DIRECT ECONOMIC BENEFITS ARISING FROM TECHNOLOGY DEVELOPMENT WORK ON G1 BASE PAVEMENTS

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ABSTRACT

This paper summarizes the HVS Technology Development projects related to the development of G1 material technology in South Africa, and also provides an estimate of the direct economic benefits derived from these projects. The background to the G1 technology development work, together with the main findings, is presented. The impacts of these findings on the southern African road building industry are then defined and discussed. The methodology for the assessment of economic benefits, as well as the calculated benefit indicators is also presented and discussed. It is shown that, for the stated assumptions, and considering the technology development cost contribution made by Gautrans as well as the size of the Gautrans network, a benefit-cost ratio of between 1.4 and 3.6 is obtained, depending on the discount rate and various other variables. For the contribution made by SANRAL, and considering the size of the SANRAL network, a benefit-cost ratio of between 4.2 and 10.2 is obtained. Key variables that influence this calculation are highlighted and discussed. It is further noted that the calculated benefit-cost ratios consider only those aspects that can be readily converted to economic benefits. As such, important but less tangible contributions such as the calibration of the South African Mechanistic-Empirical Design Method and technology transfer to local and international practitioners is not considered. Because of this, the calculated benefit-cost ratios represent a lower bound estimate of the benefits derived from technology development work on G1 base pavements.

1. INTRODUCTION

The South African developed Heavy Vehicle Simulator, or HVS, is a test unit capable of evaluating the rate and manner in which roads deteriorate within a short period of time. Whilst road deterioration would normally take place over a period of eight to twenty years, HVS testing can evaluate such deterioration within a period of three to six months. Since 1978, the Gauteng Department of Public Transport, Roads and Works (Gautrans)♣ has owned a HVS machine, and contributed to the funding of the HVS Technology Development Programme, which is centred on the various Heavy Vehicle Simulators that have been operating since that time. From the early 1990's, the Gautrans HVS has been the only operational HVS in South Africa.

♣ The Gauteng Department of Public Transport, Roads and Works is generally referred to as Gautrans. Prior to 1994, this department was known as the Transvaal Roads Department (TRD). In this paper, the term Gautrans will be used wherever possible. Owing to the historical context of this study, the term TRD will also be frequently used where required by the context.

The HVS Technology Development programme is aimed at developing innovative and cost-effective solutions to identified problem areas related to road design and construction. Although the HVS technology development programme (hereafter also referred to as the *HVS programme*) is to a large extent focussed around the HVS machine, a significant portion of the work is focussed on data analysis and transmission of findings to the industry. The transmission of findings is typically effected through conference papers, presentations, seminars and workshops as well as through manuals and guidelines to aid designers in the implementation of technologies that were tested and improved through HVS projects.

As can be expected, the cost of owning and operating the HVS machine and sustaining the analysis and transmission of findings is not insignificant. In the face of increased pressure on the roads budget, it has become essential to proactively define and quantify the benefits of the Gautrans HVS programme. Gautrans thus identified a need to develop and execute an appropriate methodology for quantifying the benefits of the HVS programme. To this end, Gautrans, in October 2003, initiated an independent investigation into the benefits (economic and other) arising from the HVS technology development work.

One of the objectives of this study was to estimate the benefits arising from specific HVS projects conducted in the past. In this paper, the background to the HVS development project on pavements with Graded Crushed Stone bases (known as G1 material) is outlined, and specific findings of the project are presented. Finally, an estimate of the economic benefits arising from the technology development work on G1 base pavements is presented and discussed.

2. BACKGROUND TO THE HVS PROJECT ON G1 BASE PAVEMENTS

G1 material can be generally defined as a high quality Graded Crushed Stone which is constructed in a specific manner to obtain a high density, cohesion and friction strength. The technology for manufacturing the materials and constructing pavements with G1 base layers evolved from the efforts of the former Transvaal Roads Department (TRD), which – in the late 1950's to early 1960's, experimented with different particle gradations and construction methods for crushed stone in an attempt to achieve higher densities and hence higher internal friction and strength. Eventually a construction process was developed in which the fines (minus 0,075 mm material) could be utilised as lubricant during the final wet compaction process. In this process, excess fines were extracted and discarded, in order to achieve a densely packed stone matrix. This compaction process became known as "slushing" and although it achieved an increase in density of only 3 to 4 per cent over that reached during the normal compaction phase, the overall result was a material with significantly higher shear strength. To achieve this state, a cemented subbase was required, since this layer provided a strong, water resistant support on which the final compaction phase could be executed.

The TRD and the National Department of Transport (NDOT) started applying this newly developed crusher run specification on their heavier pavement designs and soon observed that it exhibited a remarkable ability to handle the heaviest traffic loads, was quite impervious to water ingress, and even performed relatively well if it became wet. Although the G1 technology seemed promising, the technology as a whole was at the time not well established, and there was uncertainty regarding several aspects of the new technology. Of these, perhaps the most important was the lack of confidence in the structural capacity of G1 base pavements. Researchers and engineers struggled to define the boundaries within which a G1 base pavement could be expected to perform well. Specifically, there was uncertainty regarding the ability of G1 base pavements to handle traffic in the very high traffic category (classified as 12 to 50 million standard axles, or MISA, at the time).

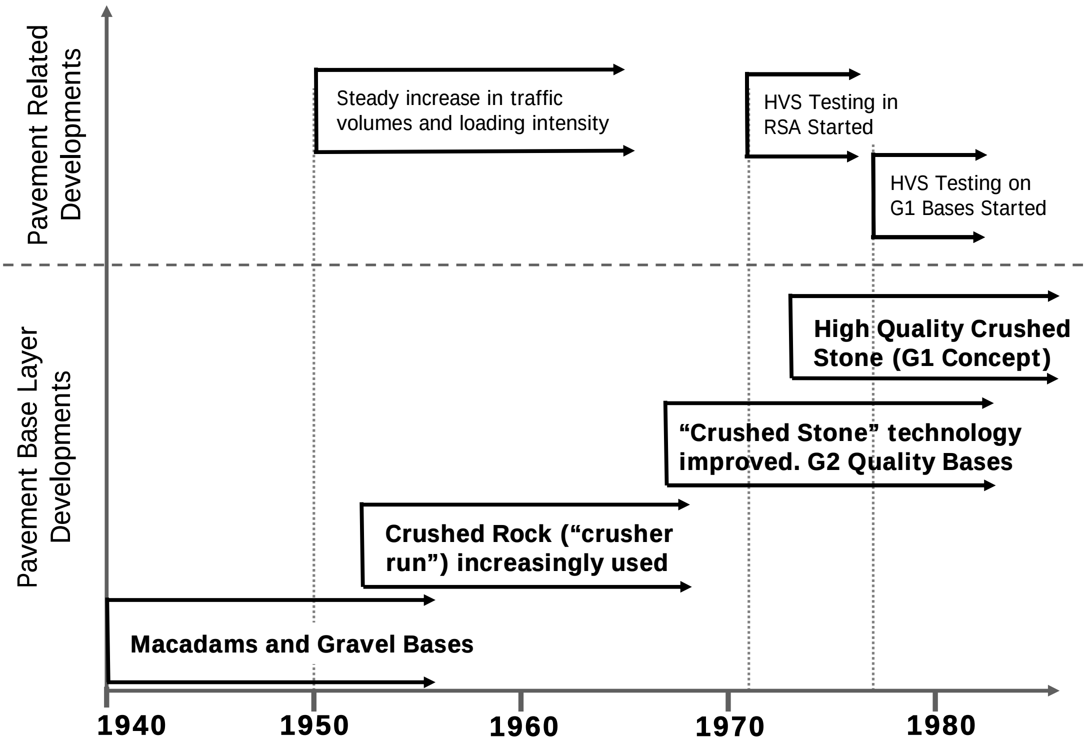

Figure 1. The evolution of unbound granular base technology in South Africa.

The general attitude of researchers and pavement designers towards the use of high quality Crushed Stone materials for these types of traffic demand is best summarized in a document prepared in 1980 by the Committee on Pavement Type Selection for the National Transport Commission (Freeme et al., 1980). This document, entitled "The Economics of Pavement Type Selection", compared the cost effectiveness of various pavement types, including bitumen, tar, crushed rock and concrete base pavements. The following statement, quoted from the introduction, well expresses the attitude towards the use of crushed rock base pavements:

"Only pavements of approximately equal traffic carrying capacity are economically compared in this document. Therefore in the high traffic range (12 to 50 million standard axles over 20 years), only bitumen base pavements are compared with concrete pavements, even though indications are that other pavement types (such a crushed-rock base pavements) may be potentially capable of carrying these high repetitions of axle loads in certain areas of South Africa. It is considered that insufficient reliable performance data are currently available to make this comparison."

To address the uncertainty with regards to the structural capacity, and also to validate some of the behavioural elements of G1 base pavements, the TRD and the National DOT funded several experiments on G1 base pavements. These tests and their main findings are summarized in the next section.

3. HVS TESTS ON G1 BASE PAVEMENTS

HVS investigations were conducted on seven G1 base pavements between 1978 and 1982. The majority of these were conducted in the former Transvaal province, with one test being conducted near Mooi River in Kwazulu-Natal, and another near Koeberg in the

Western Cape. The seven pavements tested were:

- Road S12, near Benoni (Gauteng)
- Road 1955, Section K17 near Ogies (Gauteng)
- Road 1955, Section K11 near Ogies (Gauteng)
- Road P157/1 near Olifantsfontein (Gauteng)
- Road P157/2 near Johannesburg International Airport (Gauteng)
- Road N3, near Mooi River (Kwazulu-Natal), and
- Road TR77/1, near Koeberg (Western Cape).

A summary of the main findings with further references can be found in Jooste and Sampson (2004). These HVS tests and associated investigations allowed researchers to calibrate and refine the technology related to G1 base pavements.

Some of the main findings that followed from the HVS tests are the following:

- Pavements with high quality Crushed Stone bases (i.e. materials that can be classified as G1) are capable of accommodating traffic demands of up to 50 million standard axles.
- The optimum thickness for a G1 base layer on a cemented subbase is 150 mm.
- If a pavement with a Crushed Stone base is maintained with resurfacings at appropriate intervals, the pavement can provide service for an indefinite time.
- For pavements with a G1 base on a cemented subbase, it was found that the damage, or equivalency, exponent "n" has a value of approximately 3, and not 4.2 as was commonly accepted at the time.
- The moisture content of the G1 base is a determining factor in the bearing capacity of G1 base pavements. The quality of the Crushed Stone base becomes even more apparent when moisture enters the layer.
- The high quality, high density Crushed Stone (G1), placed on a thick cemented subbase (200 mm or more), showed the least permanent deformation under loading and was also the least sensitive to moisture.
- A more open graded and less dense Crushed Stone was less stable under loading and also acted as water carrier to distribute water to the rest of the pavement structure (this observation refuted the understanding – prevalent under many researchers at that stage – that more open graded Crushed Stone layers are less sensitive to water since they do not retain water for long periods).
- There was a reasonable correlation between the calculated and observed structural capacities for Crushed Stone layers. This confirmed the appropriateness of the mechanistic design method (which was still being developed at that stage) to analyze these types of structures.

To facilitate the assessment of economic benefits derived from the HVS tests on G1 material, several key impacts were identified, and are discussed in detail in Jooste and Sampson (2004). After consideration of these impacts, and specifically of the data and assumptions needed to convert these impacts to benefits in economic terms, it was decided to combine the identified impacts into the following main benefits:

<u>Benefit 1:</u> Increased use of G1 Base Pavements for higher design classes and wet regions

<u>Benefit 2:</u> Use of a 150 mm maximum thickness for G1 base layers

<u>Benefit 3:</u> Improved maintenance and construction practices

The assessment of the economic benefits provided by these main benefits is discussed in the next section. A key element of this benefit assessment is the recognition that needs to be made to other role players that contributed to the realization of the above benefits. As such, the evaluation of economic benefits derived from HVS tests should recognize the process of technology development, as illustrated schematically in Figure 2.

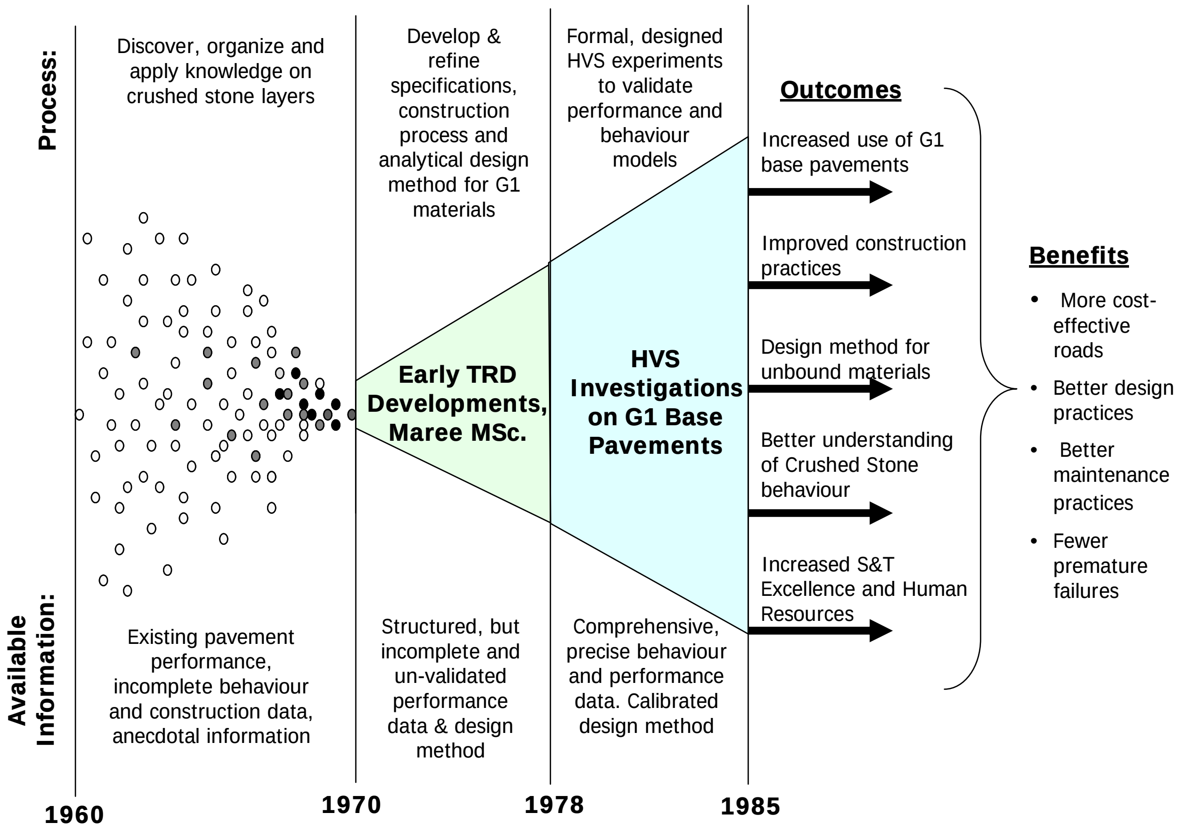

Figure 2. The contribution of HVS investigations to the development of G1 technology (concept after Ounjian and Carne, 1987; and Horak et al, 1992).

4. BENEFITS DERIVED FROM HVS TESTS ON G1 MATERIAL

Evaluations of the economic returns of research and technology development work are notoriously difficult to perform. An economic benefit can only be calculated if the outcome of a technology development effort can be compared to a scenario that would have existed had the development not been undertaken. Such an assessment includes a large element of uncertainty and subjective judgement. For example, no-one can state with certainty what direction the road-building industry would have taken in the absence of the HVS investigations on G1 base pavements. This is especially relevant in the case of a mature technology such as that of G1 material and its associated knowledge elements, which have been assimilated for several decades. Simply put: it is difficult for most South African pavement engineers to imagine a life without G1 material and the knowledge associated with it.

The methodology adopted for the evaluation of economic benefits takes this uncertainty into account, and is based on the framework established by other investigators concerned with assessment of the benefits of technology development work (ARRB, 1992; Swoveland and Cawdery, 1989). The methodology is shown schematically in Figure 3.

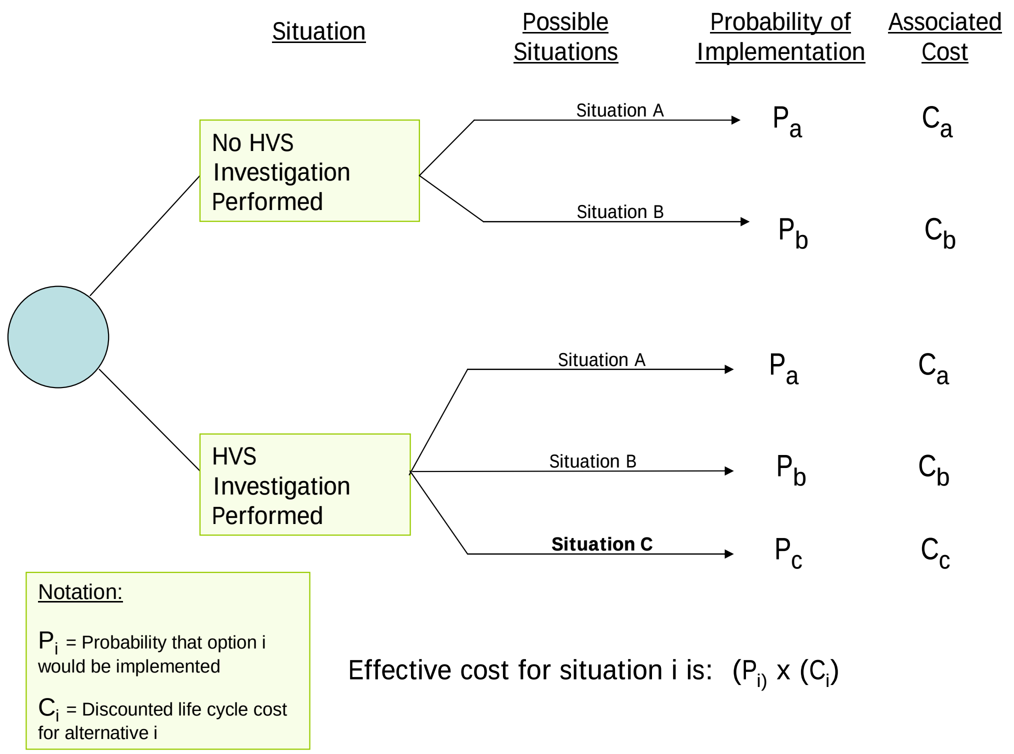

Figure 3. Methodology for evaluating the economic impact of G1 development work (based on ARRB, 1992).

Key elements of the methodology shown in Figure 3 are:

- The situation *with and without* the benefit of HVS investigation findings are assessed;
- The uncertainty of each situation being realized is acknowledged and accommodated by assigning a *probability* to each outcome;
- The cost of each outcome is determined and multiplied with the probability to obtain the *effective cost* for a given outcome.

Once the different outcomes and their associated costs are determined, the benefit of the development work is calculated by subtracting (i) the total effective cost of all options without the benefit of HVS investigations from (ii) the total effective cost of all options with the benefit of HVS investigations. The calculated benefit can then be used with the cost of the development to determine an economic indicator such as a benefit cost ratio or a rate of return.

To ensure objectiveness and credibility, each of the identified impacts and benefits were validated through formal interviews with acknowledged experts and key role players in the South African pavement design and construction industry during the period when the HVS investigations on G1 materials were being assimilated into the industry. Details of these interviews are presented in Jooste and Sampson (2004). In each interview, respondents were asked to comment on each of the identified impacts. Respondents were also asked to comment on the assigned contribution ratio (i.e. the approximate percentage contribution of HVS investigations, specifically, to each impact).

5. BENEFIT ASSESSMENT: EXAMPLE CALCULATION

To illustrate the manner in which economic benefit assessment can be performed, and example is provided of the assessment of the benefits derived from improved maintenance and construction practices. This benefit is related to the impact that the HVS investigations had on improved construction practices, better material specifications and the recognition of the importance of timely maintenance on pavements with Crushed Stone base layers. The background to these aspects is discussed in detail in Jooste and Sampson (2004). To evaluate the economic benefits for these aspects, a life cycle cost calculation was performed for three different performance scenarios. These scenarios are:

Scenario 1: Typical G1 Base Pavement Performance
This scenario is considered to be the reference case scenario, and is based on the typical G1 base pavement performance as documented in Jooste and Sampson (2004).

Scenario 2: Delayed Maintenance Causing Earlier Rehabilitation
This scenario represents a case where the maintenance of an impervious surfacing is delayed, with the result that the unbound base rapidly deteriorates when water enters into the layer. The result is earlier structural rehabilitation.

Scenario 3: Poor Compaction and Material Specifications During Construction
This scenario represents a case where the material used during construction is not of the quality required for G1 materials. More importantly, it assumes a case where the base is not properly compacted. The assumed consequence is early structural rehabilitation owing to deformation in the base and disintegration of the surfacing. The calculation of the life cycle cost for the three scenarios is presented in Jooste and Sampson (2004). The benefit calculation presumes that, partly as a result of HVS investigations and dissemination of findings to the industry, the incidence of Scenarios 2 and 3 decreased somewhat, and the incidence of Scenario 1 increased somewhat. The calculation of the economic benefit is presented in Figure 4. The savings realized through this benefit are summarized in Table 1. Key assumptions and supporting notes are provided below.

Roads with > 3 MISA Design Traffic					
Situation	**Performance Alternatives**	**Probability of Realizing**	**Life Cycle Cost**	**Adjusted Cost**	**Total Adjusted Cost**
Without HVS Test Programme	**Typical**	0.6	R 18.97	R 11.38	
	Delayed Maintenance	0.3	R 20.91	R 6.27	**R 20.34**
	Poor Construction	0.1	R 26.88	R 2.69	
With HVS Test Programme	**Typical**	0.8	R 18.97	R 15.18	
	Delayed Maintenance	0.15	R 20.91	R 3.14	**R 19.66**
	Poor Construction	0.05	R 26.88	R 1.34	
Savings	R 0.69	per square metre			
	R 2.67	per metre of 3.9 m wide lane			
	R 2,674.18	per Km of 3.9 m wide lane			
Cost Scaling:	**Owner**	**Km**	**Saving**		
	GAUTRANS	301	R 804,928		
	SANRAL	1077	R 2,880,090		
Total Aggregated Saving Estimate =			**R 3,685,018**		

Figure 4. Benefit calculation for improved maintenance and construction practices.

Supporting Notes and Assumptions for Figure 4:

- The assumed probabilities of each scenario realizing reflect a general improvement in the life cycle design approach for Crushed Stone base pavements. In particular, it assumes that the incidence of delayed maintenance and of poor construction (owing mostly to poor compaction and inappropriate specifications), decreased from 1980 to 1990. It is further assumed that the HVS investigations and the dissemination of findings significantly contributed towards the decreased incidence of delayed maintenance and poor construction.
- The life cycle cost shown in Figure 4 is per square metre, and is based on a nominal discount rate of 8 per cent, over the 25 year design period considered for the three scenarios.

- The lane-km of road used to scale the cost per square metre to an overall saving, is based on the approximate lane-km of road, owned by Gautrans and SANRAL, with G1 base layers and traffic loading greater than 3 MISA over a 25 year design period. Details of the calculation of the total lane-km are presented in Jooste and Sampson (2004). The lane-km of road used to scale the cost per square metre to an overall saving, takes into account only those G1 base pavements constructed between 1980 and 1990. Thus, the calculation shown in Figure 4 essentially considers the benefit to be relevant only for a period of 10 years.

Table 1. Savings realized due to improved maintenance and construction practices.

Benefit To	In Terms Of	At a Discount Rate Of:		
		4%	8%	12%
Gautrans	1978 Rand	R 611,679	R 469,668	R 364,108
	1985 Rand	*R 804,928*	*R 804,928*	*R 804,928*
	2004 Rand	R 1,695,861	R 3,473,828	R 6,932,651
SANRAL	1978 Rand	R 2,188,632	R 1,680,505	R 1,302,807
	1985 Rand	*R 2,880,090*	*R 2,880,090*	*R 2,880,090*
	2004 Rand	R 6,067,916	R 12,429,609	R 24,805,531
Total	**1978 Rand**	**R 2,800,311**	**R 2,150,173**	**R 1,666,915**
	1985 Rand	***R 3,685,018***	***R 3,685,018***	***R 3,685,018***
	2004 Rand	**R 7,763,777**	**R 15,903,436**	**R 31,738,182**

Note: Savings were calculated in terms of 1985 Rand, and thus the discount rate does not affect the savings in 1985 terms.

The savings summarized in Table 1 represent the total saving to the Gautrans and SANRAL (the former National Department of Transport) owing to improved maintenance, construction practices and material specifications for G1 base pavements. However, as shown in Figure 2, the HVS was only one contributor towards the realization of these savings. Based on interviews conducted with acknowledged experts in the road building industry, it is estimated that the contribution of the HVS to realizing this shift toward improved maintenance and construction practices is between 30 and 60 per cent (interview details can be found in Jooste and Sampson, 2004). Thus for a nominal 8 per cent discount rate, the estimated contribution of HVS tests on G1 base pavements to this benefit is approximately between R 5 million and R 9 million (in terms of 2004 Rand).

6. OVERALL BENEFIT ASSESSMENT

The overall estimated economic benefit stemming from the HVS tests on G1 base pavements is summarized in Figure 5. The data shown in this figure is based on economic assessments of the three main benefits noted earlier. For each of these benefits, the assessment process that was illustrated in the previous section was followed. Details of the assumptions and calculations can be found in Jooste and Sampson (2004).

Key observations stemming from Figure 5 are:

- The overall benefit cost ratio for the combined networks of Gautrans (or the former TRD) and SANRAL (or the former National DOT) varies from 2.4 to 6.1, depending on the contribution ratio and discount rate selected. For a nominal discount rate of 8 per cent, the overall benefit cost ratio varies between 2.9 and 5.1, depending on the contribution ratio selected. This range of estimated benefit cost ratios is similar to the range of 3.8 to 4.9 reported for accelerated pavement testing performed in Australia (ARRB, 1992).

- For the Gautrans network, the estimated direct benefit derived between 1980 and 1990 from the HVS investigations on G1 base pavements is roughly between R 2.2 and R 14.8 million (in 2004 Rand terms). Taking into account the contribution made by Gautrans to the funding of HVS investigations on G1 pavements, this results in a benefit cost ratio of between 1.4 and 3.6, depending on the discount rate and contribution ratio selected.
- For the SANRAL network, the estimated direct benefit is roughly between R 3.4 and R 25.2 million (in 2004 Rand terms). This results in a benefit cost ratio of between 4.2 and 10.2. This benefit cost ratio is higher than that realized by Gautrans, mainly because of the greater scaling of benefits provided by the larger SANRAL pavement network.
- It should be noted that the totals shown in columns 3, 4 and 5 of the tables in Figure 5 represent a total which consists of the sum of all the lowest estimated contribution ratios. Thus the benefit cost ratios shown in these columns represent a highly conservative benefit estimate.

7. SUMMARY AND CONCLUSIONS

This paper presented the background to the HVS tests on G1 base pavements, and summarized a methodology for evaluating the economic benefits derived from these tests. Example calculations are presented and an overall benefit assessment is provided based on the estimates documented by Jooste and Sampson (2004).

The evaluation of economic benefits suggest that the overall benefit cost ratio (i.e. when contributions by all agencies are considered) varies from 2.4 to 6.1, depending on the contribution ratio and discount rate selected. For a nominal discount rate of 8 per cent, the overall benefit cost ratio varies between 2.9 and 5.1, depending on the contribution ratio selected. If the funding provided by Gautrans (or the former TRD) is considered in isolation, then the estimated direct benefit and funding cost results in a benefit cost ratio of between 1.4 and 3.6, depending on the discount rate and contribution ratio selected. If the funding provided by SANRAL (or the former National DOT) is considered, the estimated direct benefit and cost of funding results in a benefit cost ratio of between 4.2 and 10.2. This benefit cost ratio is higher than that realized by Gautrans, mainly because of the greater scaling of benefits provided by the larger SANRAL pavement network.

It is important to note that the benefit assessment presented in this paper include only those aspects which could be converted to economic savings with reasonable confidence. There are several other benefits resulting from the HVS investigations on G1 base pavements, which cannot easily be converted to economic savings, yet are sure to impact positively on the Gautrans and SANRAL budgets and networks over the long term.

These Indirect Benefits include aspects such as:
- Calibration of the South African mechanistic-empirical design method;
- Technology transfer to local and international practitioners which raised the technical competence of designers working for Gautrans and SANRAL;
- Improved understanding of the systems behaviour of granular base pavements, and particularly the interaction between the granular base and cemented subbase.
- Improved understanding of the behaviour of cemented subbase layers under loading. This led to further research into the behaviour and performance of cemented layers.

Since none of the above impacts are included in this assessment, it will be appreciated that the benefits presented in this paper represent a lower bound estimate of the benefits of HVS investigations on G1 base pavements. As suggested by Scott et al (2002), the simple linear benefit assessment process followed here fails to take into account the further downstream benefits and the impact of these benefits on the population at large. This means that the benefit assessment documented here probably greatly underestimates the true benefit stemming from the HVS investigations on G1 base pavements.

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Benefit Summary for Gautrans Investment in HVS Investigations on G1 Base Pavements								
Benefit	Lower Contribition Ratio				Higher Contribution Ratio			
	Contribution Ratio	Discount Rate of 4%	Discount Rate of 8%	Discount Rate of 12%	Contribution Ratio	Discount Rate of 4%	Discount Rate of 8%	Discount Rate of 12%
Increased use of G1 Base Pavements	50%	R 535,117	R 410,881	R 318,534	80%	R 856,187	R 657,409	R 509,654
Increased use of 150 mm Thick G1 Layers	20%	R 55,267	R 42,436	R 32,898	30%	R 82,900	R 63,653	R 49,347
Improved Maintenance and Construction Practices	30%	R 183,504	R 140,900	R 109,233	60%	R 367,007	R 281,801	R 218,465
Total Benefit (in 1978 Rand):	**N/A**	**R 773,887**	**R 594,217**	**R 460,665**	**N/A**	**R 1,306,094**	**R 1,002,863**	**R 777,467**
Total Cost (in 1978 Rand):	**N/A**	**R 358,261**	**R 340,669**	**R 324,813**	**N/A**	**R 358,261**	**R 340,669**	**R 324,813**
Benefit: Cost Ratio	**N/A**	**2.2**	**1.7**	**1.4**	**N/A**	**3.6**	**2.9**	**2.4**
Total Benefit (in 2004 Rand):	**N/A**	**R 2,145,579**	**R 4,395,036**	**R 8,771,091**	**N/A**	**R 3,621,107**	**R 7,417,530**	**R 14,803,024**

Benefit Summary for SANRAL Investment in HVS Investigations on G1 Base Pavements								
Benefit	Lower Contribition Ratio				Higher Contribution Ratio			
	Contribution Ratio	Discount Rate of 4%	Discount Rate of 8%	Discount Rate of 12%	Contribution Ratio	Discount Rate of 4%	Discount Rate of 8%	Discount Rate of 12%
Increased use of G1 Base Pavements	50%	R 488,451	R 375,049	R 290,756	80%	R 781,522	R 600,079	R 465,209
Increased use of 150 mm Thick G1 Layers	20%	R 85,307	R 65,501	R 50,780	30%	R 127,960	R 98,252	R 76,169
Improved Maintenance and Construction Practices	30%	R 656,590	R 504,152	R 390,842	60%	R 1,313,179	R 1,008,303	R 781,684
Total Benefit (in 1978 Rand):	**N/A**	**R 1,230,347**	**R 944,702**	**R 732,378**	**N/A**	**R 2,222,661**	**R 1,706,634**	**R 1,323,063**
Total Cost (in 1978 Rand):	**N/A**	**R 218,277**	**R 194,911**	**R 174,765**	**N/A**	**R 218,277**	**R 194,911**	**R 174,765**
Benefit: Cost Ratio	**N/A**	**5.6**	**4.8**	**4.2**	**N/A**	**10.2**	**8.8**	**7.6**
Total Benefit (in 2004 Rand):	**N/A**	**R 3,411,101**	**R 6,987,351**	**R 13,944,522**	**N/A**	**R 6,162,261**	**R 12,622,867**	**R 25,191,213**

Benefit Summary for Combined Gautrans and SANRAL Investment in HVS Investigations on G1 Base Pavements								
Benefit	Lower Contribition Ratio				Higher Contribution Ratio			
	Contribution Ratio	Discount Rate of 4%	Discount Rate of 8%	Discount Rate of 12%	Contribution Ratio	Discount Rate of 4%	Discount Rate of 8%	Discount Rate of 12%
Increased use of G1 Base Pavements	50%	R 1,023,568	R 785,930	R 609,290	80%	R 1,637,709	R 1,257,488	R 974,864
Increased use of 150 mm Thick G1 Layers	20%	R 140,573	R 107,937	R 83,678	30%	R 210,860	R 161,905	R 125,517
Improved Maintenance and Construction Practices	30%	R 840,093	R 645,052	R 500,075	60%	R 1,680,187	R 1,290,104	R 1,000,149
Total Benefit (in 1978 Rand):	**N/A**	**R 2,004,235**	**R 1,538,919**	**R 1,193,042**	**N/A**	**R 3,528,755**	**R 2,709,497**	**R 2,100,530**
Total Cost (in 1978 Rand):	**N/A**	**R 576,538**	**R 535,580**	**R 499,578**	**N/A**	**R 576,538**	**R 535,580**	**R 499,578**
Benefit: Cost Ratio	**N/A**	**3.5**	**2.9**	**2.4**	**N/A**	**6.1**	**5.1**	**4.2**
Total Benefit (in 2004 Rand):	**N/A**	**R 5,556,680**	**R 11,382,386**	**R 22,715,611**	**N/A**	**R 9,783,368**	**R 20,040,396**	**R 39,994,235**

Note: Discount rate is applied in converting savings (which are in terms of 1985 Rand) to 1978 Rand and to 2004 Rand

Figure 5. Summary of benefits derived from HVS investigations on G1 base pavements.