1. INTRODUCTION

Effectiveness, Efficiency and Environment, these three E-s are clear and present targets for road administration. The performances of road organisations are justified with their outcomes, not only outputs. In order to increase their outcomes, they should increase their inputs in traditional scheme or increase their output per input with more business-like approaches.

Life cycle cost of road is one of the key issues many road organisations and researchers have engaged in. Not only road administration cost but also road user’s cost and cost for inhabitants and communities should be included in the life cycle cost in order to assist infrastructure investment decision. Thus in estimating life cycle cost, road user’s viewpoints are essential even if technical capabilities of estimation are not sufficient.

Performance-based management and maintenance has been discussed because using innovative methods and procedures is believed to cut life cycle cost and improve service quality of roads.
2. MANAGEMENT AND MAINTENANCE

Pavement forms road surface with which the road users evaluate service quality level of the roads. In order to maximize road users’ satisfaction and minimize the cost for road administration, the efficiency and effectiveness of maintenance operations should be increased. Performance-based management and maintenance of pavement is a new concept which requires technical and management skills. Management means to define what to do, where to do it, when to do it, and how to do it. Outsourcing of pavement management, which is major part of road administration, to private sector needs long discussion before putting into practice in Japan.

2.1. PERFORMANCE INDICATOR

A key component of successful road projects is a well-defined set of goals and objectives. In order to set targets, performance indicators are necessary as tools. They are very useful to evaluate the degree to which goals and objectives have been achieved or identify those inputs, process, outputs and outcomes associated with a project required to achieve the goals and objectives.

Performance indicators for each project should be selected in accordance with the goals and objectives of the project. Road user’s view, of course, should be incorporated into them. Saying “The Right Pavement in The Right Place”, road users would judge the pavement right or not.

![Figure 2: Performance Indicators selected from Road User’s Viewpoint](image)

2.2. TARGET

To manage the pavements, targets should be set for each performance indicators, and which should reflect road user’s viewpoint. As targets, two types of level could be defined; desirable level and critical level. Besides, criteria for maintenance/rehabilitation should be defined also.

Desirable levels are not difficult to define. For example, desirable level of roughness and rutting depth is zero (The less, the better). On the other hand, permeability is an example of ones characterised with “The more, the better”. Trying to achieve desirable levels needs huge budget in monitoring and maintaining. It has more reality in using desirable levels to understand that such a level is just ideal one, declare so and introduce supplementary indicator such as customer’s satisfaction.

Critical levels mean the boundary between acceptable condition and non-acceptable condition for road user and are difficult to define technically. Criteria for maintenance/rehabilitation could
be described as levels generously margined to critical levels in order to encourage safety, comfortableness and so on.

![Performance Curve of Pavement and 3 Levels of Targets](image)

**Figure 3: Performance Curve of Pavement and 3 Levels of Targets**

### 2.3. OUTSOURCING

Lack of resources of public sector and business skills of private sector have driven the road agencies to outsource some portion of their roles. In Design and Build schemes, the design phases which were conducted by road agencies have been outsourced. Outsourcing of management phases, however, should be considered carefully, because road agencies are the only organisations responsible for safe and fulltime services of roads.

<table>
<thead>
<tr>
<th>SCHEME</th>
<th>PHASE</th>
<th>Traditional</th>
<th>Design and Build</th>
<th>Performance-Based Maintenance</th>
<th>Private Finance Initiative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan</td>
<td></td>
<td>Road Agency</td>
<td>Road Agency</td>
<td>Road Agency</td>
<td>Road Agency</td>
</tr>
<tr>
<td>Design</td>
<td></td>
<td>Road Agency</td>
<td>Contractor</td>
<td>Contractor</td>
<td>Contractor</td>
</tr>
<tr>
<td>Build</td>
<td></td>
<td>Contractor</td>
<td>Contractor</td>
<td>Contractor</td>
<td>Contractor</td>
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<tr>
<td>Maintenance</td>
<td>Road Agency</td>
<td>Road Agency</td>
<td>Contractor</td>
<td>Contractor</td>
<td></td>
</tr>
<tr>
<td>Management</td>
<td>Road Agency</td>
<td>Road Agency</td>
<td>Road Agency</td>
<td>Contractor</td>
<td></td>
</tr>
</tbody>
</table>

![Outsourcing of Roles of Road Agencies](image)

**Figure 4: Outsourcing of Roles of Road Agencies**
3. CONTRACT OF REHABILITATION WORK

In 1998, performance-based contract of pavement rehabilitation work of national road network started on trial basis. As performance indicator, tyre/road noise level was selected from road users' perspective and the accepted minimum thresholds were defined with engineering judgement, which were 89 dB after completion of works and 90 dB after a year in service. This trial opened the way to design-build approach and warranted highways. A new type of vehicle for measuring tyre/road noise has been developed and five vehicles are in operation.

Porous asphalt mixtures had been applied to surface layer of the drainage pavement for many years and it was understood that surface layer with porous asphalt mixture could reduce tyre/road noise. A number of data in Japan showed that average mark of noise level after completion of works is 89 dB and those after a year in service is 90 dB. Targets for performance-based contracts have been determined in such a statistical way.

Newly developed vehicle to measure noise level uses a technique known as the Close-Proximity (CPX) method. This method measures the noise from a tyre of special tread using microphones placed close to tyre. The vehicles are operated at speed of 50km/h without the need to disrupt traffic flow.

Cases with this type of contract initiated on trial basis by the Ministry of Construction in national road network have increased rapidly, from 2 cases in 1998 to 98 (76+22) in 2001. 123 (73+50) cases are supposed to be contracted in 2002.

4. SPECIFICATION

Pavements have been constructed based on recipe or method based specifications for many years in Japan. In order to introduce novel construction methods and materials in the construction process and to maximize efficiency, the Ministry of Land Infrastructure and Transport enacted a performance-based specification as a ministerial ordinance in June 2001, which was “Structural Standard for Pavement of Carriageway and Marginal Strip”.

As performance indicators, the ordinance defined the followings:
- Wheel number for fatigue failure
- Wheel number for plastic flow
- Evenness of surface
- Permeability

The former three are indispensable, the latter if necessary. The accepted minimum thresholds of these indicators after completion of works were also defined.

Wheel number for fatigue failure is an indicator defining the performance of pavement structure. On the other hand, wheel number for plastic flow, evenness of surface and permeability are indicators defining the performances of surface layer.
Among the indicators, wheel number for fatigue failure, which is defined as cumulative 49kN equivalent wheel number loaded before the pavement is cracked, dominates the structural design of pavements. Public Works Research Institute conducted the nationwide questionnaire survey concerning asphalt concrete pavement in 1997 towards road administrators in Japan. As a result of the survey, reliability of the asphalt concrete pavement constructed with the traditional specifications was 90%. According to the result of the examination and analysis, the Ministry officially noticed the validity of the pavements designed with traditional structural design methods as well as the validity of surface layer of cement concrete concerning wheel number for plastic flow.

5. EVALUATION OF PERFORMANCE

With introducing performance-based specification, one of the roles of Road Administration would change from inspection to evaluation which includes inspection and prediction. Evaluation of pavement is getting to a new business in Japan. Effective and efficient methods/devices for measurement of performance are strongly required and under research and development.

5.1. MANAGEMENT PRACTICE

In traditional schemes, performances of pavement have not been defined clearly but materials and methods have been specified. On the other hand, nothing but performances of pavement would be defined with performance indicators in performance-based scheme.
Introducing performance-based scheme is a sort of challenge for both sides; road administration and contractor. Hence step-by-step introduction has a reality. Defining performances of pavements with performance indicators in traditional scheme could improve the accountability for the projects. Without limiting design method, materials and procedures to be used, introduction of innovative technologies and materials could be easily accelerated on the condition that evaluation methods of outputs of pavements and properties of materials have been determined in advance.

![Figure 6: Transition from Traditional Scheme to Performance-Based Scheme](image)

5.2. TECHNOLOGY PRACTICE

One of the goals of performance-based contracts is to use innovative methods and procedures for road works. Outcomes and performances defined in advance should be measured and evaluated directly without specifying the materials or methods to be used. However, technical or economical reasons might justify the indirect evaluation methods which measure outputs of the pavements and properties of the materials and confirm that the pavements are the same with approved ones.

In-situ accelerated loading tests could evaluate directly outcomes and performances of the pavements. They, however, would not be so smart in case they are destructive methods. Non-destructive technologies which measure outputs of the pavements and properties of the materials would be smarter and could be applied on the condition that the influence of variability in pavement outputs and material properties on the performance of pavements is determined.

In-situ testings after completion of works sometimes delay the service and accelerates the congestion. Testings with specimen would be smarter and could be applied on the condition that the pavement is confirmed to be the same with the specimen.
Table 1: Object and Characteristic to be evaluated (durability, as an example of performance)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Outcome and Performance of Pavement</th>
<th>Output of Pavement and Property of Material (*1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Situ</td>
<td>In Situ Testing of Outcome and Performance of Pavement&lt;br&gt;Eg. Accelerated Loading Test with Heavy Vehicle Simulator</td>
<td>In Situ Testing of Output of Pavement and Property of Material&lt;br&gt;Eg. Deflection measured by Falling Weight Deflector</td>
</tr>
<tr>
<td>Specimen (*2)</td>
<td>Specimen Testing of Outcome and Performance of Pavement&lt;br&gt;Eg. Results of Existing Roads or Test Fields</td>
<td>Specimen Testing of Output of Pavement and Property of Material&lt;br&gt;Eg. Deflection measured by Bending Test</td>
</tr>
</tbody>
</table>

*1: The influence of variability in pavement outputs and material properties on the performance of pavements should be determined.

*2: The pavement should be confirmed to be the same with the specimen.

6. CONCLUSION

(1) To set the targets for quality level of service is the most important for highway infrastructure asset management and outsourcing of some part of road administration’s role in such form as performance-based contract or Private Finance Initiative.

(2) The service required of pavement and the levels of them are diverse in accordance with the conditions of road, traffic and community. They should be determined from the viewpoint of road user, inhabitants and citizens.

(3) Outsourcing of management phases should be considered carefully, because road agencies are the only organisations responsible for safe and fulltime services of roads. Nobody but only road agencies could compensate to road users for accidents or damage caused by the state of the roads.

(4) In the world of performance-based management, the most important role of the road administration is to evaluate the performance of pavement.

(5) Testing and evaluation methods should be selected or combined among a variety of in-situ/specimen testing and direct/indirect methods in light of efficiency and reliability.
7. REFERENCES

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