HIGHWAY PERMITS PROGRAM REVIEW

WORKS CONSULTANCY SERVICES LTD,
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AN IMPORTANT NOTE FOR THE READER

CONTENTS

EXECUTIVE SUMMARY

The Highway Permits computer program stores overload capacity data for all state highway bridges, and some local authority bridges, together with a description of the highway network. On entry of details of an overweight vehicle and its proposed route, the program provides details of restrictions which will be imposed on the vehicle as it crosses any of the bridges on the route.

The report records a study made to determine if operating economies or increased efficiency would be gained in changing the method of operation of the program or the type of data stored, and to determine whether changes to existing calculation elements, and/or addition of new ones would be economically justified.

Program efficiency review

- The Highway Permits program is operating efficiently, with typical permit runs incurring less than 2.0 seconds CPU (Central Processing Unit) time.

- Little scope exists for improvements in program efficiency and the cost/benefit of undertaking improvements is unlikely to be favourable.

- Use of the TEST option instead of the TRUCK or SPECIAL options of the TRUCK command in routine processing would incur large computing costs, and steps to obviate this are suggested.

- Alteration of the grid analysis calculation of the DECK element to use a plastic analysis method rather than an elastic method would improve program efficiency. The method used should be compatible with design practice.

- As data input/output is not a great consumer of resources within the program, little merit would be gained in changing methods of data storage in the database.

LONG element Eccentricity Factor

The Eccentricity Factor calculation in the LONG element should be changed from the current form.

INF2, INTER and INTER2 elements

The INTER element should be developed as provided for in the input program, but the INF2 and INTER2 elements should not be developed.

ABSTRACT

The Highway Permits computer program stores overload capacity data for all state highway bridges, and some local authority bridges, together with a description of the highway network. On entry of details of an overweight vehicle and its proposed route, the program provides details of restrictions which will be imposed on the vehicle as it crosses any of the bridges on the route.

The report records a study made to determine if operating economies or increased efficiency would be gained in changing the method of operation of the program or the type of data stored, and to determine whether changes to existing calculation elements, and/or addition of new ones would be economically justified.

1. INTRODUCTION

The Highway Permits computer program stores overload capacity data for all state highway bridges and for some local authority bridges, together with a description of the highway network. On entry of details of an overweight vehicle and its proposed route, the program provides details of restrictions which will be imposed on the vehicle as it crosses any of the bridges on the route. The program is described in *Highway Permits Assurance Manual* (Vogel Corporation 1992).

This project was initiated because:

(a) The Highway Permits computer program was developed in the early 1970s, and it was expected that techniques now available, 20 years later, might improve efficiency in operation.

(b) In some cases, the parameters stored, and the method of using them, are simplified and hence conservative. This applies particularly to determination of eccentricity factors in the LONG element which is the most frequently used parameter, and common to most of the bridges.

(c) When the program was first developed, the intention was to include calculation elements to allow for the following vehicle effects:

- Interaction effects, e.g. moment and direct force.
- Situations where different influence lines are required for the truck in its own lane, and for the truck central on the bridge, rather than using different scale factors on a single influence line. (Influence line represents the effect of loads on a beam.)

Because of budget constraints, these elements were not developed, although the input program allows the data to be stored. For the situations where they would be used, simplifying assumptions have been made in developing the data in order to use one of the other elements.

The objective of this study was to determine if operating economies or increased efficiency would be gained in changing either the method of operation of the program or the type of data stored, and to determine whether changes to existing calculation elements, and/or addition of new ones would be economically justified.

2. PROGRAM EFFICIENCY REVIEW

2.1 Introduction

The objectives of the review were:

(a) To investigate the program operation and determine which functions absorb the most computer time.

(b) To determine whether alterations could be made to improve efficiency.

2.2 Background

The Highway Permits program is part of a suite of three programs called the *"Highway Overweight Permit Checking System"*. The program is used in processing permits for highway vehicles that exceed the legal weight limits. On entry of details of an overweight vehicle and its proposed route, the bridges, crossings and pavements on the route are automatically selected from stored inventories and checked for their ability to carry the load. The program provides details of restrictions which will be imposed on the vehicle as it crosses any of the bridges or crossings on the route. The *"Highway Overweight Permit Checking System"* was developed by Computer Services (now Vogel Corporation) of Ministry of Works and Development (now Works Consultancy Services Ltd) in the early 1970s. The program source code is written in PL/I (high level program language).

2.3 Description of the Review Procedure

An analysis of program operations was carried out for a typical overload vehicle over two defined routes in three test runs using the PL/I execution analyser.

The PL/I execution analyser provides a statistical analysis of where CPU (Central Processing Unit) time is being spent by monitoring the job at specified sampling intervals and keeping a record of what procedure and, optionally, what statement is currently being executed over the length of the job. The sampling interval chosen was 0.02 seconds.

For the purposes of the review, the typical vehicle was assumed to be a 6 axle transporter with the axle details in Table 1.

Table 1. Axle details of typical overweight vehicle.

Axle Number	Axle Type	Axle Load (t)	Axle Spacing (cm)	Tyre Size	Track (cm)	Inner Track (cm)
1	1	5.5		std	200	n/a
2	2	8.0	360	std	180	n/a
3	2	8.0	140	std	180	n/a
4	8	10.0	570	std	260	100
5	8	10.0	240	std	260	100
6	8	10.0	240	std	260	100

Note: Axle types are defined as follows:
1 = single tyred axle
2 = twin tyred axle
8 = eight tyred oscillating axle

This is meant to represent an overload vehicle of the kind that commonly require checking for issue of a permit.

The typical overload vehicle was run over the following two routes:

- Route 1: State Highway 1 from Picton to Christchurch

  HIGHWAY 1S FROM JN 16 TO JN 740

- Route 2: Hamilton to north of Napier via Taupo

  HIGHWAY 1N FROM RP 463/0.00 AT JN 30 TO RP 617/0.00 AT JN 55

  HIGHWAY 5 FROM RP 135/0.00 AT JN 55 TO RP 262/0.00 AT JN 59

  HIGHWAY 2 FROM RP 638/0.00 AT JN 59 TO RP 626/3.20

Routes 1 and 2 are meant to be representative of typical South and North Island routes, respectively. 35% and 44% of the bridges on the two routes respectively have an overweight classification below 100%. Table 2 describes properties of the chosen routes.

Table 2. Properties of the routes chosen for the program analysis.

Route		**1**	**2**
Total Route distance (km)		**341.47**	**287.39**
No. bridges	CLASS:		
	120 and over	40	6
	100-119	21	9
	80-99	20	11
	60-79	10	1
	Below 60	3	0
	Total	94	27
No. of rail crossings		5	0

The three efficiency test runs were:

Test E1: typical vehicle on Route 1 (normal checking)
Test E2: typical vehicle on Route 2 (normal checking)
Test E3: typical vehicle on Route 2 (test mode)

Tests E1 and E2 used the TRUCK form of the vehicle input specification and are typical of normal permit runs. Test E3 used the TEST form of the vehicle input specification. This is provided for program testing purposes and would not be used in normal operation. The TEST option forces detailed checking of all bridge elements. This is useful for the purposes of the efficiency review in identifying checks that consume large amounts of computing resources. It is not, however, meant to be representative of normal program usage.

2.4 Summary of Results

The total CPU time consumed by each of the three jobs is tabulated below along with a breakdown by external procedure name. The tabulated data, except for the total CPU, has been derived from the PL/I execution analyser results. The total CPU time was obtained from the job log, and has been corrected for resource usage by the execution analyser.

Total CPU time, seconds		
Test E1	**Test E2**	**Test E3**
1.55	2.0	28.9

Procname	Percentage of Total CPU time		
	Test E1	**Test E2**	**Test E3**
HPCHKR		2.3	0.1
HPINVM	4.4		
HPGETF		1.1	0.1
HPGRID		58.5	95.2
HPINLD			0.3
HPLNGC			0.1
HPLNGI			0.1
HPPERM	26.4	30.4	2.0
HPRNET	1.4	1.1	0.1
HPTRKM	26.8	4.7	0.3
HPTRUK	1.4		
HPVLON	38.8		

2.5 Discussion of Results

The small total job CPU for tests E1 and E2 indicates that little benefit is to be derived from implementing any improvement in efficiency. There is little point improving efficiency by say 25%, if this only results in a saving of 0.5 seconds of CPU, unless only a very minor program change is required.

The following points can be inferred from an investigation of the PL/I execution analyser results interpreted in conjunction with a program compile listing.

- The CPU resource is expended mostly in performing the structural calculations for the bridge checks.
- Data input/output operations do not figure highly in the CPU resource usage.
- 58.5% of the total CPU resource usage for the E2 run is related to a grid analysis to perform deck slab checking for one bridge only (the Mohaka River bridge). This bridge failed the simple deck check but subsequently passed without restrictions under the more detailed grid analysis.
- 95.2% of the total CPU resource for the E3 run is incurred in providing detailed checks on bridge deck slab elements via the grid analysis (HPGRID). Bridge deck checking was performed for a total of 24 bridges during this run. The grid analysis is the predominant user of the CPU resource by a very wide margin.

3. LONG ELEMENT ECCENTRICITY FACTOR

3.1 Present Calculation of Eccentricity Factor

The data stored for each LONG element includes an Eccentricity Factor, ESTD. This factor takes account of how the loading on the most heavily loaded beam (or other member) in the cross-section of the span compares with the average loading on all beams in the span. ESTD is calculated for the standard bridge classification load, which is one lane of 0.85 HO (Highway Overload) and one lane of 0.85 HN (Highway Normal Load). These loads are defined in the Transit New Zealand *Bridge Manual: Design and Evaluation* (1991).

During a permit run, the Eccentricity Factor used in the calculation is a modification of ESTD, to take account of the difference between the load from the truck and the load from 0.85 HO. The relationship used is:

$$Eccentricity\ Factor = ESTD\ \frac{1 + KBASIC^{-1}}{1 + K^{-1}}$$

where KBASIC is the ratio $0.85M_{HO}/0.85\ M_{HN}$

M_{HO} is the moment due to HO loading

M_{HN} is the moment due to HN loading

K is the ratio $MTRUCK/0.85\ M_{HN}$

MTRUCK is the moment due to the truck

The above Eccentricity Factor formula was developed using data from only a limited number of computer grid analyses of typical superstructures. It produces a generally conservative result for values of K greater than KBASIC, and unconservative values for K less than KBASIC.

3.2 Proposed Calculation of Eccentricity Factor

A series of grid analyses were performed on typical superstructures of various spans and span to width ratios with and without intermediate diaphragms, and with a range of K values. This enabled determination of the way in which Eccentricity Factor varies in typical circumstances. From these analyses, the following modified formula has been derived:

$$Eccentricity\ Factor = ESTD\ \frac{1.3 \times SPAN/WIDTH + KBASIC^{-1}}{1.3 \times SPAN/WIDTH + K^{-1}}$$

where SPAN is the beam span

WIDTH is the roadway width

(Both these values are already stored as part of the element data)

The effect of this change is illustrated in Figure 1 in which Eccentricity Factor is plotted against K for five typical bridges, as derived from:

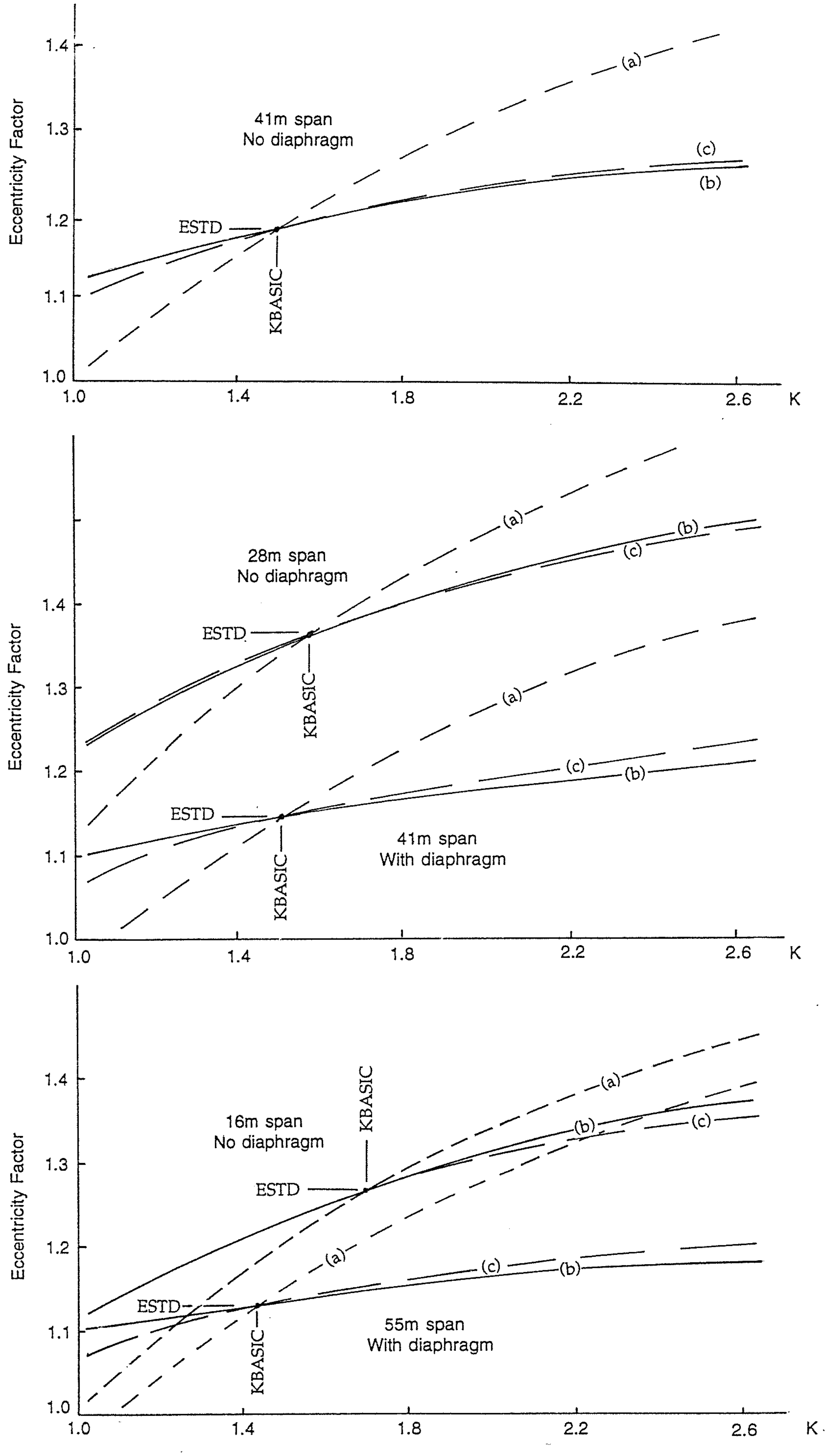

Figure 1. Comparison of Eccentricity Factors derived by:
(a) Existing formula, (b) Grid analysis, (c) Proposed formula.

(a) existing formula
(b) computer grid analysis
(c) proposed formula

This shows that the difference between (b) and (c) is generally less than 3%. This change to the program has the advantage that no changes are required to existing data, since WIDTH and SPAN are already part of the data.

3.3 Costs

The costs of introducing the change (modified formula) is estimated at $1,600, and verification of the program operation to cost $400. The programming change and verification could be completed within one week of approval to start.

4. INF2, INTER AND INTER2 ELEMENTS

4.1 General

Discussions were held with those responsible for maintenance of the Highway Permits data in each of the Works Consultancy offices. These discussions were to determine how much use the proposed elements might get if they were to be developed. The consensus opinion was that further sophistication of the range of elements would be of limited value, although some specific circumstances exist where some changes would be warranted. Each proposed element is discussed below.

4.2 INF2 Element

The INF2 element would allow for situations where different influence lines are required for the truck in its own lane and for the truck central on the bridge. This is an alternative to using scale factors and a single influence line as in the present INF element.

INF2 elements would be of use in cases where the bridge cross-section is irregular, and the type of bridge member critical for the truck in its own lane is different from that for the truck central. This situation is thought to be so rare that it would not be worth allowing for in a special element, since it can always be allowed for by using two separate INF elements: one for the truck in its own lane, with a zero scale factor for effects of the truck central, and one for the truck central with a zero scale factor for the truck in its own lane.

4.3 INTER Element

The INTER element would allow for situations where critical effects are the result of the interaction of two separate load effects, for example moment and direct force.

The most likely use of this element would be to represent an arch rib. The Descriptive Inventory records 48 bridges containing arches on the state highway system. An examination was made of the Highway Permits data stored for the most critical of these, that is the 20 bridges which have an overload classification less than 100. Of these, the arch itself is critical in 12 cases, the remainder being critical in transoms, stringers or approach spans. An examination of the Highway Permits frequency file was made, to see if any of these 12 bridges are restrictive. The data in the frequency file are, for each bridge:

(a) The number of times the bridge has been checked for a permit application,

(b) The number of times the program has required restrictions on a vehicle passage over the bridge,

(c) The number of times a vehicle was refused a permit.

The figures available were for the period December 1987 to June 1992.

Four of the 12 bridges either required no restrictions or a minimal number. One bridge was severely restrictive, to the extent that 14% of applications required restrictions, and 62% of applications were refused a permit. The frequency records of the remaining seven bridges were compared with those of other bridges on the same segments of highway. In each case the segment of highway contains a significant number of other bridges which require an equivalent or greater number of restrictions than the arch bridge.

The conclusion is that in fact only one bridge - the Fish River Bridge on State Highway 6 - would benefit immediately and significantly from development of this element.

However, it is likely that at some future time, when other bridges have been replaced, some of the other arches could become the critical bridges on their routes. Therefore, from the point of view of making the system able to handle all situations, and considering that the development cost is not great, it is recommended that the element should be developed.

4.4 INTER2 Element

The INTER2 element would allow for situations where a different pair of influence lines is required for the truck in its own lane and for the truck central on the bridge. The same remarks that apply to the INF2 element apply to this element.

4.5 Costs

The estimated cost of developing the new elements and modifying program manuals is as follows:

INF2	$1,000
INTER	$1,250
INTER2	$1,250

The estimated cost of verifying the operation of any one of these elements is $800, and the programming and verification could be completed within three weeks of approval to start.

The estimated average cost of developing the data for an arch bridge, which would use an INTER element, is $2,000. It is expected that this would cover the specific case of the Fish River Bridge.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Program Efficiency Review

- The Highway Permits program is operating efficiently, with typical permit runs incurring less than 2.0 seconds CPU time.

- Little scope exists for improvements in program efficiency and the cost/benefit of undertaking improvements is unlikely to be favourable.

- The testing has emphasised that use of the TEST option instead of the TRUCK or SPECIAL options in the TRUCK command incurs large computing costs. As an example, if 10% of permit runs were to use the TEST option, this would introduce a cost overhead of 135%. There is no indication that this is happening but a memo to permit issuing offices is suggested, and a draft has been included in the Appendix.

- The grid analysis calculation of the DECK element is expensive, but gives a less conservative estimate of deck capacity than the simple analysis. Alteration of the element to use a plastic analysis method rather than an elastic method would improve program efficiency in this area.

However, the method used should be compatible with design practice, and therefore any change should be carried out in conjunction with a revision of design criteria in the Transit New Zealand *Bridge Manual: Design and Evaluation* (1991). A specific proposal to do this will be put forward as a separate exercise.

- Data input/output is not a great consumer of resources within the program. Little merit would be gained in changing methods of data storage in the database.

5.2 LONG Element Eccentricity Factor

It is recommended that the Eccentricity Factor calculation in the LONG element should be changed from the current form to the following:

$$Eccentricity\ Factor = ESTD\ \frac{1.3 \times SPAN/WIDTH + KBASIC^{-1}}{1.3 \times SPAN/WIDTH + K^{-1}}$$

The estimated costs for the modification are:

Programming and documentation	$1,600
Verification	400
	$2,000

5.3 INF2, INTER and INTER2 Elements

It is recommended that the INTER element should be developed as provided for in the input program, but that INF2 and INTER2 elements should not be developed.

The estimated costs for the INTER element are:

Programming and documentation	$1,250
Verification	800
Data for one bridge	2,000
	$4,050

6. REFERENCES

Transit New Zealand. 1991. *Bridge Manual: Design and evaluation.* Transit New Zealand, Wellington.

Vogel Corporation. 1992. *Highway Permits Assurance Manual.* Vogel Corporation, Wellington.

APPENDIX. DRAFT MEMO TO PERMIT ISSUING OFFICES

Highway Permits

A recent review of the operation of this program has highlighted the very large difference in computer cost between use of the TRUCK command with:

(a) the TRUCK or SPECIAL options, and
(b) the TEST option.

Under the TRUCK or SPECIAL options, elements are only checked if the vehicle fails the simple check, and then only to the Restriction Level necessary for it to pass.

Under the TEST option, all elements are checked up to Restriction Level 2 at least. The major consumer of computer time is the grid analysis performed by the DECK element check in this option.

Would you please draw this to the attention of all permit issuing staff, and ensure that the TEST option is not used unless there is good reason for wanting all elements checked.