

Performance Measures for Pavement Assets under Performance Based Contracts

Zaid Alyami, M.A.Sc., PMP., PhD Candidate
Department of Civil and Environmental Engineering
University of Waterloo
200 University Avenue West, Waterloo, Ontario, Canada N2L 3G1

Susan L. Tighe, Ph.D, P.Eng.
Professor and Norman W. McLeod Professor in Sustainable Pavement
Engineering, Canada Research Chair
Director, Centre for Pavement and Transportation Technology
Department of Civil and Environmental Engineering
University of Waterloo
200 University Avenue West, Waterloo, Ontario, Canada N2L 3G1

Douglas D. Gransberg, PhD, PE
Professor and Donald and Sharon Greenwood Chair of Construction Engineering
Iowa State University
Department of Civil, Construction, and Environmental Engineering
494 Town Engineering Building, Ames, Iowa 50011-3232

Maria Bianchin, P. Eng.
Lead, Structural Performance Specifications Task Group
Ministry of Transportation Ontario
Engineering Specifications & Standards Office
301 St. Paul Street St. Catharines, Ontario, L2R 7R4

Corresponding Author: Zaid Alyami

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Abstract

Over the past decade, there has been a movement in North America towards Performance Based Contracts (PBC). In PBCs, the client agency specifies defined minimum performance measures to be met or exceeded during the contract period. PBC operates through a continuing performance measurement and review systems against a set of minimum level of services (LOS). Therefore, performance measures in contract administration are fundamental to the successful usage of this type of contract. The paper presents a review of PBC focusing on performance measures. A review of the current state-of-the-practice is conducted to identify key performance measures employed by various agencies. In addition, a literature review of several road agencies in North America is conducted to evaluate the important physical attributes agencies are using as performance inputs to evaluate the overall condition of the road assets. Moreover, the study provides a review of performance specifications implemented by the Ministry of Transportation in Ontario (MTO) including Pavement with Warranty and Minimum Oversight Contracts. A monitoring framework of performance measures is presented. Finally, recommended performance measures for flexible, rigid pavements and granular shoulders are presented for the use in MTO's PBCs.

INTRODUCTION

Traditionally, agencies specify their maintenance and rehabilitation contracts specifying the means and methods to be performed and the sequence of the job (1). However, this traditional way of contracting had shortcomings to achieve the agencies main goal to maintain the road networks at acceptable Level of Service (LOS) while reducing the cost (1). Therefore, the challenge of maintaining the road networks at the best possible condition by investing the minimum amount of money will always keep transportation agencies searching for innovative approaches (2). As a result, road agencies have increased private sector involvement through warranty contracts (3). According to road agencies around the world, there has been a movement over the last two decades towards Performance Based Contracts (PBCs), a long term warranty contract (2-5).

In traditional Method-Based Contracts, the owner agency specifies techniques, materials, methods, quantities, along with the time period for the contract. In contrast, in PBC, the client agency specifies certain clearly defined minimum performance measures to be met or exceeded during the contract period and payments are explicitly linked to the contractor successfully meeting or exceeding those performance measures (6). Incentives and penalties maybe introduced and consist of increase or decrease of a payment due to exceeding or falling short on achieving the specified performance measure (7).

The basis of a PBC is defining performance measures and performance goals that are expected to be achieved by the contractor under the PBC. Performance measures are a set of defined outcome-based conditions (for example Roughness) that an agency uses to evaluate the success of the contractor. Performance Goals are the minimum acceptable levels to be achieved for each performance measure (for example an IRI of 2 m/km) (5).

PBC operates through a continuing performance measurement and review systems against a set of specified LOSs. Therefore, performance measures in contract administration are fundamental to the successful performance specifications. As such, it is important that the owner agency properly identify which physical attributes of the road network are required and the associated level of service to be achieved (4).

OBJECTIVE AND SCOPE OF PAPER

This paper presents a review of PBC focusing on performance measures. A literature review of the current state-of-the-practice is conducted to identify key performance measures employed by various agencies in PBCs. In addition, a literature review of several road agencies in North America is conducted to evaluate the important physical attributes agencies are using as performance inputs to evaluate the overall condition of road assets. Moreover, the study provides a review of performance specifications implemented by Ontario Ministry of Transportation (MTO) including Pavement with Warranty (PWW) and Minimum Oversight (MinO) Contracts. A framework for performance measures monitoring is presented. Finally, recommended performance measures for flexible, rigid pavements and granular shoulders are presented for the use in MTO's PBCs.

PERFORMANCE MEASURES

Performance measures in a PBC could be grouped into two types: pavement performance measures and non-pavement performance measures (8). Non-pavement performance measures include those non-pavement highway attributes such as signs, vegetation, lights, barriers etc. Pavement performance measures are those attributes that indicate the condition or performance of the pavement, such as rutting, cracking and skid resistance, those are referred to as single performance measures. Furthermore, those single pavement performance measures can be grouped based into general performance measures including Functional Performance Measures, Safety Performance Measures, and Structural Performance Measures.

Functional Performance Measures: are performance measures representing the demand on the road by the users including roughness, cracking, potholing, etc. Safety Performance Measures: are performance measures that contribute to a safe environment for road users including skid resistance, texture, rutting, etc. Structural Performance Measures: are performance measures that represent the service and remaining life of the road as a function of traffic, environment, and material properties.

Single performance measures could relate to one or more general performance measures. For example, rutting can influence the functionality of the road to the user; on the other hand, rutting affects the safety of the road.

PERFORMANCE GOALS

Performance goals, also referred to as LOS, are the targeted level or value to be achieved by contractor for the performance measure. Agencies must take care when developing the performance goals such that the goal is not too high, resulting in high cost, nor too low, resulting in poor quality (8). There are different methods suggested by National Cooperative Highway Research Program (NCHRP) Synthesis 389 “Performance Based Contracting for Maintenance” to establish the level of service or goals including the following (7):

- Base performance goal to that achieved by the In-house staff
- Examine the literature, procurement document and contracting information on performance goals of other agencies; compare to other goals adapted by other provinces, states, and countries
- Conduct benchmarking studies
- Set a scale from 0-100 for each performance measure and set the goal at 80

Regardless of the method used to establish the performance measure and goal, it is important that they are addressed with the contractors in early stages of the contract acquisition, that ensure the measures and goals are realistic and agreeable by potential bidders (7)

PERFORMANCE MEASURES SELECTION

Performance measures and specified LOSs are perhaps the most critical elements of performance contracting (9). The performance measures have to be clearly defined and objectively measurable in order to avoid ambiguity and risk disputes (10). Moreover, experts argue the benefit of using a few key performance measures instead of many because of the associated simplicity and manageability of those performance measures (7). It is therefore important that the owner agency properly identify which physical attributes, performance measures, of the road network are required and the associated level of service to be achieved (4).

In the Guidebook for Performance Measurement (11) performance measurement is defined as “The specific representation of a capacity, process, or outcome deemed relevant to the assessment of performance. A performance measure is quantifiable and can be documented.” For a performance measure to be effective, the following questions should be considered (12)

- Is the performance measure **specific**?
- Is the performance measure **measurable**?
- Is the performance measure **achievable**?
- Is the performance measure **results oriented**?
- Is the performance measure **timely**?

- Does the measurement **meet** the **agency’s objectives and desires**?
- Has the performance been **measured before**?
- Does the measurement **conflict** with the **agency’s standard specifications**?
- Is the measurements **aim to improve performance**?

In an investigation commissioned by Land Transport New Zealand to study the effectiveness of their current key performance measures (13), it was noted that an adequate PBC is based on the following essential requirements and/or assumptions:

- The performance requirements are consistent with the policies and objectives of the community and with those of the owner
- Policies can be expressed with the help of measurable parameters, ie qualitative policies can be translated into quantitative measures or parameters Some examples of policies measures include safety, preservation, mobility etc.)
- The relationship between quantitative measures and future performance can be modelled reliably. Deterioration models for local conditions are available and are satisfactorily calibrated
- The input parameters for the performance models can be measured satisfactorily and accurately at a cost commensurate with the asset value
- The funding level of the asset management activities is consistent with the desired outcome and asset value

Table 1 presents an example of the performance measures and goals specified by some Latin American Countries (10).

TABLE 1 Performance Measures and LOS for Different Latin American Countries (10)

Performance Measure	Performance LOS
Potholes	No potholes
Roughness (asphalt)	IRI < 2.0 (Argentina), IRI < 2.8 (Uruguay)
Roughness(bituminous)	IRI < 2.9 (Argentina), IRI < 3.4 (Uruguay)
Rutting	< 12mm (Argentina), < 10mm (Uruguay, Chile)
Cracks	Sealed

PERFORMANCE MEASURES REVIEW

Under The International Technology Exchange Program, the United States Federal Highway Administration conducted a study of the European Practice of PBC (14). The study presented a summary of the performance measures used in Europe as well as some of the US states. It is noted that the scan was conducted in 2003, and there might have been further development to the identified performance measures in the host countries. However, difficulties were faced in identifying more current review of performance measures in the literature. Therefore, a survey to agencies is necessary to establish a comprehensive and up-to-date list of performance measures. Figure 1 presents some performance measures and the frequency of occurrence of each performance measure among agencies reviewed (14, 15)

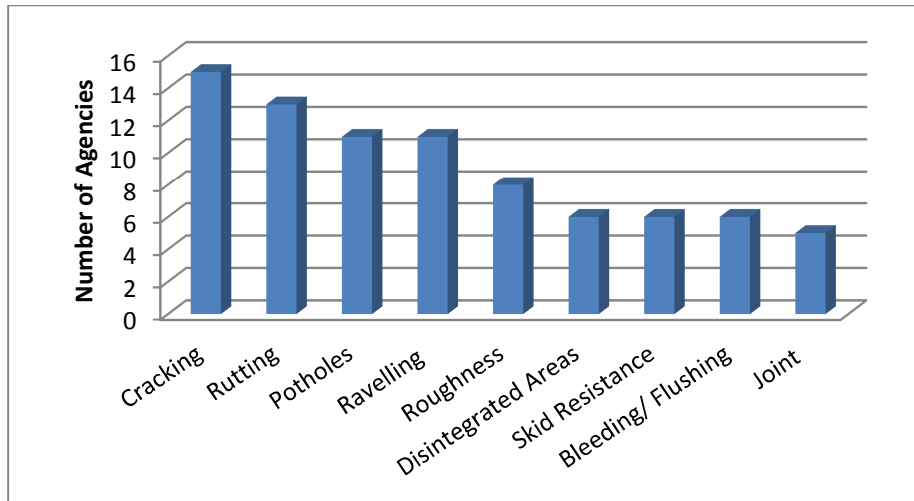


FIGURE 1 Pavement Performance Measures

The study shows that agencies employ different sets of performance measures in their PBCs (14). This could be attributed to the project scale, warranty or contract period, as well as the long term strategic goal of the agency; however, the analysis of the reasons is beyond the scope of this paper.

Performance Measures for Overall Road Condition Indices

Agencies tend to establish pavement evaluation indices that incorporate different pavement performance measures to quantify the overall pavement condition. Each agency calls and calculates its overall condition index differently to some extent. Condition indices, such as Pavement Condition Index (PCI), are a mathematical equation of which the inputs are values of different performance measures such as rutting and cracking. For the purpose of this study, 21 road agencies in North America were reviewed (16). Figure 2 and 3 present performance measures for 21 transportation agencies' indices and the frequency of performance measures occurrence.

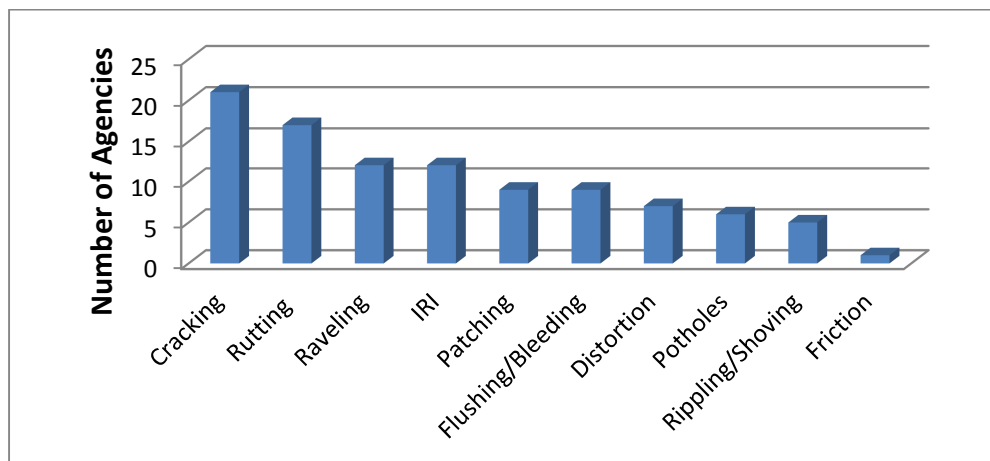


FIGURE 2 Typical Use of Performance Measures for Flexible Pavement

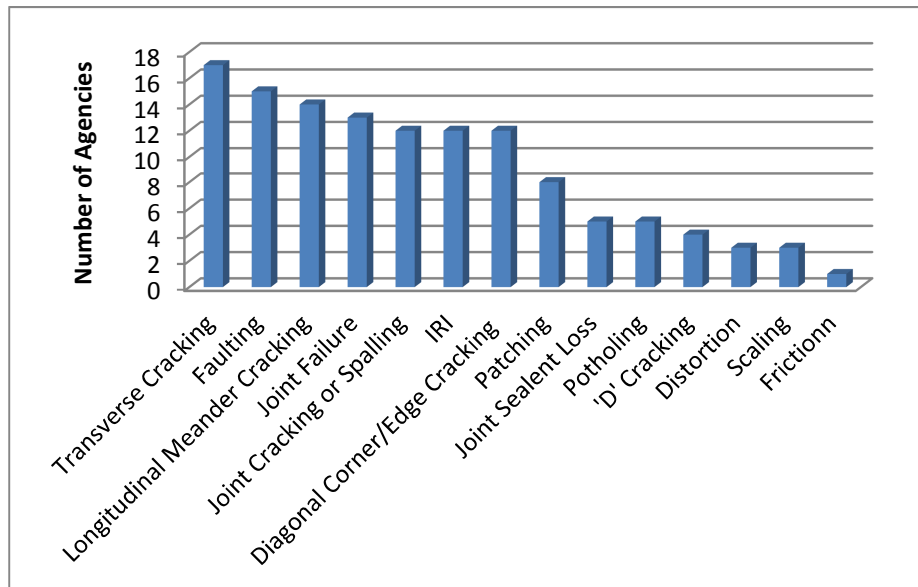


FIGURE 3 Typical Use of Performance Measures for Rigid Pavement

In addition, in a study conducted under the National Cooperative Highway Research Program (NCHRP) (17), a survey of 55 agencies including 46 states and 9 Canadian Provinces was conducted to evaluate the data collected by various agencies. It was found that the data collected by agencies are significantly different as a result of the variation in environmental condition, material used, different pavement designs, and historical practices.

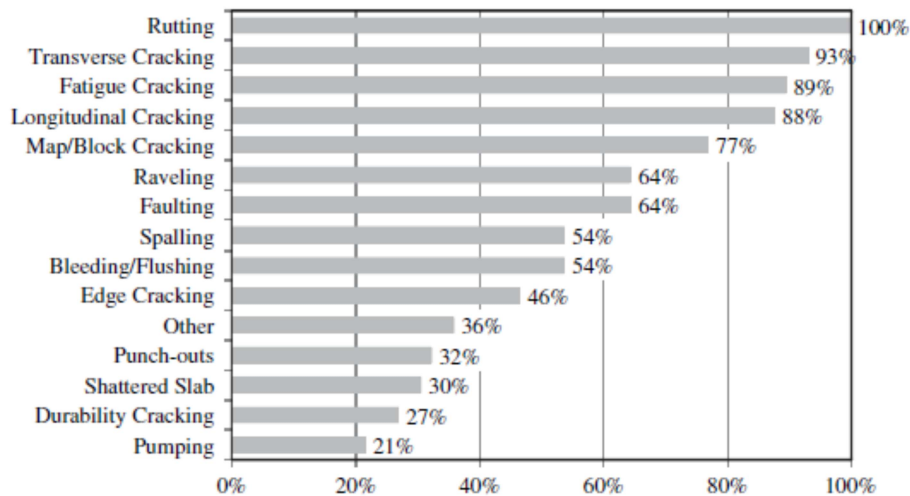


FIGURE 4 Summary of Distress Data Collected by Different Agencies

The literature review of performance measures used in PBCs and the scan of performance measures for the overall condition of pavement assets for different agencies showed that each agency has its unique set of performance measures. As indicated earlier, this can be attributed to

the variation in environmental condition, material used, different pavement designs, historical practices, as well as the long term strategic goal of the agency however, the analysis of the reasons is beyond the scope of this paper.

It is noted that there are common performance measures that are employed by agencies as indicated in Figure 1, 2, 3, and 4. In addition, it is evident that some performance measures are more commonly employed than others. For example, cracking, roughness, rutting, and raveling for flexible pavements and cracking, faulting, joint failure and roughness for rigid pavements. The findings of the literature review is used as a basis to develop and recommend performance measures for the use in MTO's PBCs.

PERFORMANCE SPECIFICATIONS AT MTO

Pavement with Warranty Contracts

PWW, also referred to as 7-year pavement warranty, is a type of contract where the contractors bid on the pavement portion of the project without the conventional specifications. The contractor's responsibilities include design, materials and construction. MTO does not prove the design; however, it depends on the performance requirements during the warranty period (18). The current performance requirements specified by MTO for new construction and rehabilitation/ reconstruction PWW projects are:

- Roughness
- Rutting
- Friction
- Course aggregate loss
- Rippling
- Shoving
- Flushing
- Cracking
- Potholing

PWW initiative involved numerous regional offices and MTO head office collaboration. The collaboration resulted in awarding the first two 7-year warranty project in 2006, and others followed (19).

Minimum Oversight Contracts

Minimum Oversight (MinO) contracts were introduced in 2008. The delivery method is used for relatively small, low risk capital projects such as shave and pave, microsurfacing, and surface treatment. In this contract model, MTO is responsible for assessing the roads' performance over the warranty period (20) . The contracts are reviewed to identify the current performance measures used for different types of contracts and pavements as shown in Table 2. Since 2008,

there are about 75 projects under MinO Model (20). MTO has reported that the quality of the projects are comparable or at the same level of traditional contracts.

TABLE 2 Performance Measures in MinO Contracts

Performance Measure	Contract Type					
	Asphalt Mix Type A	Asphalt Mix Type B1	Asphalt Mix Type B2	Micro-surfacing Single and Double	Surface Treatment Single	Surface Treatment Double
Rutting	X	X	X			
Friction	X	X	X	X	X	X
Coarse Aggregate Loss	X	X	X	X	X	X
Rippling				X	X	X
Shoving				X		
Flushing			X	X	X	X
Cracking						
Potholing	X	X	X			X
Joint Separation	X	X	X			
Delamination				X		
Streaking					X	X
Warranty Period (Years)	3	3	3	2	2	2

X: During Warranty Period

Recommended Performance Measure for MTO

Based on the literature review, as well as the review and feedback from MTO, the following performance measures are recommended for MTO’s PBC for flexible, rigid pavements and granular shoulders as shown in Table 3.

TABLE 3 Recommended Performance Measures

Flexible Pavements	Rigid Pavements	Granular Shoulders
<ul style="list-style-type: none"> • Coarse Aggregate Loss • Cracking • Cross-Fall • Flushing • Ponding • Potholing • Ravelling • Roughness • Rutting • Skid Resistance • Structural Adequacy • Texture 	<ul style="list-style-type: none"> • Cracking • Cross-Fall • Disintegrated Areas • Faulting • Joint Failure • Joint Sealant • Load Transfer Efficiency • Ponding • Roughness • Scaling • Skid resistance • Spalling • Structural adequacy • Texture 	<ul style="list-style-type: none"> • Cross-Fall • Edge Drop-off • Ponding • Rutting • Shoulder Elevation • Stability • Wash Outs

The identified performance measures are a result of the study conducted as well as the review and feedback from MTO. The performance measures are selected based on the applicability and

effectiveness for the use in MTO contracts. The enforceability of these measures is evaluated based on the ability of MTO to evaluate and monitor these performance measures. That is, the ability to use automated or semi-automated technologies. Nonetheless, performance measures that are not possibly monitored using available technologies can be monitored manually. Table 4 below presents the identified performance measures and comments on enforceability.

TABLE 4 Enforceability of Recommended Performance Measures

Performance Measure	Surface			Enforceability		Comments
	Flexible	Rigid	Granular Shoulder	✓ : Automated/ semi-automated monitoring Available	✓ : Manual Monitoring Available	
Coarse Aggregate Loss	✓			✓	✓	Can be identified by imaging systems Or using MTO Manual for Condition Rating
Cracking	✓	✓		✓	✓	
Cross-Fall	✓	✓	✓	✓	✓	Can be identified by profiler systems
Disintegrated Areas		✓		✓	✓	Can be identified by imaging systems Or using MTO Manual for Condition Rating
Edge Drop-off			✓	✓	✓	
Faulting		✓		✓	✓	
Flushing	✓				✓	MTO Manual for Condition Rating
Joint Failure		✓		✓	✓	
Joint Sealant		✓		✓	✓	Can be picked up by imaging systems
Load Transfer Efficiency		✓		✓	✓	
Ponding	✓	✓	✓	✓	✓	Can be picked up by imaging systems
Potholing	✓			✓	✓	
Ravelling	✓			✓	✓	
Roughness	✓	✓		✓	✓	
Rutting	✓		✓	✓	✓	
Scaling		✓		✓	✓	Can be identified by imaging systems Or using MTO Manual for Condition Rating
Shoulder Elevation			✓	✓	✓	Can be identified by profiler systems
Skid Resistance	✓	✓		✓	✓	
Spalling		✓		✓	✓	Can be identified by imaging systems Or using MTO Manual for Condition Rating
Stability			✓	✓	✓	
Structural adequacy	✓	✓		✓	✓	
Texture	✓	✓		✓	✓	
Wash Outs			✓		✓	using MTO Manual for Condition Rating

Because the PBC define the success of a contractor in terms of how well they meet the performance goals alone, they spark contractor innovation and improve quality which in turn creates opportunities for value engineering and improved efficiencies (21). Agencies who have implemented performance based contracts claim cost saving between 10-50%, reduction in house work force, improved level of service, and greater user satisfactory (3, 10, 22, 23). Moreover, some of the advantages found in the literature (7) include:

- Potential reduction in costs
- Improved level of service (could cost more)
- The transfer of risk to the contractor
- More innovation
- More integrated services
- Enhanced asset management
- Ability to reap the benefits of partnering
- Building a new industry
- Achieving economies of scale

Although there are many advantages to PBCs, some of the challenges had been cited in the literature in implementing PBCs include (7, 8, 24, 25):

- Lack of government support (legislative or executive branch)
- A significant change in culture required by the contracting agency and contractors not familiar with this approach
- Adjustments required to go from method to performance specifications
- Inadequate experience with PBMC or a negative experience on the first try
- Lack of training
- Lack of legal authority
- Challenges in estimating in-house and contractor costs
- Insufficient contractor capacity
- Concern over loss of control over methods, equipment, and material used
- The need to secure substantial funds through the budgetary process for large, multiyear contracts

PERFORMANCE MONITORING

In PBC, contractors are paid based on the end result achieved not on following the specified method of performing the work. In other words, the contractor is paid based on how well they meet the specified performance measures (7). Thus, performance monitoring is a major factor in the success of PBC model (21). In addition, data collection, or performance monitoring, requires time, effort, and money to collect, store, retrieve, and use (26).

To ensure that assets under PBC are maintained in accordance with the specified performance measures and the associated LOSs, agencies must develop and implement a comprehensive and

reliable performance monitoring system (2). The monitoring system should be carefully developed and implemented for projects under PBCs.

There are different approaches to monitor and evaluate the performance measures. One approach is the agency being responsible for monitoring the performance measures periodically. In addition to periodic monitoring, the agency may wish to use a random, unannounced inspection of performance measures (7)

Another approach, the monitoring could be performed by the contractor. In this case, the agency requires the contractor to present periodic (monthly, annually etc.) reports of the performance measure. The agency also may assure that the monitoring and evaluation of performance is done properly by joining the contractor during data collection as well as scheduling random quality assurance evaluations. Finally, the monitoring could be performed by an independent third party, which may result in added cost (7).

Performance Monitoring Framework

Figure 5 presents a step-by-step framework to develop an evaluation and monitoring system. It is noted that the evaluation methodology is affected by the project (i.e. road class, traffic volume, pavement type, expected service life, etc.).

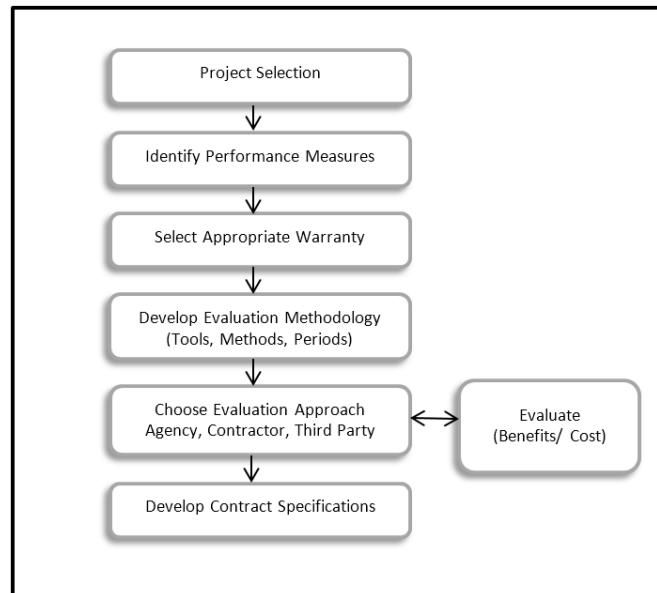


FIGURE 5 Performance Monitoring Framework

The project type requires a set of performance measures and a warranty period. For each project, the agency should develop a monitoring methodology including methods, tools, and periods of evaluation. The methodology should be clearly and accurately defined in the contract to prevent any misunderstanding from the contractor's side and avoid potential disputes (6). Then the agency selects a monitoring approach by evaluating benefits to cost ratio of the approach in

relation to the project. Finally, the agency must clearly and accurately spell out the monitoring specifications in the contract to avoid ambiguity and risk of disputes.

SUMMARY AND CONCLUSIONS

Performance measures in contract administration are fundamental to the successful usage of PBCs. A literature review of performance measures employed by various agencies was conducted as well as a scan of performance measures used in overall pavement condition evaluation indices. Current MTO's performance specification contracts including PWW, and MinO Contracts were reviewed in this study.

The literature review indicated that agencies employ unique sets of performance measures in their contract; which could be attributed to different project scale, warranty or contract period, and overall strategic goal of the agency. It was found that there are common performance measures used by agencies; which were used as a basis for developing recommended performance measures for MTO projects. Performance measures for flexible, rigid pavements and granular shoulders are developed and recommended based on the findings of this study and the review and feedback of MTO. A framework for monitoring and evaluating performance measures is presented.

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