DP-041

BRIDGING THE GAP BETWEEN APT RESULTS AND PRACTICE

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ABSTRACT

In many a country, exciting research results are gathering dust in the folds of dutifully compiled reports without being put to innovation nor practice. This might be because of the lingering archaic consideration that research is research and practice is practice and never the twain shall meet.

For the past 25 years the Heavy Vehicle Simulator (HVS) test projects in South Africa have been managed on a day to day basis by the Transportek Division of the Council for Scientific and Industrial Research (CSIR). Publications regarding the projects have focused mainly on the many exciting technological results. However, in so doing, it seems that an important component of the "success carrier wave" has largely been taken for granted during the entire operation. In retrospect it is evident that the credit for this successful interaction must be ascribed to the fact that both research and practice had an active and committed partnership approach, guided by an agreed upon overall vision, mission and strategy, which took both the technological as well as the practical objectives into account.

This paper describes the managerial approach and the process developed by the CSIR and the road authorities in managing the HVS projects and implementing the findings. It also highlights the importance of viewing APT testing as the link between laboratory testing and eventual long-term pavement performance and shows that a holistic approach is necessary to ensure technology enhancement and practice accepted technology transfer. The paper is concluded with a diagrammatic representation of the interactive process between research and practice towards credible technology enhancement and guidelines.

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1. INTRODUCTION

The first of an eventual fleet of four Heavy Vehicle Simulator (HVS) machines in South Africa, started operating towards the middle of 1971 (1. Freeme *et al*, 1981; 2. Freeme *et al*, 1982). During the period 1977 to 1992, the four HVS machines were continuously engaged in testing a variety of pavement structures on roads across the length and breadth of the country, as illustrated in Figure 1. More recently, a number of the very machines which saw service in South Africa as well as a few modernized versions of these early mechanical pioneers have started appearing at other international test sites (3. Nokes *et al*, 1997).

The development of the HVS and the impact of the work done with these machines have been well documented and presented at numerous forums across the world (4. Walker *et al*, 1977; 5. Kleyn *et al*, 1985; 6. Freeme *et al*, 1987; 7. Horak *et al*, 1992; 8. Rust *et al*, 1997). The importance of this link between laboratory studies and implementation was also discussed by Nokes (3), Rust (8) and Hugo *et al* (9). Rust (8) aptly illustrated the role of APT testing in a holistic approach to pavement engineering development as shown in Figure 2. The aspect of compatibility between the results obtained from APT studies is addressed by the Task Force on Accelerated Pavement Testing (A2B52) at the annual TRB Meetings - kick-started by a forum discussion on 9 July 1996 at the CSIR in Pretoria, South Africa. However, only the so-called "sharp edge" of the research work has been highlighted, and mostly without much mention of the all important managerial milieu within which this activity took place. This, inadvertently, could have fostered the perception that an APT project mainly entails keeping the machine running and retrieving the data.

Additionally, in the publication by Horak (7) the usefulness of the HVS data is related and reference is made to a figure originally published by Freeme (10. Freeme *et al*, 1984), shown here as Figure 3, which relates the project complexity, benefits, cost and confidence or reliability of results. Attention was drawn to the fact that the application of the HVS-derived and -verified technology, as well as the transfer of such technology enhances the usefulness of other decision tools. However, the way in which this was to be achieved was not expanded upon. Furthermore, while this figure did much to organize the early thinking regarding the impact of the HVS/APT work, it, once more, neglected the importance of the interaction between research and practice in developing and getting the technology generally accepted and applied.

The intention of this writing is to augment the publications mentioned above as well as update a similar paper delivered at the International Colloquium on Full-Scale Pavement Tests (11. Maree *et al*, 1982), by highlighting the managerial and organizational support which made the technological advances possible. The paper will also direct attention to the co-operative approach shared between the road authorities and the research institute, which is believed to hold the key with respect to bridging the gap between the "APT Testing" and "Implementation" phases shown in Figure 2.

2. PROJECT DESIGN AND MANAGEMENT

Since the South African road authorities and the CSIR had established a very healthy working relationship over a number of years, the acquisition of the HVS machines, the project designs and management was done in close co-operation with one another. Although this strategy was locally considered to be the logical approach at the time, subsequent discussions with international players in the field indicate it to be the exception rather than the rule, especially as far as interactive technology transfer and application is concerned.

At the time there was no ready-made guideline regarding the partnered management of a facility like this between a road authority and a research institute and it was decided that the design of the project would be based on the traditional structured approach generally applicable to any endeavor (Goal, Purpose, Strategy, etc. - 12. Hubbard, 1996), which would then serve as managerial directive for the technical, financial and manpower components of the venture. This approach might be simplistically illustrated as shown in Figure 4, where the organization may be seen as a (spiraled) assembly line which is motivated and driven by needs which are addressed and processed by the components of the organization against the central organizational "guidelines" in order to produce a valuable and wanted end product. Note that, regardless of the number or variety of components contained within the organization, "understanding" is the vital link between the organization and the external needs as well as the product offered.

However, while a definite structured approach was taken by the parties involved, it was foreseen that a certain amount of optimizational amendment would be necessary during the project - relying heavily on mutual trust in order to avoid much of the time consuming traditional red tape associated with this type of venture. Utilizing the conceptual approach illustrated in Figure 4, this process of harmonizing the aims of and benefits to both parties may be illustrated as shown in Figure 5.

Of necessity, the first managerial step taken by both parties was to appoint a small, yet dedicated, Steering Committee consisting of two to three senior engineers from either party plus a so called "champion" from either side . The Champions would be middle management engineers who would handle the day to day running of the project. Although it was understood that the Champions would still have other normal duties within their organizations, it was expected that they would "live" with the project. Each member of the Committee had to be intimately associated with the road building field and especially the pavement engineering and materials side of it.

At this point in time it was agreed that, in general, the Road Authority Champion would be more concerned with the applicational aspect of the project, while the CSIR Champion would handle the operational aspect (including manpower and finance) as well as the technical developments. However, as it turned out, no succinct distinction was enforced in practice because of the continuous "sound boarding" between these two persons.

The Steering Committee for each HVS spent considerable time in designing and formulating their project before the arrival of their machine, even though it was clear that it would only be "first drafts" that would see many optimization attempts and "borrowing" from one another in the years to come. Reviewing the approach which the Steering Committee for HVS4 took in defining the project and its management, the major managerial components addressed may be itemized and ranked as shown in Table 1 below. A brief discussion of these topics follows.

TABLE 1: Managerial Components Clarified Prior to Commencing with the HVS Project	
1. Goal/s	5. Programs and Activities
2. Purposes	6. Managerial Statistics
3. Policies	7. Deliverables and Valuable Final Products
4. Strategic Plans	

While the managerial components considered by the Steering Committees were essentially the same, it is clear from Figure 1 that the focus of each machines differed slightly from the other, reflecting the role anticipated for each machine within the national need as perceived by the Steering Committees. Some machines focused more on long-term evaluation of the local pavement composition principals while others concentrated more on short-term solutions related to the relative differences between alternative base course materials.

In retrospect the value of these early decisions was validated in the abovementioned paper by Horak *et al* (7) when they quoted the axioms for successful research (13. Oujian and Carne, 1987) indicated below, and wrote: "At this stage it is heartening to observe that the HVS management has, unbeknown to itself, been following the concepts expressed by the above axioms".

Axiom 1: Utilization is inversely proportional to the distance between the researcher and the users of research.

Axiom 2: Utilization is inversely proportional to the degree of formality in the communication between the researcher and the user.

Axiom 3: Utilization of research increases with the degree of understanding that the researcher and the user have of each other's problems and motivations.

2.1. Goals

It is common knowledge that any directed activity is normally spawned by a goal, dream or vision, even if not always clearly stated. However, since it is the most senior item in the chain of action for any endeavor, in support of which all activities have to be aligned, it should preferably be defined quite succinctly and supported undisputedly by the parties involved.

Although both parties regarded the setting of a goal as the "right way to go about it", its importance in anchoring and maintaining the guiding golden thread of the project amidst many tempting suggested diversions only later became tangibly clear and much appreciated. To a large extent the motivation used by the road authorities to initiate the national HVS project had already exposed the more senior need and postulated goal for the project. Hence, the Steering Committee virtually had a ready-made goal which was formulated as shown in Table 2.

TABLE 2: The Goal of the HVS Project
• Gain an understanding of the basic structural behavior of road pavements and
• appraise the relative viability of the locally developed pavement design philosophy.

2.2. Purposes

While the Goals were taken to state the overall postulate for the project, it was considered necessary to underpin them with some of the more specific supportive components of the Goals in order to enhance the focus of the activities as well as to afford project mile-stones. Even though some of the purposes were slightly amended during the project, Table 3 serves to illustrate the initial vision. Note that these purposes were augmented by the "unforeseen deliverables" as indicated under paragraph 2.7.

TABLE 3: The Purposes of the HVS Project
To identify/evaluate/determine/define: • The behavior of typical pavement structures as a system. • The effect of shallow vs deep pavement systems. • The meaning and impact of strength balance within a pavement system. • The sequential structural changes that take place in the system under trafficking. • The different failure / aging mechanisms of the different pavement types. • The water sensitivity of the different pavement types. • The behavior of different materials (as layers) within the various pavement types. • The remedial measures for some typical pavement failure mechanisms. • The typical load sensitivity / equivalency factors applicable. • The cost efficiency of the different pavement types (Cost / length / Million Std Axles). • The typical life cycle strategies for different pavement types.

2.3. Policies

Notwithstanding the mutual trust and a number of gentleman's agreements built in and up over years of co-ordinated project handling, the Steering Committee considered it wise to tie some of the agreements pertaining to this project down more succinctly than before. While it never developed into any cause for friction in the years to follow, it certainly, once more, assisted in focusing conduct and imparting legitimacy to the activities of the project. Table 4 highlights some of the operational policies which had to be addressed and clarified.

TABLE 4: The Policy of the HVS Project
• The role and activities of the Steering Committee. • Selection of HVS test sites. • Defining and maintaining the "ideal scene" of the various components of the project. • Data retrieval, storage and ownership of the data. • Handling of the funding and finance aspects. • Implementation of significant findings "on the run" (prior to any documentation). • Reporting back to top management and field (locally as well as internationally) • Handling of any change in the operational plans and activities. • Handling of site visits by team members, dignitaries and visitors. • Handling of site management. • Handling of machine maintenance. • Long-term monitoring of sites.

2.4. Strategic Plans

Following on the formulation of the Goals, Purposes and Policies, the Committee looked at the various levels of planning necessary to achieve the Goal. First in line, of course, was the Strategic Plan which had to provide direction for all the activities of the echelons below it. This requires the Committee members to have a complete overview of the existing scene (hence the careful composition of the Steering Committee in each case) and was defined in fairly broad terms as indicated below, with the knowledge that each one would have to be detailed, as necessary, when taken into account during the programming of the subsequent stages of the project. Tables 5, 6, 7 and 8 show a list of the guiding strategic plans that were followed in South Africa.

It should be kept in mind that even though the strategies may be stipulated to the best of the Steering Committee's ability, amendments are virtually bound to happen due to technological advancements and change in managerial viewpoint during the project (14. Rust *et al*, 1996). Although such changes are generally advantageous in the long-term they may be quite frustrating at the time. An example of this is the way the data was stored during the early stages of the South African projects. This was done on first generation tape, having been the "latest" and most viable technology then.

The inevitable replacement of that method by long-lasting magnetic tape (and later by CD-ROM technology) caused a lot of frustration at the time but none as unpleasant as the fact that the initial tape is now no longer readable, resulting in some of the initial data being lost. This, of course, once more emphasizes the prime importance of the data storage process and the immediate analysis and reporting of test results and (early) conclusions.

Regarding the strategy of having the laboratory test results of the pavement materials available before commencing with the HVS test, apart from the obvious reasons, it was also considered important to investigate the nature of the link between the two "test" methods. The rationale behind this thinking being that laboratory tests are always cheaper, faster and easier to obtain than HVS results and therefore a correlated model would be very useful, even if only to improve entry level pavement performance estimation.

TABLE 5: The General Strategic Plan for the HVS Project
• Work on pavements that have stood the test of time, not experimental sections. • Adhere to the program (pavement type, road, site, test section) - the "golden thread". • For logistical purposes, work as close to base (or satellite office) as practically possible. • The machine must be operated on a 24 hours per day basis, if practical. • Start with the lightest pavement types and progress to the heavier classes. • Have "as built" and maintenance records available of the pavement. • Have laboratory test results available on all materials in the pavement to be tested. • Have *in situ* strength (Dynamic Cone Penetrometer, DCP) and deflection available. • Adhere to all applicable road and factory safety regulations at all times. • The HVS and site must be well lit at night - for the above reason. • Regularly interject "research" cycles with "application" cycles. • Follow a well founded, state of the art, permanent data storage program. • Develop appropriate measuring equipment as and when necessary.

TABLE 6: The Technical Strategic Plan for the HVS Project
• Postulate the expected pavement behavior based on the laboratory and other test results - have a friendly competitive atmosphere. • Perform HVS tests on properly evaluated, measured and instrumented test sites. • Only use sites which are safe and structurally sufficiently uniform. • Plan and identify sequential sites well in advance. • Have a standardly evaluated, measured and instrumented "control" section. • Include a test with the standard wheel load (40 kN) and tire pressure (620 kPa). • Start analyzing and evaluating the results immediately during the test. • Champions to have frequent site visits, especially when "something happened" (live with the test). • Never move from the test section before it has "failed" in some quantify-able way. • Never move from the site while in doubt as to what had happened. • Keep in mind that the test results pertain to an *STPP window on the **LTPP curve. • Always relate the results to the "known and proven" but never force it to agree. • Eventually verify the pavement behavior and performance on the **LTPP sections.

* : Short-Term Pavement Performance
** : Long-Term Pavement Performance

Since it was obvious that "transfer functions" would be involved to convert the HVS results or Short Term Pavement Performance (STPP) "windows" to practical pavement design and evaluation or Long Term Pavement Performance (LTPP) tools, it was considered essential to identify and evaluate various short sections of pavement along the test site route, which may then be monitored over their service life. Ideally, one of these sections, called a "control section", had to be within the HVS test site area and treated, instrumented and measured exactly like the adjacent sections under test, only not trafficked by the HVS.

It has to be well understood from the outset that the value of the HVS tests lies in the data analysis, its interpretation and the technology transfer . To maximize the benefit of the HVS project, sufficient funds must be available to drive the program as well as for second level analysis and information dissemination. Based on Gautrans's experience with HVS4, the cost of laboratory testing and

TABLE 7: The Financial Strategic Plan for the HVS Project
• The Road Authority (RA) would provide the HVS machine and operational funds to the Operator (CSIR in South Africa). • The funding would pay for first level analysis of the data. • Funding for second level analysis and information dissemination would be handled / solicited for by the Operator in co-operation with the RA. • The operational funding would include laboratory tests of the pavement material. • The operator would submit detailed proposed annual budget to the road authority. • HVS testing may not proceed without the necessary budget ratification, unless borne by the Operator. • The Operator would submit quarterly financial reports to the road authority. • Anticipated over expenditure would be reported immediately and if not successfully rectified by the road authority, would be handled internally by the Operator and/or through amendment of the test program.

TABLE 8: The Human Resource Strategic Plan for the HVS Project
• Select project personnel purposefully. • Put all site personnel through an appropriate information and training regimen. • Have regular site feedback and call-ins as soon as "something happened". • Have precise "normal" and "emergency" site conduct regulations. • Have regular (at least once a month) information sharing and co-ordination meetings. • Have a mutually agreed to shift and transport program. • Have an accountability structure / organigram (diagram of the organizational structure). • Supply adequate and practical site accommodation and facilities.

second level analysis can amount to 50% of the operational cost (inclusive of first level analysis cost). Keep in mind that, for the sake of continuation and credibility, the second level analysis more often than not also includes previous and international tests. This necessitates a bird's-eye view approach to the overall Information and Technology Transfer (IT^2) program and cost and, in effect, a long term IT^2 life cycle strategy vision.

2.5. Programs and Activities

One has to bear in mind that Accelerated Pavement Testing (APT) is very costly and still quite time consuming, hence all activities should be well planned, co-ordinated and systematically executed. This tactical planning and programming should be done in accordance with the Strategic Plans.

As mentioned before, the strategic plan has to be underpinned by medium-term programs and short-term activities which would detail the sequential steps to be taken in order to accomplish the respective Programs and the Strategic Plans. For obvious reasons only one example of such a program and activity write-up is given in Tables 9 and 10.

Obviously the steps in the activity write-ups require further supportive activity planning, clarifications and instructions, as necessary, depending on the skills required and available. However, the above should suffice to convey the general approach.

TABLE 9: Program for Selecting a Site of Appropriate Bearing Capacity and Uniformity
• Scan data base for candidate roads regarding pavement composition and potential appropriateness of bearing capacity. • List candidates, ranked in terms of closeness to base (Pretoria for HVS 4). • Starting from the closest road, do site inspection to evaluate environmental suitability • Evaluate functional safety factors along route. • Evaluate accommodational and other operational factors along route. • Select candidate safe and operationally friendly sites along route. • Measure and evaluate in situ bearing capacity potential of candidate sites. • Evaluate uniformity of potential sites with "correct" bearing capacity. • Select site/s conforming to above prerequisites. • Do detailed measurement and evaluation for bearing capacity and uniformity. • Rank sites with respect to appropriateness.

TABLE 10: Activity Write-Up for the Selection of a Uniform Site by DCP
• Do the Dynamic Cone Penetrometer (DCP) measurements at intervals of approximately 10 m along the selected road section. • Do the measurements in the "wheel path" of the HVS. • Prepare the measurements in the appropriate manner (graphically and tabulated). • Obtain uniformity parameters applicable to the particular test from the Champions. • Evaluate the entire structure (DCP pavement structure number) for uniformity. • Evaluate the upper pavement layers for strength uniformity. • Evaluate structural balance of the pavement for representativeness and uniformity. • If possible, select successive uniform sections commensurate to the HVS "test wheel run length" for the envisioned number of tests to be done. • If not possible, select another site.

2.6. Managerial Statistics

Strictly speaking statistics are those numbers which simply "count" the products attained or obtained and while for some people life revolves around the manipulation of such "counts", effective management revolves around the interpretation of statistical "messages" and the consequent action taken to achieve the postulated goal. In other words stats should be an indication of the degree of attainment of "something" as well as an indication of the correct action to be taken regarding the attainment of that thing. Hence, statistical management is the only kind of management to apply to an assembly line scene, such as in this case.
This means that each of the Purposes shown in Table 3 and their underpinning Programs and Activities had to be analyzed with respect to determining the correct indicator to be applied and monitored in order to obtain a meaningful statistic. Fortunately many of the activities are well known and thus have well developed monitoring processes which sometimes only required re-grouping and/or re-alignment to mutual satisfaction of the parties involved, *a la* Figure 5.

The Steering Committee was very aware of the fact that however carefully and extensively the project needs were surveyed, discussed, defined, programmed and monitored, the results and their speed of attainment were bound to come in for some criticism from the powers that be as well as colleagues. Hence, apart from the Steering Committee wanting to know what was happening in order to properly manage the operation, it was equally important to properly monitor, measure and represent what was happening at a test site in order to demonstrate competency and warrant credibility.

A number of statistics were selected whereby the general "flow" of things were monitored as well as technical progress measured and directed. These were basically classified in terms of, a) Operational and b) Goal Alignment issues. Depending on the purpose and managerial implications of the statistic it was generally considered a short-term (e.g. load/deformation graphs) or long-term (e.g. operational cost breakdown pie-charts) managerial tool. This determined the updating urgency and frequency of the statistic - some of the short-term statistics were updated on site to afford immediate corrective action as and when necessary by the Champions. Without going into the detail and format of each statistic (which is mostly self-evident by nature), Table 11 serves to list some of the typical parameters monitored as managerial statistics.

TABLE 11: Typical Parameters Monitored During an HVS Test

a) Operational

- Test directive measurements regarding the pavement behavior.
- Machine consumables (fuel, lubricant, etc.)
- Machine statistics ("operative", "measuring", "servicing", "breakdown" and "inoperative").
- Site staff remuneration, subsistence, transport, services, etc..
- Site visits by management and local and overseas dignitaries.

b) Goal Alignment

- Technical representations regarding pavement behavior and performance.
- Enquiries and information dissemination.
- Regular technical reports by Operator.
- Papers written for conferences.
- Comments from the Steering Committee, local and international experts.
- Feedback from application by road authorities.
- Official response from various technical committees in the field.
- Alignment of results with existing knowledge and road authority manuals.

2.7. The Deliverables and Valuable Final Products

By nature, the production of specific and wanted products as the end result of an activity is the reason for the existence and continuation of any business. This basic law was also applied to the HVS project by the Steering Committee and the degree of success achieved evaluated by the parameters mentioned above. Although a number of foreseen deliverables were identified as mentioned under "Objectives", a surprising number of "nuggets" eventually agglomerated to the "golden thread". Some of them would merely modify or augment known understanding while others would present surprising and/or far reaching new view points. However, all of them, in one way or another, constituted valuable final products and were reported on in numerous publications regarding the HVS work. Some of the more memorable unforeseen deliverables are listed below in Table 12.

TABLE 12: Examples of Memorable Unforeseen Deliverables

- Very little is learned if a pavement cannot be "failed" in some manner by the load.
- The load can "mould" a pavement structure into another state of internal strength distribution aimed at "Pavement Strength Balance" and effecting the load sensitivity.
- A functionally "failed" pavement may actually have increased in structural value.
- The merit of Dynamic Cone Penetrometer (DCP) measurements was proven.
- The mechanism responsible for the pumping of fines from a pavement was qualified.

3. TECHNOLOGY TRANSFER AND IMPLEMENTATION

It is common knowledge that one only really utilizes that which one understands - which one has made one's own. Without understanding one might, at best, be persuaded to go through the motions of utilizing something but, more often than not, such activity is haunted by inexplicable counter intentional mishaps, which in practice basically boils down to non-compliance. Hence, while it is essential to do research and technology development, it is to no avail if it is not transferred in such a way as to result in ownership and implementation by the recipient.

As mentioned earlier, the South African road authorities and the CSIR had been enjoying a close working relationship since before the advent of the HVS era. This does not mean that the parties always had the same approach but rather that the end goal regarding the delivery of a service to the community has always been quite similar. Hence, while it was very noticeable that an atmosphere of professional competition between the engineers in "practice"and those in "research" existed, the consideration of "we need each other" to deliver the optimum service always prevailed. It is clear that this situation has mostly been positively managed to the benefit of all, rather than ignored. It was seen to that both sides frequently and regularly met in local and national interest, through different committee activities or brainstorming sessions, to air and focus opinions and findings towards co-ordinated research and implementation. This co-ordinated co-operation was, once again, utilized very successfully in respect of the HVS project, especially regarding technology transfer and implementation.

It is only later, through international contact, that one started to appreciate the value of having such a co-ordinated co-operative system - a "management system" in its own right - the vehicle through which practice and research may successfully interact and deliver. The following description summarizes the process as utilized in respect of the HVS test results.

3.1. Living With The Project

As mentioned earlier, the two Champions were expected to "live" with the project - meaning that they would not miss a beat of what was happening at the test site. It meant that they would analyze and evaluate what was happening, virtually, as it occurred. It meant that they could amend the test procedure and/or the time spent on it at short notice in order to maximize productivity and effectivity without first having to refer back to the Steering Committee. Note, that such action can only be taken with the necessary confidence if the Champions know their business. This process also facilitated improvement to the machines themselves, as mentioned at ICAP '97 (8).

The site crew had instructions that if they noticed any change in what was happening under the wheel or any deviation from the "norm" in their regular measurements, they were to call (by radio link) the Operator Champion. He would evaluated the situation and inform the Road Authority Champion and together they would decide whether to have a site inspection and what the urgency factor was. In this way both Champions, more often than not, got to see and "live" through any groundbreaking happening on site.

On both sides this evaluation would incorporate each other's initial prediction of the progress of the test - the friendly competition. Both parties would act as control on one another, inhibiting biased write-ups and evaluations to suit a particular viewpoint, but more importantly, it would supply an immediate opportunity for brainstorming the events and behavior of the pavement - the first phase in the technology formulating and transfer chain. However, this had to be followed up by the systematic and scientific analysis and evaluation of the accumulated data. Refer to Table 13 for a summary of what "living with the project" implies.

TABLE 13: What Living with the Project Implies
• Applying all the available appropriate monitoring and measuring systems. • Regular and frequent measurements on the test section - also the control section. • Regular feedback from site personnel. • Immediate "alert" feedback from site to the Operator if anything happens. • Evaluation of situation by the Operator and communicate to Road Authority Champion. • Regular and special site inspection by Champions (together). • Immediate evaluation of the pavement behavior by the two Champions. • Immediate short term amendment of specific test and the long term program. • Immediate analysis and evaluation of the data accumulated. • Continuous notes and regular reports on site occurrences. • The Champions could always convey the latest information at short notice.

3.2. Disseminating And Implementing The Test Results

Since the Champions both had an intimate knowledge of their field and their organizations, they could evaluate the implications of any indication or change in trend at the test site with understanding. Thus, "scoops" could be identified rapidly and conveyed to the Steering Committee long before the regular reports could be compiled. Thus, practice could be alerted and notaries and personnel invited to a special pavement behavior demonstration on site - extending the perception of ownership of the results to management and construction personnel alike.

Even if a special site inspection was not considered necessary, both Champions could rapidly incorporate the latest find into their systems - affecting Long Term Pavement Performance (LTPP) sections with the latest Short Term Pavement Performance (STPP) information. In essence, it boiled down to continuous rapid dissemination of the important test results. Refer to Table 14.

3.3. Acceptance Of The Results By The Road Authorities

By virtue of the early and probably the phased implementation of the HVS test results (by road authorities and researchers who have been afforded the chance to "buy in" on the program) while the test programs were still being executed, a number of parallel LTPP sections were, in essence, created.

TABLE 14: What Rapid Dissemination of Test Results Implies
• Knowing the subject and field. • Living with the test. • Identifying the "scoops" and "nuggets" immediately. • Disseminating the latest findings and their implications immediately. • Enhancing ownership by special site demonstrations and construction feed-in. • Regular (even interim) reports on the latest finds and their implications. • Holding seminars on the latest finds, related to the tried and trusted.

These sections augmented the work done by HVS by accelerating the evaluation and verification phase of the results. Not only did this approach enhance the credibility of the results but, maybe more importantly, served to accelerate the application of the findings to the normal design procedures and manuals as well as the contract specifications of the road authorities. Refer to Table 15.

TABLE 15: What Acceptance of Test Results by the Road Authorities Implies
• Having an active Champion from each road authority. • Keeping the Champions and Steering Committees informed of the latest results. • Highlighting the impact on theory and practice on a continuous basis. • Arranging cross-fertilizing brain storming sessions/seminars with the authorities. • Keeping intra-authority competitiveness alive on a friendly basis. • Demonstrating continued technology co-operation and sharing. • Interactive assistance with the amendment of applicable road authority manuals.

3.4. National Introduction Of The Test Results

In South Africa the tradition has evolved whereby the national and provincial road authorities in conjunction with the CSIR compile "national" manuals which may be applied on a broad basis by practicing engineers and other bodies involved in road management and construction field. These manuals are called Technical Recommendations for Highways (TRH) and Technical Methods for Highways (TMH).

The prerequisite for the recommendations and methods given in these documents is that they be time tested and proven by the road authorities. In other words, any engineer or body utilizing these manuals has great confidence therein because of the fact that the advice and designs given are based on practical application and experience by the road authorities in conjunction with co-ordinated and applicable technology developed by the CSIR.

Thus a system was created through which the needs and/or problems of practice could be addressed in research and the results could be verified and validated by the larger road authorities to a point where it could be released in refined format to the field. This very same avenue was also used to introduce the HVS findings to the road building fraternity on a national basis. Refer to Table 16 for a summary of what the process of national introduction implies. Table 17 lists some examples of APT findings that have been handled in this manner in order to improve procedures in South Africa - bourn out by the abovementioned references as well as references 15, 16, 17 and 18.

TABLE 16: What National Introduction of the Tests Results Implies
• Provincial and national road authority manuals and practice utilize the test results. • Appropriate national sub-committee identifies need to update/initiate a TRH or TMH. • National sub-committee obtains permission from National Co-ordinating to proceed. • Draft document is produced by working group of sub-committee. • Draft document is made available by the appointed distributor. • The draft document is allowed to be applied in practice for about one year. • Comments on draft document are collected by sub-committee. • Document is amended as necessary by sub-committee. • Final document is ratified by national Co-ordinating body. • Document is made available by the appointed distributor.

TABLE 17: Examples of APT Findings That Have Resulted in Improved Procedures
• The dramatic effect of water taken to heart in designs & maintenance procedures. • Bearing capacity of road authority light pavement catalogue stepped-up. • A deformed pavement has not necessarily failed structurally (Traffic Moulding). • The concept of deep vs shallow pavement composition accepted & applied. • Pavement designs must strive for strength-balance (Provincial, TRH & Sabita manuals). • The load equivalency exponent (n) normally lower than "4" for local pavements. • Cemented-base-only pavements used only for very light traffic by road authorities. • Crushed Stone base proven top-performer - in national specification document. • Local (inverted) pavement design philosophy sound - used by all road authorities. • APT findings have been incorporated into local pavement mechanistic modeling.

4. CONCLUDING DISCUSSION

The partnered management approach developed between the CSIR and the major road authorities in South Africa regarding the national Heavy Vehicle Simulator (HVS) project has been described in this paper. It was shown that the much acclaimed contribution made to the advancement of pavement technology by this project rests squarely on a foundation of dedicated structured research management and information dissemination to bridge the gap between APT testing and implementation (Figure 2). This, of course, highlights the fact that the "product", *a la* Figure 4, answers the "need" only to the degree that it finds application.

This implies that something has to happen before research results "find" application - technology transfer has to take place. This also implies that technology transfer can only be deemed successful to the degree that it results in application and, even more so, to the degree that it results in feedback - a two-way communication between the researcher and the practitioner. It immediately tells one that technology transfer has to encompass far more than merely the publishing of information. It has to positively manage the transition of research information into practical implementation as well as the feedback from practice, otherwise the information seems to disappear - and so too the need for research.

It is true that application can be enforced, and so create a false positive statistic but it is equally well known that such application is doomed to failure, either slowly or rapidly, due to persistent and inexplicable mishaps leading to functional non-compliance - the only feedback then being "it did not work". Experience has taught that such situations can relegate the most innovative research to dusty shelves. Effective and lasting application comes from being able to think and plan with the research information, which stems from a basic understanding of both the subject as well as the prevailing situations which have to be handled and managed.

On reviewing the South African HVS projects, it is clear that while the results and technology enhancement which flowed from it occupied much of the center stage, the continuous process of technology transfer between the CSIR and the Road Authorities, on a one-to-one basis, was really the carrier wave for the success of the project - it resulted in the information being understood and applied. Without putting any effort into it, following the partnered managerial and technical processes highlighted in this paper, it has resulted in a systematic and co-ordinated enhancement of the understanding of the behavior and performance of the various types of pavements. Which, in itself, constitutes a valuable final product, confirming the validity of the locally evolved technology transfer process which had been practiced as a natural follow-on to the atmosphere of mutual co-operation enjoyed by the road authorities and the CSIR.

Although it might seem like stating the obvious, the importance of having a dedicated managerial team representative of research and practice who "live" with each test can not be overstated. Despite its size and complexity, the machine is merely another measuring instrument in the hands of the research engineer - it needs continuous directing regarding operational time, wheel loading, measurement timing, et cetera, to optimize the results and reflected trends. This can only be done with knowledgeable personnel who monitor the progress of tests on a continuous an personal inspection basis, otherwise ".. the machine will only tell you how long the pavement lasted!" It is through these people that the latest finds are disseminated and even applied while it is still happening - enthusiasm is maintained - buy-in is accomplished.

In respect of the credibility and meaningfulness of the results and models, it is important to predict and correlate the HVS results with known practical and theoretical technology. This not only keeps the project management team on their toes and facilitates timely changes to the program but also lends credibility to the exercise when discussed with interested parties and clients - facilitates national acceptance and application in guideline documents. Hence, the recommendation that laboratory tests and in situ measurements all be applied for each test to predict the behavior and performance of the pavement and that the predictive models developed be refined through Long-Term Pavement Performance (LTPP) monitoring.

One might now draw from Figures 3 and 5 to illustrate the process described in this paper. Taking Figure 3 as representative of the research orientated perspective on the impact of the HVS work, a similar figure may be compiled to represent the practice orientated perspective. The overall interactive procedure followed with the HVS program towards the attainment of research credibility and implementation may be illustrated by the general flow diagram shown in Figure 6. Note that the processes represented by Figures 3 and 5 are incorporated within the internal management milieu of each of the parties involved and that each interactive encounter also results in enhanced understanding and capability for each member. Figure 6 should be seen to represent a typical module within a continuous technology transfer and practice enhancement process. Phase 1 represents the preparatory sub-proses which a number of identified needs may have to follow in order to successfully launch and close Phase 2. Note also the necessity for an interim period through which the suggested solutions to the needs must pass to undergo de-bugging and to gain credibility.

5. ACKNOWLEDGEMENT

The Head of Department, Gautrans of the Gauteng Provincial Administration and the Director of Transportek of the CSIR is thanked for permission to publish this paper.

REFERENCE LIST

1. Freeme, C.R., Meyer, R.G. and Shackle, B. A method for assessing the adequacy of road pavement structures using a Heavy Vehicle Simulator. Proceedings of the 9th IRF World Meeting, Stockholm, June 1981, Vol. T55, pp 151-167.

2. Freeme, C.R., Maree, J.H. and Walker, R.N. User's experience with the South African Heavy Vehicle Simulators. Proceedings of the Conference on Bearing Capacity of Roads and Airfields, Vol II, The Norwegian Institute of Technology, Norway, 1982.

3. Nokes, W.A., Harvey, J.T., Du Plessis, L. and Long, F. Caltrans Accelerated Pavement testing (CAL/APT) Program - Test Results: 1993 -1996. Proceedings of the 8th International Conference on Asphalt Pavements, Seattle, USA, 1997.

4. Walker, R.N., Paterson, W.D.O., Freeme, C.R. and Marais, C.P. The South African Mechanistic Pavement Design Procedure. Proceedings of the 4th International Conference on Asphalt pavements, Ann Arbor, USA, 1977.

5. Kleyn, E.G., Freeme C.R. and Terblanche L.J. The Impact of the Heavy Vehicle Simulator Testing in the Transvaal. Proceedings of the Annual Transportation Convention (ATC), Pretoria, South Africa,1985.

6. Freeme, C.R., De Beer, M. and Viljoen, A.W. The Behaviour and Mechanistic Design of Asphalt Pavements. Proceedings of the 6th International Conference on Asphalt pavements, Ann Arbor, USA, 1987.

7. Horak, E., Kleyn, E.G., Du Plessis, J.A., De Villiers, E.M. and Thomson, A.J. The Impact and Management of the Heavy Vehicle Simulator (HVS) Fleet in South Africa. Proceedings of the 7th International Conference on Asphalt Pavements, Nottingham, UK, 1992.

8. Rust, F.C., Kekwick, S.V., Kleyn, E.G. and Sadzik, E.S. The Impact of the Heavy Vehicle Simulator (HVS) Test Programme on Road Pavement Technology and management. Proceedings of the 8th International Conference on Asphalt Pavements, Seattle, USA, 1997.

9. Hugo, F., McCullough, B.F. and Van der Walt, The Development of a Strategy for the Implementation of Full-scale Accelerated Pavement Testing for the Texas SDHPT. Annual Meeting of the Transportation Research Board, Washington DC, USA, 1991.

10. Freeme, C.R., Servas, V.P. and Walker, R.N. Pavement Behaviour from heavy Vehicle Simulator Results. Proceedings of the Annual Transportation Convention, 6-9 August 1984, Pretoria, South Africa.

11. Maree, J.H., Freeme, C.R. and Kleyn, E.G. Heavy Vehicle Simulator Testing in South Africa. Proceedings of the International Colloquium; Full-Scale Pavement Tests, Zurich, Switzerland, 1982..

12. Hubbard, L.R. Speaking From Experience - Illustrated Solutions To The Business Problems You Face Every Day. An illustrated book summarizing the extensive publications of L Ron Hubbard on management, published by Concept Technologies Inc., 200 North Maryland Avenue, Suite 301, Glendale, California 91206, USA, 1996.

13. Oujian, M.L. and Carne, E.B. A Study of the Factors Which Affect Technology Transfer in a Multi-business Ubit Corporation. Technical Management Notes. IEEE Transactions on Engineering Management, Vol EM-34, No 3, August 1987.

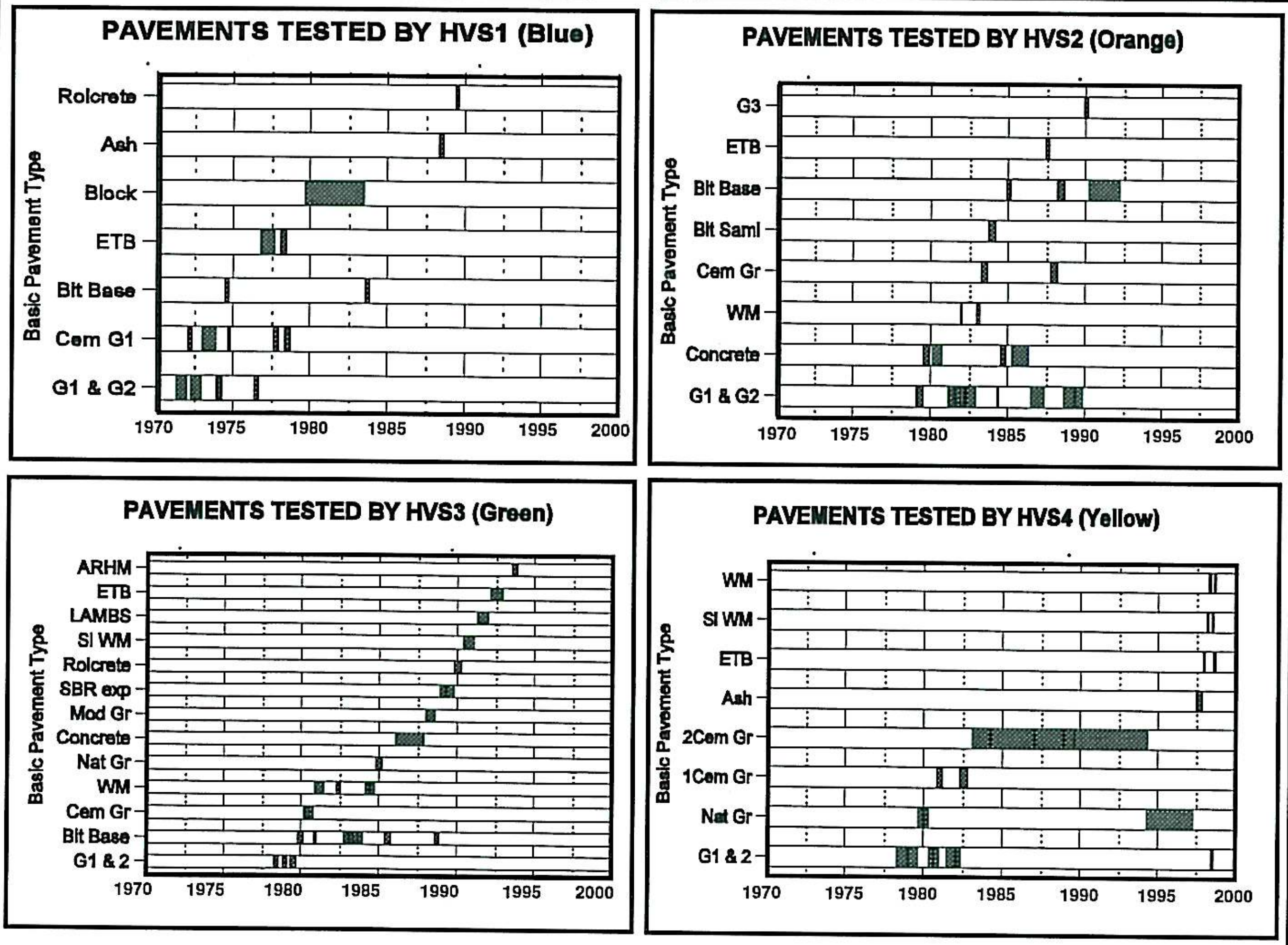
14. Rust, F.C., Sadzik, E.S., De Beer, M. and Kleyn, E.G. A Strategy for the Gautrans HVS. Research Report, DP/96/007, CSIR, Pretoria, South Africa, 1996.

15. Draft TRH4, Revised 1996. Structural Design of Flexible Pavements for Inter-urban and Rural Roads. Department of Transport for the Committee of Land transport Officials (COLTO), Pretoria, South Africa.

16. Sabita Manual 21, 1999. The Design of Emulsion-Treated Bases. South African Bitumen and Tar Association (Sabita Ltd). PO Box 6946, Roggebaai 8012, Cape Town, South Africa.

17. Theyse, H.L., De Beer, M. and Rust, F.C. Overview of South African Mechanistic Pavement Design Method. Proceedings of the TRB Meeting, Washington, USA, 1996.

18. Standard Specifications for Road and Bridge Works for State Road Authorities,1998 Edition. Prepared and drafted by COLTO , Department of Transport, assisted by The South African Institution of Civil Engineering (SAICE), The South African Association of Consulting Engineers (SAACE) and The South African Federation of Civil Engineering Contractors (SAFCEC). Published by SAICE, PO Box 93495, Yeoville 2143, Johannesburg, South Africa.



LEGEND

ARHM:	Armorshield Rubber Modified Hot Mix base pavements
Ash:	Ash and ash composition base pavements
Bit Base:	Bituminous base pavements
Bit Sami:	Bituminous Sami Interlayer surfaced pavements
Block:	Portland cement segmental paving block pavements
Cem G1:	Cemented crushed stone base pavements
Cem Gr:	Cemented gravel base (1Cem Gr) plus subbase (2Cem Gr) pavements
Concrete:	Portland cement concrete pavements
ETB:	Emulsion Treated base pavements
G1 & G2:	Crushed stone base pavements
G3:	Mine dump rock base pavements
LAMBS:	Large Aggregate Mixes for Bases pavements
Mod Gr:	Non-traditional modified gravel base pavements
Nat Gr:	Natural gravel base pavements
Rolcrete:	Rolcrete base pavements
SI WM:	Slurry modified Water-bound Macadam base pavements
WM:	Water-bound Macadam base pavements

FIGURE 1: Pavement Types Tested by the HVS Fleet in South Africa.

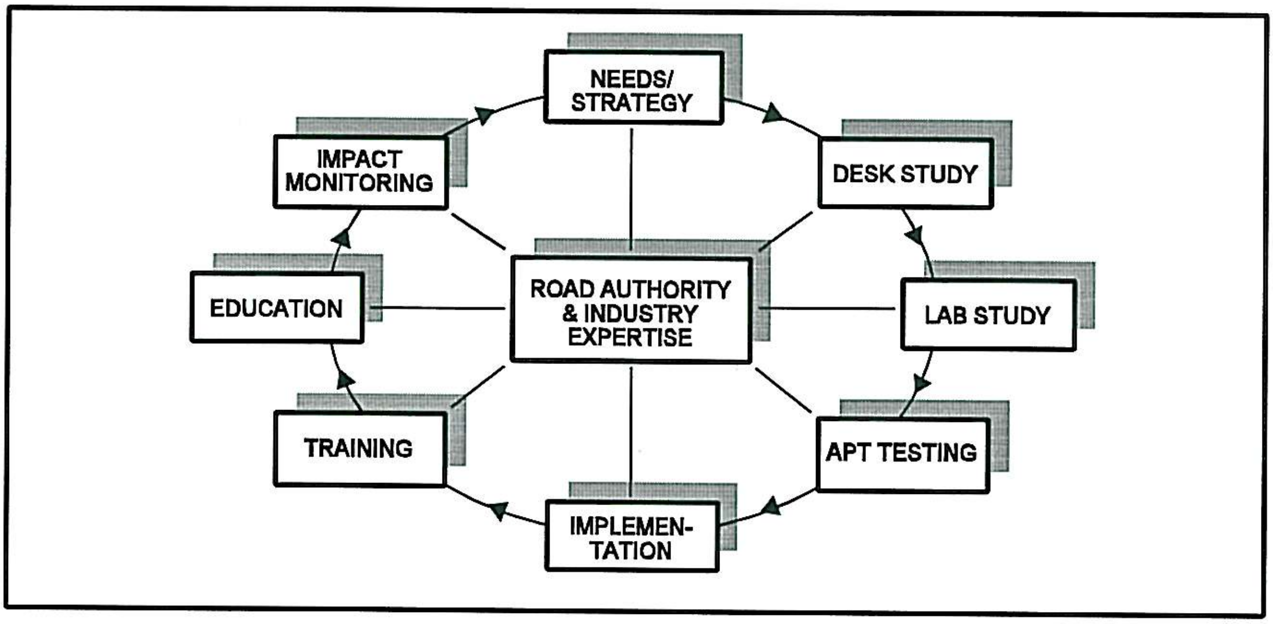


FIGURE 2: The Role of APT in a Holistic Approach (after Rust *et al*, 1997)

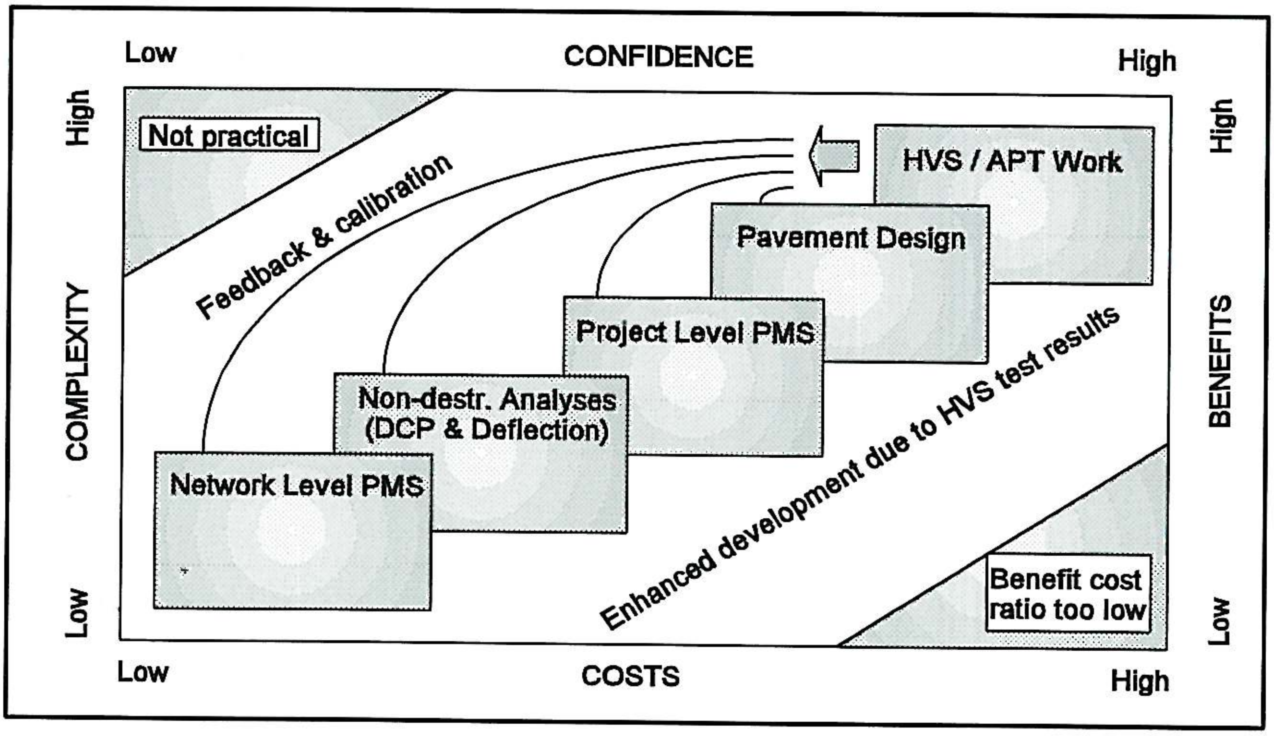


FIGURE 3: A Research Orientated Perspective on The Impact of the HVS Work on Investigation Tools in South Africa. (amended after Freeme et al, 1985)

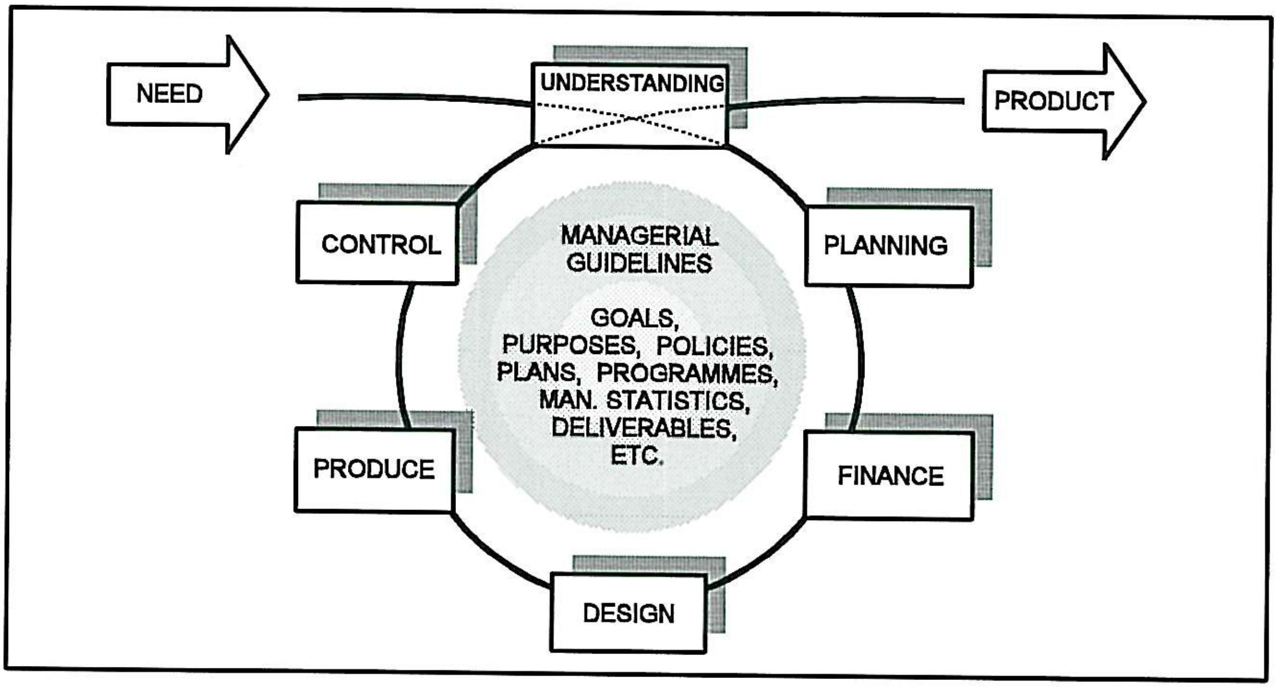


FIGURE 4:The Basic Organisational Process of Converting a Need into a Product.

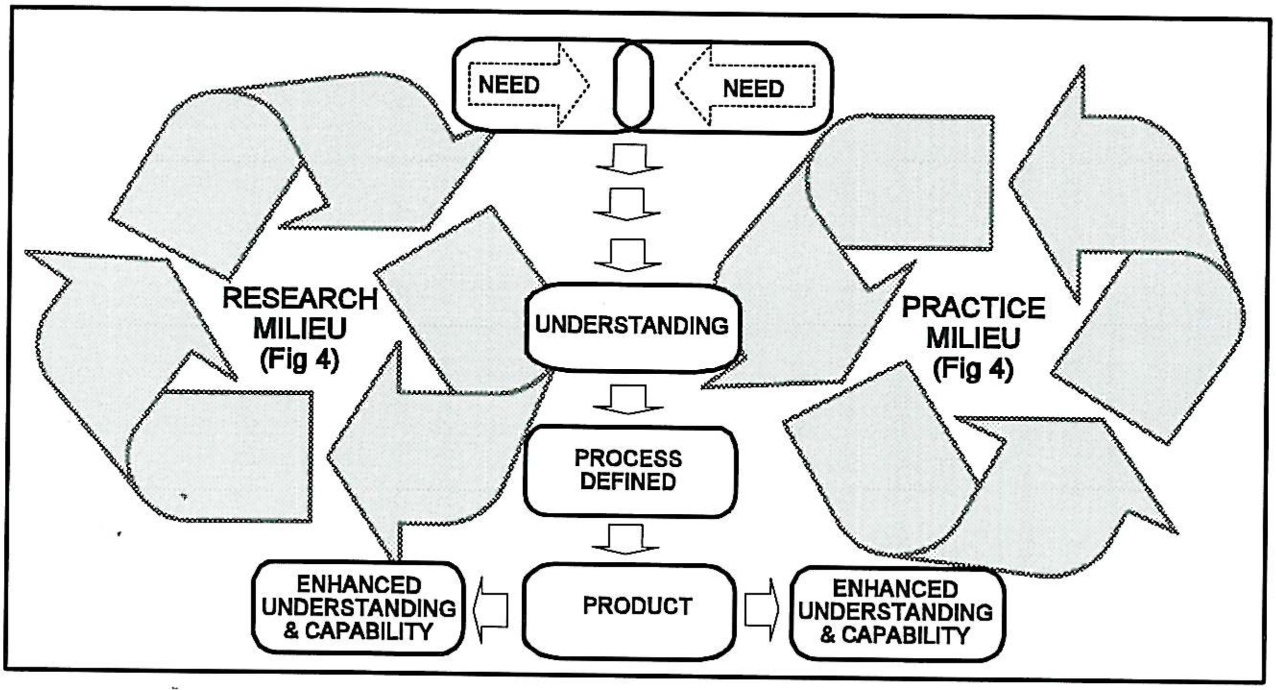


FIGURE 5: The Project Design Process for Partnered Research and Practice.

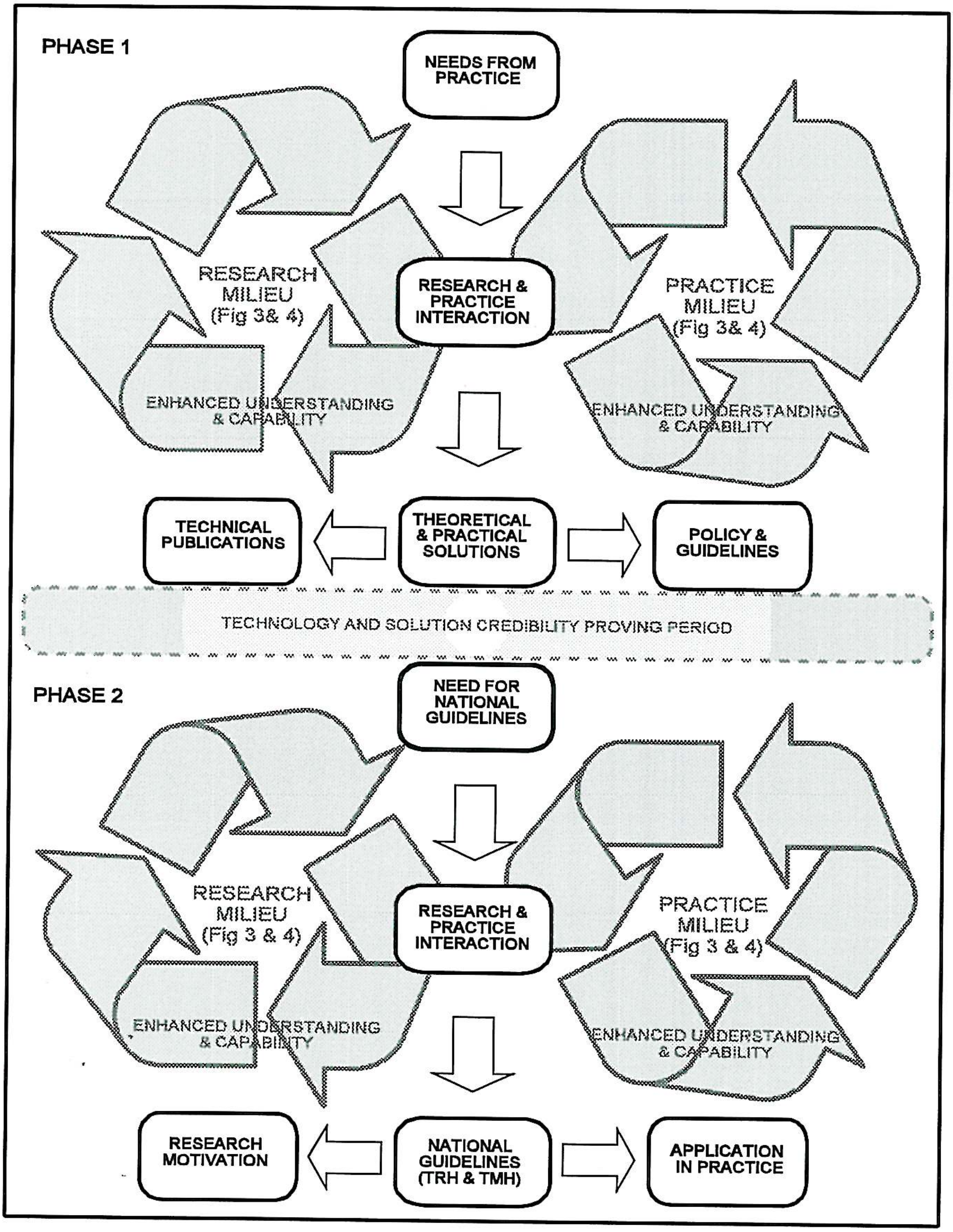


FIGURE 6: The Interactive Process Between Research and Practice Towards Credible Technology Enhancement and Guidelines