have had to be processed outside of the system. All these loads exceeded 2,200 kN (495,000 lbs.) in total load and would have required significant managerial consideration in any case.

Use Off-the-Shelf Software Wherever Possible to Reduce the Need for Custom Development

A certain amount of custom development is required for any permit issuance system. However, selecting the right development platform can minimize the amount of custom work. When we began development of the TDOT system, we first assumed that a Relational Database Management System (DBMS) would form the core component of the software. We were willing to approach the project with an open mind, however. As we worked with the software developer for the project, Cambridge Systematics, it became apparent that we needed a workflow type of application rather than a traditional transaction processing system. This distinction may be made clearer with an example. When one goes to a bank ATM machine and withdraws some money, one has completed a simple transaction. The only elements involved are the bank customer and the bank ATM system. On the other hand, when one creates a draft document that is then passed to a number of people for review before being finalized, then one is participating in a workflow.

If one could automate the permit issuance process to the point where a single computer could make all decisions, then the process could be considered a transaction. In actuality, the decision to issue or deny a permit may require the input of many people and is most accurately represented as a workflow. A traditional DBMS tends to work best for a transaction based system. Some of the more advanced database programs have begun to develop workflow features. However, the development team felt that a system designed, from the ground up, to accommodate workflows would work best.

For this reason, the software developer recommended that the permit issuance system be developed on the Lotus Notes software platform, instead of a traditional DBMS, as this would best suit the complex workflow process involved. By using the Lotus Notes platform we gain many necessary features, such as built-in security, built-in communications, built-in replication and synchronization of remote databases, and the capacity for future growth. The off-the-shelf cost of the software, less than $15,000, was reasonable given that it allowed us to use a standardized, industry-accepted approach to these design issues. There is no doubt that the amount of custom development required for our system was significantly reduced, compared with a DBMS, due to the selection of Lotus Notes as our development platform.

Design the System to Allow for Future Growth

As noted in the introduction for this paper, the trend in permit vehicle travel is toward ever increasing levels of traffic. Any system that does not allow for this fact is soon rendered obsolete. One primary design requirement for Tennessee's system was that it could grow, change and evolve as necessary to meet future needs. Below are just some of the features that allow for growth.

- The system uses a table of "System Variables" that act to control the way in which the program processes data. These variables encapsulate the business rules for TDOT. For example, if the Tennessee Legislature were to make changes to the permit fee structure or the rules governing legal height, width, length or weight, we would be able to accommodate these changes simply by editing the controlling system variables. These values are not "hard coded" into the system software.
- The TDOT permit system currently communicates with remote customers over phone lines by modem. Trucking companies and permit services, that wish to use the TDOT system, submit permit requests and receive finish permit documents via these connections. At this moment, TDOT has no plans to switch to providing service over the Internet. However, the development team designed the system to be easily converted for Web-based carrier data entry or data access, and the underlying Lotus Notes platform can function natively as a "Web Server" if so desired.
- Lotus Notes is available for many operating system platforms. Currently, the TDOT system runs on Microsoft Windows NT™ based servers. However, if future growth were to place strains on this platform, we could scale up to AS/400™ or Unix servers. Even astronomical growth could be handled by moving the system to an IBM mainframe platform. With Lotus Notes, all these platforms are available, and scalability is therefore assured and transparent to the permit issuance application itself.
- The TDOT system is designed to work with any bridge analysis system. The Lotus Notes application does not directly handle the bridge analysis part of permit processing; instead it functions by passing data to and then calling a separate analysis program that was developed by the author. As more sophisticated bridge analysis software becomes available, TDOT may wish to switch analysis engines. For example, AASHTO is currently developing a software system, called VIRTIS, which may contain features to expedite permit vehicle analysis over highway bridges. Tennessee has supported VIRTIS development and may wish to use the software for future permit vehicle analysis. Since the modularity of the bridge analysis engine is a core component of the system design, switching analysis engines will only require re-coding of the changes in the data exchange process needed for the new system.

A Complete Analysis of Every Bridge on Every Requested Route Is Unrealistic

One of the most challenging aspects to permit vehicle routing is bridge analysis. In an ideal world, every bridge crossed by a permit vehicle could be thoroughly analyzed. Indeed, some modern systems purport to be capable of accomplishing this feat. Closer examination, however, usually reveals fatal flaws with these claims. To even attempt to accomplish this goal requires a detailed electronic analysis of all bridges that could be subject to permit vehicle traffic. Few, if any, States have such a complete record of data available. The State of Tennessee does not yet have such a complete record but is working to assemble such data within the bounds of time and staffing constraints. Delaying the implementation of a permit issuance system until such data was available was not a feasible option given the rapid growth in permit request submittals.

In addition, bridges with unusual or complex designs are often "Skipped" by the analysis program. These bridges could range from arch, truss or suspension designs to common culvert bridges. Even for bridges that are relatively easy to analyze, for example, steel or concrete girder bridges, the analysis is often limited to a few capacity checks in the high moment and shear regions. This is hardly a thorough analysis since it omits any type of engineering calculation involving the deck, substructure or bearing devices.

The assumption is often made that the substructure will not control the bridge capacity because it is designed with a higher "Safety Factor" compared to the bridge superstructure. However, the author is not aware of any studies that support this assumption. Indeed, the author was involved in a recent series of permit vehicle movements where the substructure did control. The loads in question ranged from 2,225 kN (500,000 lbs.) to 3,075 kN (692,000 lbs.) in total load and needed to traverse a four span bridge, on State Route 19, which crosses over Interstate 40. This bridge was designed with a concrete T-beam superstructure and concrete, two-column bents. By forcing the permit loads to travel along the centerline of the bridge at crawl speeds, the stresses to the superstructure could be minimized. However, this scheme tended to maximize the stress to the concrete bent capbeams. It was necessary to place temporary steel supports under these capbeams in order to allow the moves to proceed. See Figure 3 below.

Figure 3: Temporary substructure supports.

Beyond the limitations of "Superstructure Only" analysis, the large numbers of structures that must be crossed further complicates the problem. For example, suppose a request is received for a permit vehicle to travel from North Carolina to Arkansas via Interstate 40. This is a well-traveled route and a common request for Tennessee. If permission is granted, this permit vehicle will need to cross 405 bridges and 62 culverts. The total number of spans encompassed by these structures is 2,073. If only the maximum moment and maximum shear values are checked for each span, this would total 4,146 required engineering checks. A thorough check of every component of every structure, including decks, bearing devices, substructure units, etc., would increase this total to tens of thousands of detailed engineering checks. No computer system currently available or projected can complete such an analysis within the cost and time constraints that must govern the permit issuance process.

The author's purpose in listing the difficulties involved in permit vehicle analysis was not to provoke despair. Rather, it was to point out the utter futility of attempting to reach the goal of a "complete" analysis of every bridge on every requested route. To focus on this unreachable goal forces one to treat permit vehicle analysis as an engineering problem that requires the most advanced computer solutions. It is not. Rather it is a ***Quality Control*** problem that can be solved using the mathematics of ***Acceptance Sampling***. The permit issuance process is a regulatory process designed to exclude unacceptable vehicles from using the highway system.

In structure, it is no different than conducting acceptance sampling on parts that are shipped to a factory for use in production. The quality control engineer can attempt to test each and every part to see if it is acceptable, just as a bridge engineer can attempt to analyze each and every bridge to see if it is overstressed by a permit vehicle. However, if one is dealing with thousands of parts or hundreds of bridges, the size of the task soon renders this approach unworkable. The quality control engineer solves his problem by applying statistics, deciding on an acceptable quality level, and developing a sampling plan. The author suggests that a similar approach can be applied to permit vehicle analysis. The mathematical techniques required for such an analysis are well developed and can be found in a number of texts and reference volumes. One standard approach is illustrated below and was adapted from just such a reference work (*1*).

Let "N" be the total number of engineering checks required to thoroughly test a permit vehicle over a proposed route. Let "n" be a sample of these engineering checks, selected at random, that will actually be performed. Let "c" be the number of engineering check failures that will be acceptable (usually this is zero), "x" be the number of failures that occur in the sample, and "A" be the event that the permit request is approved to move.

It is clear that the corresponding probability P(A) depends not only on "n" and "c" but also on the number of failures in the total universe of engineering checks possible for the route. Let "M" denote this number, let the random variable "X" be the number of defectives in a sample, and suppose that we sample without replacement. This, of course, would be true since one cannot place a completed engineering check back into the total universe to do again. Given the above conditions, the probability of "A" can be computed as:

$$\mathrm{P(A)} = \mathrm{P(X \le c)} = \sum_{\mathrm{X}=0}^{\mathrm{c}} \binom{\mathrm{M}}{\mathrm{x}} \binom{\mathrm{N}-\mathrm{M}}{\mathrm{n}-\mathrm{x}} \Bigg/ \binom{\mathrm{N}}{\mathrm{n}} \qquad \text{(Eq. 1)}$$

Note that if $M = 0$ (no engineering failures in the entire universe of possible engineering checks for a route), then X must assume the value 0 and the probability of being approved becomes

$$P(A) = 1 = 100\%$$

The ratio of the number of failures (M) divided by the total number of checks (N) may be defined and is referred to as the **fraction defective** for the route. It is usually given the symbol θ.

If the number of checks is large (i.e., it is a long route with numerous bridges) and if θ is small (less than 10%), and finally if the sample size is such that $n\theta$ is moderate (less than 20), then the hypergeometric distribution illustrated in Eq. 1 may be approximated using the Poisson distribution with mean $\mu = n\theta$. This simplifies matters since the Poisson distribution is tabulated in many reference works.

For example, take the case of the hypothetical permit request to travel from North Carolina to Arkansas along Interstate 40 given above. Suppose we accept 5% as the **significance level** of our test, a common assumption in statistical analysis, and do only 100 of the possible 4,146 superstructure checks for the route. Also suppose that all engineering checks passed without a single failure. If we approve this permit to travel, what is our risk of making a Type II error (the probability that bridges will be unacceptably overstressed)? Given that $x = 0$ and $\mu = n\theta = (100)(0.05) = 5$, the risk can be computed to be 0.04 or only 4%.

This risk can be reduced even further by not selecting bridges at random to test. Despite being designed to the same live load standards, certain bridges will inevitability prove sensitive to permit traffic. This seems to be a function of several specific circumstances. Over the years, the author has developed a few "Rules of Thumb" that act as indicators as to bridge permit vehicle sensitivity. These are:

- Bridges with intermediate span lengths, $15\text{ m} < L < 40\text{ m}$ ($50\text{ ft} < L < 130\text{ ft}$), often prove sensitive. Long-span bridges seldom prove sensitive because their design is controlled by lane loading, which seems to approximate a permit load. The number of axles that can be placed on short-span bridges is limited, which also limits their sensitivity as long as reasonable restraints are placed on individual axle weights.
- Continuous bridges tend to be more sensitive than simple span bridges because adjacent spans can be loaded to produce large negative moments.
- Girder type bridges with large spacing between girders tend to be sensitive. This wide girder spacing produces significant distribution factors. In addition, larger fractions of the superimposed dead load can be distributed to each girder.
- Excessive dead load on the structure. Often a deep asphalt wearing surface or upgraded bridge rails (or both) are added to the bridge over time. These loads may go beyond what the bridge designer originally intended and will directly subtract from the live load capacity of the structure.
- Errors in the original bridge design.

Because of the above factors, different bridges will react in different ways when subjected to permit vehicle traffic. In Tennessee, we have compiled a database of these sensitive structures and use them to test permit vehicle traffic. Our system is designed to first subject overweight permit vehicles to a level 1 screening based upon the Federal Gross weight formula. This screening method was developed by the author and has been verified in a study conducted by the University of Tennessee (*2*). Naturally, it is somewhat conservative but it does act to approve permit requests that clearly pose no danger to Tennessee bridges.

If the permit request fails the level 1 screen, it is transmitted (via the workflow features built into Lotus Notes) to the Bridge Office for a more detailed (level 2) analysis. Here it is tested using the known sensitive bridges along the requested route. Because we bias the test by using sensitive bridges, rather than bridges selected at random, our risk of making a Type II error is undoubtedly reduced.

If the permit request fails the level 2 analysis, it is automatically rejected by our system. This is one disadvantage (or advantage depending upon one's point of view) of using an acceptance sampling method for permit vehicle approval. One cannot try to "work around" bridges that fail the test. To do so would invalidate the acceptance sampling method. Only if one were willing to test each and every structure would this be permissible.

Hopefully, the above discussion will act to stimulate more efficient analysis of permit vehicle traffic by the use of sampling techniques. It is the author's opinion that, given the limitations of manpower, time, funding, computer technology and available bridge data, the approach of using acceptance sampling is more reasonable than attempting to thoroughly analyze every bridge along every possible route.

Do Not Neglect Training and Long-Term Support

Implementing a multi-user permit issuance system is not a trivial task. The users of the system must be thoroughly trained and the natural reluctance to change must be defeated. This takes time and effort. Eventually one climbs the learning curve and becomes comfortable with the new system. When the TDOT system was implemented, we faced these same challenges. However, we had provided for adequate testing and training in our budget and, in the author's opinion, have passed this hurdle. After only a few months using the new system, our employees have adjusted and, in fact, are so happy with the new system that there would now be considerable resistance to any suggestion of returning to the old paper-based method of issuing permits.

There are always problems when implementing new systems, of course, and TDOT did have its share. A conflict between Lotus Notes and our backup procedures caused a series of server crashes during the first month of operation. Once the source of the problem was identified, the system was stabilized. In addition, once a software system goes into daily use, any number of usability and performance enhancements can be identified.

All this points to the need to include training and support into the budget for the system. The most advanced system available is ineffective if it cannot be implemented or the end users reject it.

CONCLUSIONS

Permit vehicle analysis is an interesting and varied field of study. The field is broad enough to support the development of numerous different approaches to deal with the problem of rapid and continual growth. TDOT has studied the needs specific to Tennessee and developed a system that varies markedly from what "conventional wisdom" says that an overweight/overdimensional permit issuance system should resemble. Our system rejects a GIS map interface in favor of a simpler and faster text based approach. It rejects a DBMS data storage system in favor of groupware software. Finally, it rejects the requirement to analyze every bridge in favor of screening and acceptance-sampling methods of evaluating permit requests. Despite being different, however, it has enjoyed broad acceptance by the TDOT employees who must struggle each day to keep up with the ever-increasing numbers of permit vehicle requests.

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2. Deatherage, J.H., and Chou, K.C. *Evaluation and Testing of the Software Program for the Analysis of Overweight Vehicles on Tennessee Highway Bridges*, Vol. 1 & 2. The University of Tennessee Transportation Center, Knoxville, TN, 1995.