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# TITLE Directing research to ensure that cost - effective solutions to highway problems are found and implememted

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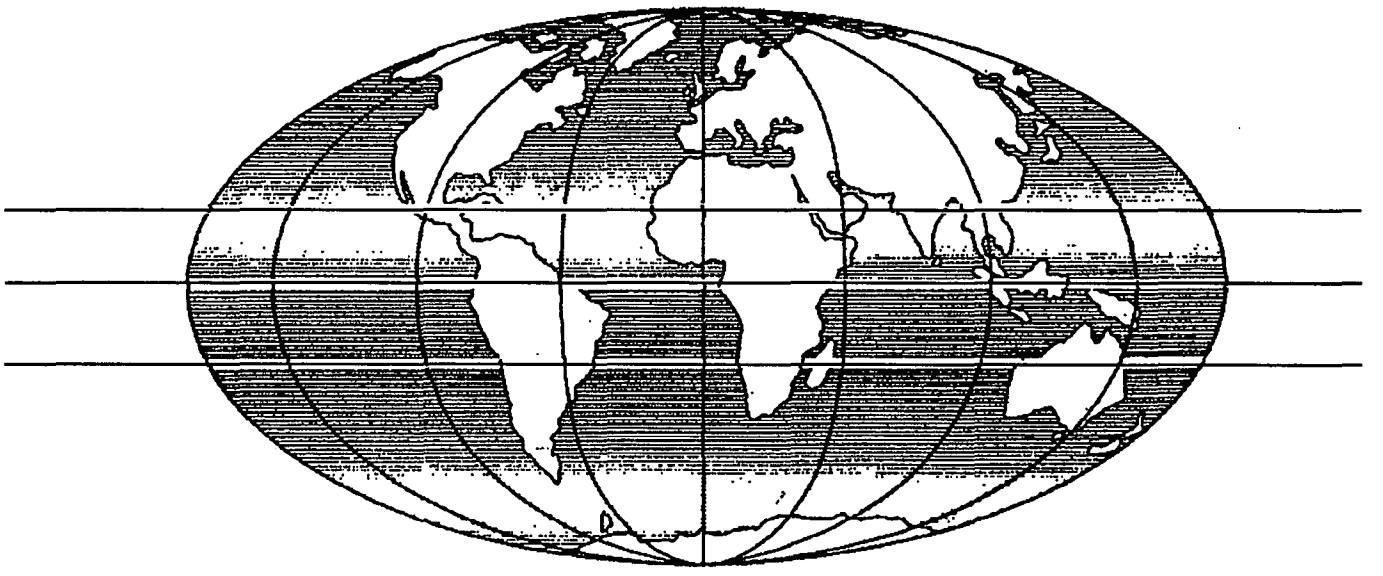

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# DIRECTING RESEARCH TO ENSURE THAT COST-EFFECTIVE SOLUTIONS TO HIGHWAY PROBLEMS ARE FOUND AND IMPLEMENTED

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**SUMMARY**

In order to justify the cost, a research project should be judged to offer a good return on the capital invested. This can best be achieved by precisely describing the objectives, the means of attaining them and the methods of assessing the results in a project description or framework. Each phase of the programme should be reviewed against this original specifications, which must include procedures to ensure that the results of the work are applied in practice. Appropriate quality must be observed at each stage and should also be defined within the programme description.
The example chosen to illustrate the various aspects of a project framework is that of a research programme to improve treatments to worn concrete road pavements: the main features of this being a literature revue, pilot scale trials and full scale construction incorporating elements of training.

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# DIRECTING RESEARCH TO ENSURE THAT COST-EFFECTIVE SOLUTIONS TO HIGHWAY PROBLEMS ARE FOUND AND IMPLEMENTED

## I INTRODUCTION

Research is expensive in terms of manpower and money, and can only be justified if it is considered to be an investment. To be acceptable, an investment must cover its costs and return a profit in the medium to long term.
It is important too, that research is seen to be cost-effective and that the objectives are seen to be achieved. For this to happen, the whole programme must be mapped out in detail in terms of objectives, methods, inputs, costs, outputs and methods to be used to assess each of them.

## II DEFINITIONS and OBJECTIVES

Each item of research must be clearly defined. The aims must be stated, as far as they are known, the likely outputs and consequences, the inputs and costs, and how all these are to be measured must all be defined at the beginning of the programme. The resulting project plan or framework is most usefully written on one sheet of paper under headings and columns as in Table 1. Extracts may then be drawn from it e.g in financial terms for the accountants, in journey times for the commuters, and so on for all the interested parties.

For the purpose of illustration, the example chosen here is that of a typical research project, which addresses the problem of reflective cracking in overlays on worn concrete road pavements. This is recognised as a universal problem. Trials to discover the most cost-effective solutions have been reported by a number of highway authorities and ad hoc attempts to discover solutions are being made in many countries.

Firstly the problem needs to be identified and defined. Then, from this definition, a precise specification can be written for the research project in terms of objectives, immediate and more general, methods to be used, and outputs, which may include several items other than the specific answer required by the problem definition.

In this example the problem is "that overlays on concrete pavements fail prematurely". The objective of the research programme can be defined as "to improve the performance of remedial treatments to concrete pavements".

The wording of the objective is very important because the outputs and the procedures employed must conform to this definition. In this case the word "overlay" appears in the problem but not in the objective. This is because premature failure of overlays is only an indication of difficulties in dealing with worn concrete pavements, the solution to which might not be within the category of overlays at all.

Within this general objective, "to improve the performance of treatments to worn concrete pavements", will be specific objectives. These will all contribute toward the general objective and constitute intermediate goals. An example of this might be "an assessment of current treatments from published reports". In total, these specific objectives should be sufficient, when completed, to achieve the general objective. Note that in this example the general objective is to "improve the performance", not simply to find out how, but to effect a change in the lasting quality of the treatments to the worn pavements. This requires not only the discovery of the most appropriate procedures and materials but the application of these by highway departments.

Too frequently, research projects are carried through with enthusiasm to the point of reporting the results in detail and drawing appropriate conclusions. The final and most important component of the research program, that of ensuring that the benefits of the investment are applied, is ignored. This will not be the case if the objective of the programme is clearly worded to include the application of whatever solution or procedure is the result of the research. This may of course require a training programme or further stage of research to determine how best to ensure that the application of the recommendations actually takes place. It can be argued that, without this final stage of the programme, all previous work is non-productive.

## III METHODS OR SUBSIDIARY OBJECTIVES

After the definition of the objectives come the methods to be employed. Each of the objectives will require at least one method of approach. A clear link is required between the method used and the objective it addresses. There may be several outputs resulting from the research other than those that meet the stated objectives, so discipline is required to concentrate on the result required by the objective. It is not uncommon for researchers to be diverted into interesting sidelines but the project framework will state the objective of each part of the programme and this must be adhered to.

In the example mentioned above of "an assessment of current treatments from published reports", it may be necessary to read reports that deal only partly with the treatment of worn pavements. In this case, effort must be confined to reviewing only the parts relevant to the objective.

The intention is that each minor objective will produce a result, which will mark a step on the way to achieving the main objective. Each result needs to be appraised. The project framework will define how this appraisal will be carried out. The interim result may be precisely what is required to proceed to the next step or it may indicate that the whole research programme is no longer worth pursuing. The methods to be used to assess the results of research must be known at the outset, because these too will influence how the research is carried out and reported. In the example, the review of relevant literature will probably result in a list of treatments that have been used with various degrees of success in other countries.

There may not be a consensus of opinion about the relative merits of the various treatments. If there were, it would be possible to proceed straight to the final stage of the programme. Most likely, the success or otherwise of each procedure is dependant on certain conditions e.g. the effects of freeze-thaw, the availability of specialised equipment, the properties of available materials. The literature review will note all these conditions.

It is also likely that the costs of the treatments will vary. If possible, the literature review will assess these too. So the results of the literature review will be a list of treatments with as much information as can be gleaned on their costs, the technology required to carry them out, the expected performance, the limitations, and recommendations concerning which of them might be worth field trials.

## IV FIELD TRIALS

It was anticipated at the planning stage that field trials would be required and this was included as one of the objectives, because it is well known that techniques and procedures are not simply transferable from one region to another. Some are not applicable and others may well require modification. The objectives of the field trials will be carefully defined so that attention is given only to those solutions judged most likely to yield a desired result. The methods employed for the field trials will also require careful consideration to ensure that:

a) each procedure has a fair trial,
b) full account is taken of local conditions,
c) a realistic comparison can be made between all the variations.

This is where many practical difficulties occur. The purpose of field trials is to assess the performance of techniques or procedures, some of which will be unfamiliar. This may require the purchase or fabrication of equipment not previously used. Most likely, the construction of the trial pavements will be supervised more intensely than would be the case on general construction sites. Unfamiliarity with techniques may result in slow progress at first. Small trials do not reflect all the conditions found on large construction or maintenance sites. Furthermore, it will take a considerable time to assess the relative merits of techniques where the main attribute is meant to be durability.

There may be one further complication in that trials may be conducted either under ideal conditions, which tend to be more uniform for the purpose of comparison, or conditions less than ideal but are more representative of those under which the chosen techniques will be required to perform. This is where a detailed knowledge of the region is required so that this aspect can be fully covered in the plan.

For some research projects it is necessary to exercise a high degree of quality control, for other projects it is important to allow the levels of control to apply that would be exercised on normal construction projects. The choice depends on the nature of the project but in the final stage of research, where the results need to be

applied in practical situations, it will be necessary to demonstrate the value of the solution under normal conditions.

An example of this concerns conditions where supervision is less than ideal and where the last finishing jobs on site are frequently neglected. One method of preventing cracks in an old pavement from reflecting through to the new concrete overlay is to install a separation layer of flexible material between the old concrete and the new. Two materials for trial as separation layers could be a graded sand and asphaltic concrete, both of which can be laid over the old pavement prior to casting the new concrete. When the forms are removed, the asphaltic concrete is stable but the sand requires restraint and protection from erosion. Unless this is provided in the form of a concrete or asphalt fillet, the sand will be rapidly eroded by rainwater running down the gutter, thus removing the necessary support from under the edge of the new concrete slabs. Supervision during the trial can ensure that all the necessary finishing and detailing is completed but the trial will not be representative of conditions general to the region. The objectives and the methods must be detailed on the project framework in a manner to address the final objective, which was to improve actual performance.

Another aspect of the problem is the question of why, or how, the old pavement came to require treatment of the kind under study. It may be justified to examine this, if it is found that the overlays failed prematurely because of the condition of the old pavement. One way of improving the performance of treatments to old concrete pavements may be to improve the performance of the original pavements themselves. This is a policy decision and must be considered during the writing of the original objectives of the programme.

To include trials of different designs, materials and construction techniques for new pavements would vastly increase the scope and costs of the project. However, in order to address the problem of premature failures in a comprehensive manner, this may be necessary. The manner of failure of the old pavement is important to the design of the remedial treatment. If the overall view is taken, that the purpose of the research programme is to derive the best available benefit to cost ratio, the objectives of the research should be defined accordingly. Alternatively, a review of progress and the results achieved part way through the programme might lead to an extension to the objectives in the light of what has been achieved to-date.

To study the performance of new pavements would almost certainly require a review of current designs and construction practices throughout the region. Designs and materials for new pavements are easier to compare than remedial treatments to old pavements. Comparisons can be made between short, unreinforced slabs and longer slabs with steel reinforcement, dowelled and undowelled joints etc, etc, in terms of costs and suitability to current conditions of workmanship, availability of equipment and quality control, without the complication of taking into account the effects of an underlying construction.

However, what was a modest research programme with limited aims and well defined procedures has now become much wider in scope and more costly. It can be argued, however, that the desired benefits are more likely to accrue from this more comprehensive approach. Certainly, the benefits could be applied to a larger region than that in which the work is carried out, suggesting that contributions toward the work in terms of finance, personnel or donations of equipment should also come from the region or an organisation representing the region.

## V PROJECT MONITORING

At stages during the progress of a research project there should be assessments to:

a) check that the objectives as stated are being addressed,
b) check that the costs are also according to agreed limits,
c) confirm that predicted progress is being achieved (or discover why not and make changes as necessary),
d) review the results to-date and decide whether to continue according to the original plan or whether to modify it in the light of results achieved.

These reviews should be structured to examine each subsidiary objective according to the predicted indicators of achievement shown in the table. The indicators are stated on the original project framework together with the manner in which they are to be assessed.

In the example, an indicator of the achievement of the literature review will be a list of alternative treatments, their merits and limitations, their costs and a short-list of those suitable for trials. The success of this objective can be assessed by a check list including:

a) Is the list comprehensive?
b) Does it adequately review the costs and limitations?
c) Are the results sufficiently detailed to pass on to the next phase?

Part of the project may be the construction of pilot-scale trials after the literature review and before full-scale demonstrations or trial constructions are attempted. The objectives for the pilot-scale trials will be clearly stated at the design stage and these will be reviewed as the indicators of achievement. They can be assessed by checking if sufficient progress has been made or enough knowledge has been acquired to permit the project to progress to full-scale trials.

## VI QUALITY STANDARDS

Undoubtedly, the application of quality assurance and quality control procedures brings benefits to all aspects of research. If customer and research contractor are to be separate organisations, both will benefit from formal procedures aimed to ensure an appropriate quality of each aspect of the programme. Where the research is undertaken by a branch of a government ministry or a department of a private

organisation on behalf of the parent office, it is equally important to ensure that value for money is as high as possible and this can be best achieved by applying quality assurance procedures.

This entails setting quality standards for all aspects of the programme and defining how and when they are to be verified. The interim reviews discussed above form part of this but they were confined to the progress of the work. The concept of quality assurance should be applied to:

- personnel management,
- the provision and maintenance of office, laboratories and equipment,
- the design or planning of each step in the programme.

The standard of quality must be appropriate to the aims and the resources available. It must also be clearly defined and agreed by all parties at the commencement of the project. If the standard is set too high, the work may take longer to complete than the customer is prepared to wait - and cost too much. If the standard is set too low, the results will be of little value. If the standard of quality is not defined clearly enough, there may be both unwarranted expense, delay and an inappropriate result. The programme of laboratory testing should also be written in an appropriate manner to:

- be understood by all involved,
- be thorough enough for the purpose,
- be within the time limit and resources available.

An example of appropriate quality standards applied to laboratory work is the testing of samples of fresh concrete taken from a construction site and made into test pieces for verification of concrete strength.

To ensure that statistically significant results are obtained, an adequate number of tests must be carried out, the test equipment must be in good condition and the technicians must be well trained and well supervised. Clearly, the data obtained at this stage of the programme must be both accurate and consistent. The quality of work carried out in materials test laboratories varies greatly, usually according to the standard set by officer in charge.

Firstly, the test equipment must be maintained to an acceptable standard. The moulds should be inspected after each use, cleaned and repaired or rejected by the technician in charge. The press should also be well maintained. It should be checked and calibrated regularly by an accredited agent.

Secondly, the operators should be trained to carry out the testing. They should appreciate the reasons for high quality work and be able to recognise lapses from the specified standard. They must be familiar with the techniques to be employed and be diligent at every application. These standards must be set by the engineers in charge and the supervisors.

## VII TRAINING

As stated above, the results of research must be applied or the programme has no use. This application of an unfamiliar technique or procedure is likely to require the training of both operatives and supervisors, and the people in the best position to carry out the training are those who researched the technique and are most familiar with it.

The obvious way to publicise a treatment for failed pavements and to train contractors, consultants and ministry administrators is to construct full-scale demonstration repairs. These can also be used to fine tune the designs eg to compare the effects of small variations in the thickness of the separation layer between the old and new concrete slabs.

If funds are available, it is relatively simple to design and commission road works. The training element is more complex and requires the cooperation of several departments within a Ministry of Transport. This is best ensured by obtaining the support of the Secretary or the Assistant Secretary for Engineering. In many administrations it will have been necessary to obtain approval at this level before the research programme could commence. The project framework describing the objectives and procedures is an essential part of the approval procedure and should include the training element.

In order to achieve the application of the research results nationwide, it is also essential to obtain the cooperation of the provincial engineers and their staff. However, cooperation from departments at headquarters in a national capital is far easier to arrange than cooperation between headquarters and the provinces. Communications between headquarters staff and provincial administrations may be tenuous and can be hampered by bureaucratic procedures, even within the same ministry. This is particularly true in respect to remote areas.

In order for new ideas to be accepted by provincial staff, who may feel that they know more about local problems and priorities than their counterparts in the capital, several conditions are required.

a) The full-scale demonstration trials must be well organised and leave no scope for criticism.
b) A close relationship must be developed between the engineers demonstrating the technique and the sceptics come to observe.
c) There must be a demonstrable advantage for the provincial engineers in terms of costs, life of the repair, less disruption to traffic during the works, or in some other way.

The experience and opinions of engineers from the provinces can be valuable inputs to the research programme and should be incorporated into final specifications whenever possible. Also, the new ideas are more likely to be accepted by the

practitioners, if they feel that they have also made a contribution which is respected by the researchers.

The demonstration/training programme can also be used to introduce new quality assurance procedures, if this has also been written into the project description. There is clearly a direct link between quality and durability in road construction and maintenance, so training in quality control and quality assurance procedures may be considered a legitimate objective toward the original one of "improving the performance of treatments to worn concrete pavements".

## VIII ACKNOWLEDGEMENTS

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