



Laval (Greater Montreal)
June 12 - 15, 2019

PERFORMANCE MEASURE FOR THE DEFINITION OF LEVEL OF SERVICE IN MUNICIPAL INFRASTRUCTURE ASSET MANAGEMENT

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Abstract: Level of service (LOS) is a measure of the user satisfaction and asset condition. This research focuses on the definition of (LOS) using performance measures for different types of assets including Roads, Bridges, Water and Waste water. Factors impacting LOS are identified. A comparative study is conducted between current practice and researcher's point of view to determine performance measure indicators for different asset classes. This research emphasizes on the review of the definitions and measurements of LOS that were employed by a large number of Asset Management Plans (AMP) developed by municipalities in Ontario. The reviewed studies indicate lack of well-defined connected indicators for measuring LOS. The main finding of this study is providing clear definition for LOS for different type of assets. The study is expected to help asset managers in setting-up an effective municipal asset management plan.

1 INTRODUCTION

Level of service (LOS) is an assessment for the operational performance and for the overall status of the serviceability of the infrastructure system. It's very essential to determine the performance measures to monitor LOS (Rajeev et al., 2017). Operational level of service mainly related to physical condition of the asset. Los is directly related to the capacity (Chasey et al., 1997). LOS measures quality, capacity, reliability, responsiveness, environmental, cost and availability (Infra guide, 2002). LOS has a direct impact on the asset management plan and on the asset condition assessment (Khan et al., 2014). According to previous research work, asset condition is the main factor that impacts the performance measures of LOS (Khan et al., 2014). The definition of LOS should indicates the performance measures that are related to decision making and satisfy the municipalities goals (Khan et al. 2014). The performance measures of LOS are related to customer and engineering perspectives. Therefore, asset managers should incorporate measures that define the customer satisfaction level (Han et al. 2015).

The International Infrastructure Management Manual (IIMM, 2011) defines infrastructure asset management as a combination of management, financial, economic, engineering and operational applied to provide the required LOS with effective cost (IIMM, 2011). Performance measures are defined to achieve municipalities' goals and asset management strategic plans. These measures illustrates the operational level of service and the status of the serviceability. LOS target is determined by asset managers. The difference between current LOS and target LOS is the basic of the asset management plan. Therefore, it is essential to clearly define performance measures for LOS (IIMM, 2011). Previous research efforts identified performance measures for LOS by incorporating environmental, social and economic factors (Han et al., 2015; Khan et al., 2014; Rajeev et al., 2017). Performance measures that are developed by different municipalities are developed to achieve specific goals. So, the main objective of this research is to clearly identify performance measures for LOS based on previous studies, asset management plans developed by municipalities in Ontario and the current practice. In section 2, The current study illustrates and select specific performance measures developed by current practice. Section 3 emphasizes on the performance indicators developed by previous studies. Section 4 provides the main method to clearly identify LOS measures. The Sumarry and future work with the main finding are illustrated in section 5.

2 PERFORMANCE MEASURES DEVELOPED BY CURRENT PRACTICE

The National Water and Waste Water Benchmarking Initiatives (NWWBI, 2016) defined six goals for determining LOS. (NWWBI, 2016) indicates that acceptable LOS should satisfy the followings:

- 1- Provide reliable service,
- 2- Ensure adequate capacity
- 3- Meet service requirements with economic efficiency,
- 4- Protect the environment
- 5- Provide safe and productive workplace and satisfied informed customers.

The Ontario Municipal Benchmarking Initiative (OMBI, 2014) relates the performance measures for LOS of roads and bridges to the volume of traffic, total cost to maintain road and percentage of roads and bridges that are rated good to very good. The (OMBI, 2014) defines LOS for water by the number of watermain breaks relative to the age and total cost treatment of drinking water and water distribution.

The current practice set up specific goals for LOS to be achieved by the municipalities. The City of Guelph identified the LOS based on the quality of the service, quantity, reliability, responsiveness, environment and cost. The city of Guelph defined LOS based on two levels: the customer level that usually used in public environment to be easily understood. The technical level of service that defines performance measures such as condition rating. The city of Ottawa defined eight core values for LOS as follows:

- 1- Accessibility: asset should be sufficient to meet demand, easy to be found and reach with less barriers.
- 2- Economic: The service should be provided with reasonable, affordable and effective cost
- 3- Community Involvement: The satisfactions of stakeholder involved
- 4- Health and safety: The service should keep employees safe and protect the public.
- 5- Customer Service: Staff should be competent, complains are resolved, service should be responsive timely and efficiently.
- 6- Quality: Assets are well maintained, comfortable and fit for the purpose
- 7- Reliability: Less interruption for the service.

8- Sustainability: Related to long term plans and environments impacts

The city of Hamilton defined five goals for LOS: Accessibility, Safety, Reliability, Regulatory and customer service. The city identified the LOS for roads based on overall condition index (OCI). Roughness Index (RI) and surface condition Index (SCI) from (0-100), where 100 indicates very smooth surface. The (OCI) overall less than 20 or equal is a failed pavement., The (OCI) 63 is a good rating. The bridge condition index (BCI) is used to measure performance of bridges. The selected Performance indicators that are defined by OMBI, 2014 and NWWBI, 2016 are illustrated in Table 1, Table 2 and Table 3 for water, waste water and roads respectively. The performance measures are selected based on main two categories of performance indicators; the condition of the asset and the capacity.

Table 1: Performance Measures for Water (OMBI, 2014; NWWBI, 2016)

| Water | |
|------------------------------|--|
| Performance Indicator | Performance Measures |
| Condition | Number of main breaks per 100 km length Percentage of leaking valves Number of water pressure complaints by customers/ 1000 people served System length tested for leakage /km length Percentage of leaking hydrants |
| Capacity | Number of hours treated water storage capacity at average day demand |

Table 2: Performance Measures for Water (OMBI, 2014; NWWBI, 2016)

| Waste Water | |
|------------------------------|---|
| Performance Indicator | Performance Measures |
| Condition | Number of blocked sewers per 100 km length Percentage of length cleaned Number of waste water main back-ups relative to the age System length tested for leakage /km length Percentage of length CCTV inspected |
| Capacity | Number of reported overflows due to capacity/100 km length Number of reported blocked service connections/ 1000 service connections Number of connections with sanitary flooding/ 1000 service connections |

Table 3: Performance Measures for Roads and Bridges (OMBI, 2014; NWWBI, 2016)

| Roads | |
|------------------------------|-------------------------------------|
| Performance Indicator | Performance Measures |
| Condition | Performance Condition Index (PCI) |
| | Roughness Index (RI) |
| | Surface condition Index (SCI) |
| | Number of crack seal/km/year |
| | Percentage of length CCTV inspected |
| Capacity | Volume of Traffic on main roads |

| Roads | |
|------------------------------|------------------------------|
| Performance Indicator | Performance Measures |
| Condition | Bridge Condition Index (PCI) |

3 PERFORMANCE INDICATORS DEVELOPED BY PREVIOUS STUDIES

Many researchers focused on the development of level of service. Han et al., 2015 defined customer level of service for water distribution network. The defined measures are related to level of customer values, level of wellbeing and level of service attributes. The level of wellbeing are classified into three categories Environmental, Economic and Social. The authors defined the Environmental category as the satisfaction of water quality, water resources. The economic category is measured based on the bill paid by the customer to reach and get the service. The functional performance is defined as part from the economic category. It is related to the customer satisfaction from water pressure and sounds. The social part includes responsiveness which is the satisfaction of durations of service interruption. Also, it includes the customer service which refers to The Water call centre for providing information. The authors expanded their research work to include the managers' perspective measures (Han et al., 2017).

Extensive efforts to define level of service has been done by Khan et al., 2014. Their definition for LOS included water, wastewater and roads. For water distribution, the LOS indicators are clustered into three categories: structural, operational and water quality. Structural category includes measures of pipe sag, corrosion and crack width. The operational part is related to roughness, leakage volume and loss in pressure. Water quality category is related to lead concentration, iron concentration and coliform bacteria.

Khan et al., 2014 defined LOS for wastewater as three main indicators: structural, operational and Environmental. The structural indicator includes measures for cracks, open joints and sag depth.

The operational indicator includes measures for encrustation, root intrusion and protruding joints. The environmental part is related to infiltration, exfiltration. The authors defined LOS indicator for roads. These indicators are defined based on surface ride quality, structural ride quality and safety concerns.

Based on the reviewed articles, researchers emphasized on the importance of the definition of LOS. It represents how the service is provided with effective cost. Clear definition of LOS helps to support decision making, maintenance, rehabilitation planning. Community and customer perspectives should be incorporated in LOS definition. Moreover, there is a direct link between condition assessment, level of service and asset management plans (Thompson, 2012).

LOS measures should reflect the budget capacity. The defined performance measures are utilized for the assessment of life cycle cost. Table 4 illustrates the definition of performance measures that are developed by researchers. For Bridges, Roads, Water and Waste Water.

Table 4: Performance Measures For Bridges, Roads, Water and Waste Water

| Type of Asset | <i>LOS Measure</i> |
|----------------------|---|
| Bridges | <ul style="list-style-type: none"> - Bridge condition, Total defected areas (Thompson, 2012; WSDOT, 2004) |
| Roads | <ul style="list-style-type: none"> - Road condition assessment includes pavement quality index (PQI), riding comfort index, (RCI), Roughness, Structural adequacy index (SAI), pavement serviceability index (WSDOT, 2004) - Incorporating strategic objectives, (IIMM, 2006; Thompson, 2012) - Customer satisfaction and technical assessment - Pavement segment indicators; (Khan et al., 2014) <ul style="list-style-type: none"> 1- surface ride quality: raveling, flushing, center line cracking, edge cracking 2- structure ride quality: rutting, block cracking, corrugation 3- safety: pothole density, water ponding, pavement marking and skid resistance |
| Water | <ul style="list-style-type: none"> - Frequency of breakage over time and deterioration rate - Including physical, environmental and operational factors (Infra, 2004) - Incorporating performance indicators for the following categories (Khan et al., 2014) <ul style="list-style-type: none"> 1- Structural performance indicators (cracks, sag, corrosion) 2- Operational performance indicators (leakage , roughness, water pressure |

| | |
|-------------|--|
| | <ul style="list-style-type: none"> 3- Water Quality indicators (lead concentration, iron concentration, coliform bacteria) - Customer and Managers' performance measures (Han et al., 2015; Han et al., 2017): <ul style="list-style-type: none"> 1- Environmental (Sustainability) 2- Economic. (Accessibility, Affordability) 3- Social. (Health, customer service, responsiveness) |
| Waste Water | <ul style="list-style-type: none"> - Structural integrity such as physical condition, functional integrity such as service condition and hydraulic adequacy or capacity (Infra 2004; WRC 2011) - Incorporating performance indicators for the following categories (Khan et al., 2014) <ul style="list-style-type: none"> 1- Structural performance indicators (cracks, open joints, sag depth) 2- Operational performance indicators (root intrusion, protruding joints, encrustation) 3- Environmental performance indicators (infiltration, exfiltration, No of pollution incident) |

4 PERFORMANCE INDICATORS DEVELOPED BY THE CURRENT STUDY

The method of this study includes revisions of one hundreds thirty three Asset Management Plans (AMPs). The performance indicators that are discussed in the current practice (OMBI, 2014; NWWBI, 2016) are utilized to define LOS performance measures. The reviewed research efforts provided a deep thought to the definition of LOS. As illustrated in Figure 1, the main input are the information collected from the reviewed studies including AMPs, OMBI, NWWBI, Infra 2004, IIMM 2006 and previous studies that are done by (Khan et al., 2014; Han et al., 2015; Han et al., 2017; Thompson, 2012; Rajeev et al., 2017; Yuan 2017). The main output from this study is the definition of LOS. It has been identified by organizing the selected performance indicators in a hierarchical.

The LOS break down structures are identified within three levels as illustrated in Figure 2. Level 1 illustrates the overall level of service. Level 2 defines three main performance indicators: Environmental, Functionality and Social. Environmental indicator is related to long term plans and environments impacts. Functionality indicator is related to how the asset service is well maintained, reliable and has less interruption. This indicator is attributed to measures of quality, capacity, condition rating and service life. The social indicator is related to customer complains solution and community involvement. It reflects who staff is providing the service and their high response to customers. The social indicator measures safety and public protection with affordable price. As illustrated in Figure 2, the social indicator is attributed to customer service, equity, responsiveness and safety.

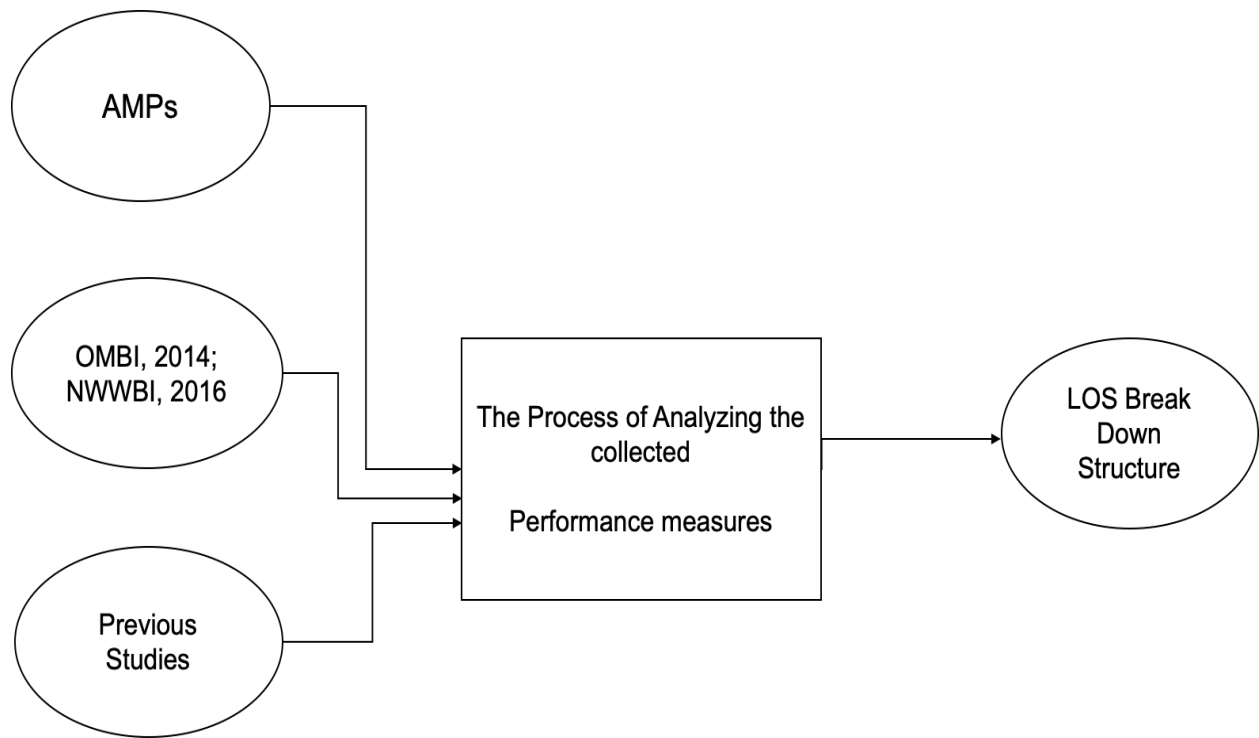


Figure 1: The main method to Identify LOS

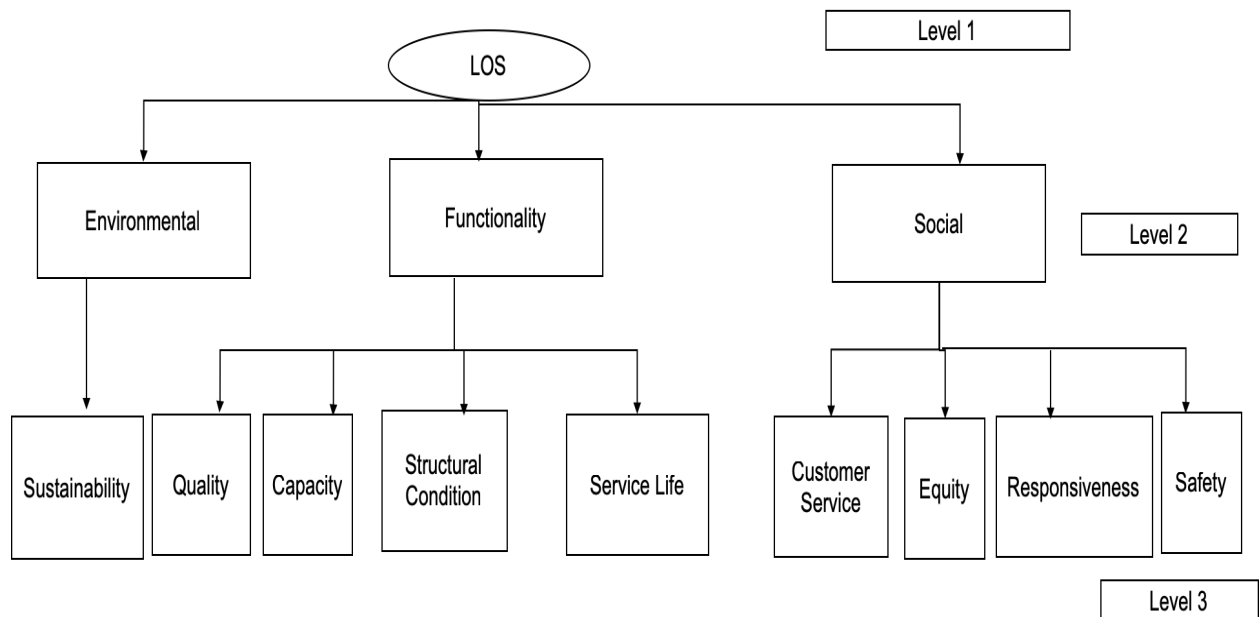


Figure 2: LOS Break Down Structure for Roads, Bridges, Water and Waste Water

5 SUMMARY

Performance measures identify and quantify level of service. It monitors performance and condition rating over the service life of the asset. Performance indicators for LOS should be selected to provide meaningful measures for customer satisfaction and engineering measures. The LOS measures should reflect the cost associated with providing this service and the budget capacity. The main finding of this study is providing one clear definition for LOS performance measures for different type of assets. This study still under development. Extensive future work will be added to target level of service. A survey will be conducted to determine the importance and the weight for each asset performance indicators. Performance measures index will be developed. The overall scale of the developed performance measure index will represent the very poor performance and the very good performance. This research work will assist managers to develop effective asset management plan for maintenance planning and rehabilitation.

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