UNDERGROUND TRANSIT SYSTEM MANAGEMENT; NEW ISSUES

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Proceedings of the 52nd Annual Conference
Canadian Transportation Research Forum

Abstract-Although by implementation of new principles, tools, and techniques infrastructure asset management has been improved and expanded rapidly, however, key concerns resulted by new economic, and sustainability issues, still must be taken into account to develop a comprehensive framework for public transit system management. Existing researches focus more in case of system performance, and level of service while physical indicators are often selected for this purpose and user convenience criteria are ignored. It is also common to see limited budgets with some funds to palliative cosmetic solutions. Many cities face an enormous pressure to handle the ever-growing traffic demand with a limited budget. At the same time, demanding for quality, comfort, and safety by travelers is increasing makes it more complicated to deal with the challenge to convince costumers to abandon the use of private automobile .

The asset management of underground transit systems is a complex process as there are different types of facilities (rail cars, stations, tunnels, etc.) with completely different nature including many subcomponents geographically dispersed across a network. This leads to the need to use of a multi-facility multi-criteria assessment and decision making approach when it comes to the management of transit systems. The main objective of this study is to address recent issues should be covered by transit system management frameworks particularly focusing on subway systems to provide a safe, reliable and convenient service in the best interest of any metropolitan transit systems. Research proposes a framework to show how sub-models reflecting new issues could be attached to common transit agency approaches.

Keywords: underground transit system, asset management, demand, ageing, budget, sustainability, optimization.

1. INTRODUCTION

Although by implementation of new principles, tools, and techniques infrastructure asset management has been improved and expanded rapidly, however, key concerns resulted by new economic, and sustainability issues, still must be taken into account to develop a comprehensive framework for public transit system management. Existing researches and transit agencies models focus more in case of system performance, and level of service while physical indicators are often selected for this purpose and user convenience criteria are ignored. It is also common to see limited budgets with some funds to palliative cosmetic solutions, however, urban transit agencies have to spend large amounts of funds to sustain adequate levels of service on such complex systems (Gkountis & Zayed, 2015). Many cities face an enormous pressure to handle the ever-growing traffic demand with a limited budget. At the same time, demanding for quality, comfort, and safety by travelers is increasing makes it more complicated to deal with the challenge to convince costumers to abandon the use of private automobile .

The asset management of underground transit systems is a complex process as there are different types of facilities (rail cars, buses, stations, tunnels, bridges, etc.) with completely different nature including many subcomponents geographically dispersed across a network. Transit systems are heterogeneous in both function and deterioration aspects. Due to interdependencies between facilities, rehabilitation of one facility could affect the efficiency and functioning of other facilities (Furuya & Madanat, 2013). This leads to the need to use of a multi-facility multi-criteria assessment and decision making approach when it comes to the management of transit systems. The main objective of this study is to address recent issues should be covered by transit system management frameworks particularly focusing on subway systems to provide a safe, reliable and convenient service in the best interest of any metropolitan transit agency. Research proposes a framework to show how sub-models reflecting new issues could be attached to common transit agencies approach.

1.2 New Issues in transit system management

To develop a comprehensive transit system management model suitable for today communities, several novel factors, and tasks must be added into the current implemented approaches by transit agencies.

1.2.1 Demand

The demand for public transportation has been steadily increasing. Although U.S. transit system is not comprehensive, as 45% of American households lack any access to transit, and millions more have inadequate service levels, Americans who do have access have increased their ridership 9.1% in the past decade, and that trend is expected to continue (ASCE, 2013).In Montreal, The "Société de Transport de Montréal" (STM) has targeted an increase of 27% for 2020 in comparison to 2010 (STM, 2012). Transit system demand nowadays is impacted not only by population but also by urban design, density, socio-economic characteristics such as household composition, income and employment status, gender, and age (ICF, 2008).

Demand issues and consequences are often ignored in transit asset management frameworks while performance conditions and facilities deterioration could be influenced by usage pattern, and expansion or increasing journeys in each line change whole transit network performance, and degradation.

1.2.2 Aging

In the meantime, extensive deterioration of already aged transit systems complicates managing the network. In North America, there are cases of subway systems being as old as 60 or 100 years, inevitably revealing signs of severe deterioration. The compromised condition of infrastructure consequently causes safety issues as well as loss of passengers and revenue (Gkountis & Zayed, 2015).

1.2.3. Budget Gap

Meanwhile, budgets are limited due to economic recession and decreased revenues. Consequently, there is enormous pressure to handle the ever-growing traffic demand with a limited budget. Rail-based systems carry just over a third of all transit trips (35%) in U.S. but have the greatest maintenance needs of all transit modes, with a backlog of $59 billion as compared with $18 billion for non-rail systems. In addition, these systems have larger than average annual normal replacement needs (i.e., annual costs required to maintain a state of good repair): $8 billion as compared with the average of $6 billion across all other transit modes (ASCE, 2013).

1.2.4. Complex hierarchy network

Urban transit systems consist of different types of facilities (e.g., rail cars, buses, stations, and tunnels) with various natures and complexity. Subway should be considered heterogeneous system with respect to functions, deterioration processes and costs. Furthermore, maintenance of one facility often affects the maintenance activities of other facilities, both economically and functionally. Thus, interdependencies, not only between facilities, but also between routes are important considerations for subway infrastructure management (Furuya & Madanat, 2013). In such multi elements asset, level of service comes from a multi facilities, and criteria assessment, and missing a main component e.g. tunnel or truck, or one indicator group e.g. user's satisfaction, could result in not precise performance assessment.

1.2.5. Automobile as a great rival

Transit agencies also deal with the challenge to convince travelers to abandon the use of automobile by providing a convenient transit service with sufficient quality, comfort, and safety. Public transportation systems, in particular, constantly face the competition of private vehicles and thus their services need to be of the best possible quality in order to attract an adequate share of travelers and maintain their ridership and financial viability. Attraction and willingness to use public transportation is critical for transit systems and is inevitably related to the condition of their infrastructures; transit travelers are often faced with an overcrowded environment and are required to directly interact with infrastructure elements. It is therefore desirable for transit infrastructures to be in the best possible structural and functional condition and offer an attractive, safe and friendly environment for travelers (Kepaptsoglou, Karlaftis, & Gkountis, 2013).Generally sociological group of indicators that address system performance in terms of costumer point of view could be managed well for this purpose.

1.2.6. Sustainable Indicators

Another dimension that shall be integrated with any asset management plan is sustainability; it implies that the asset manager shall study the effect of maintenance/replacement action on the environment (Marzouk & Abdel Aty, 2012). Although public transit obviously is sustainable system in comparison of single-occupancy vehicle (SOV), however, energy usage rate, or Greenhouse Gas (GHG) emissions could be improved among different transit types. In 2014, bus system produced almost three times more CO_2 comparing with Light Rail Transit (LRT) in Edmonton city (WSP, 2016).

1.2.7. Standards and public expectation

At the same time, demanding for quality, comfort, and safety by travelers is increasing, and transit agencies should protect users. (Torres-Machi, Pellicer, Yepes, & Chamorro, 2013)

2. LITERATURE REVIEW

Although infrastructure management topics are common among researchers especially in case of pavement, bridge and water network management, there is a lack of framework for metro system transit due to their complexity and data availability. The literature indicates that available studies, have serious limitations that restrict their real life applicability. The main gaps could be reported as:

A) Majority of studies cover merely one part of the network (stations, or tunnels) (Hastak & Abu-Mallouh, 2001); (Kepaptsoglou et al., 2013); (Semaan & Zayed, 2009), or the model is developed solely for the structural elements e.g. tunnels dome (Nishimura et al., 2015); (Dawood,T., Zhu, Z., Zayed, T, 2015); (Abouhamad.Mona, 2015; Delatte et al., 2003; Semaan & Zayed, 2014).

B) Evaluation indicators could not address all main aspects (Gallucci, Goodworth, & Allen, 2012), and selecting limit number of defects as indicators resulted in loss of critical asset indicator (e.g. safety) and does not reflect what the user cares for(Gkountis & Zayed, 2015).

C) Developing deterioration prediction model based on asset age (Semaan & Zayed, 2009) or current performance (Gkountis & Zayed, 2015) due to lack of historical data, could reduce results accuracy.

D) Application of models are limited to performance assessment (Gkountis & Zayed, 2015) unless using worst-first approach for resource allocation (Hastak & Abu-Mallouh, 2001), which has also limitations in terms of long-term impacts of decision made at different points of time, asset deterioration, and economic analysis of alternatives.

E) Available models prioritize network in level of stations for rehabilitation(Roy, Présent, & Silhol, 1986) that might be resulted to miss some elements with critical level of service (dropped below minimum service) in not selected stations, furthermore, partial rehabilitation in terms of stations components could increase total level of service..

F) Available models have not had chance to be validated well and in some studies empirical validation were used (Semaan & Zayed, 2009); (Semaan & Zayed, 2014); (Abouhamad.Mona, 2015)

G) Demand issue is ignored in both performance measurement and asset deterioration (Kepaptsoglou et al., 2013); (Semaan & Zayed, 2009).

3. THEORY

To overcome the mentioned gaps found in the literature respecting today costumer and agency needs and concerns, this research proposed model for transit system management covers three tasks of performance measurement, deterioration modeling, and optimization (Figure 1). These sub-models are designed and processed based on developer policy and strategy and might be defined variously agency to agency impacted by several of political and social issues.

1) Developing an understanding of level of service from the user's perspective in order to track individual indicators and their performance across time. The idea is to model all aspects related to the user convenience from the terminal or metro station to the metro car's ride comfort. This complexity poses challenges related to the need to integrate (or not) elements together and the interactions among them. Degree of comfort for instance, measured by assessing different elements e.g. temperature, humidity, acceleration, air quality, and noise. System components including stations, cars, and tunnels are assessed based on appropriate criteria which will be chosen through literature, customer ideas, and expert judgment.
2) Development of performance models to forecast future levels of service for each of the indicators developed in task one, and how decisions made at different points of time may impact them. Progression across time of indicators from step one will be used on step three to plan for timely interventions to ensure a reliable and convenient transit system operation. Prediction of asset condition in coming years is vital, especially those that are facing ageing, however, in the case of subway, lack of historical data is a common obstacle that this research will address. To overcome this challenge, a probabilistic approach such as Markov chain (Edirisinghe et al. 2015) could be used in assessment model of a subway system for the first time. With this stochastic approach, uncertainty could be considered in the analysis, however, its time-independency limitation will be covered by a Semi-Markov model (Thomas & Sobanjo, 2016). Innovative approach of using more data sources including available case history, expert judgment, and current condition through a Full Bayesian approach could complement the lack of historical data.
3) Development of an Optimization sub-model to allocate low budget among alternatives in terms of rehabilitation and replacement or upgrades to guarantee the highest level of service through better values of performance indicators in a subway system. In addition, the model will ensure that minimum levels of service are respected. In such complex hierarchical model, a two-stage optimization approach may be better suited to first, find out the minimum required budget while respecting minimum thresholds in order to guarantee the safety and security of the travelers and next attempt to reach even higher levels of performance with the minimum recommended level of funding.

The above models will result in a comprehensive framework that could help transit agencies to manage their assets and achieve higher levels of convenience and reliability encouraging transit ridership.

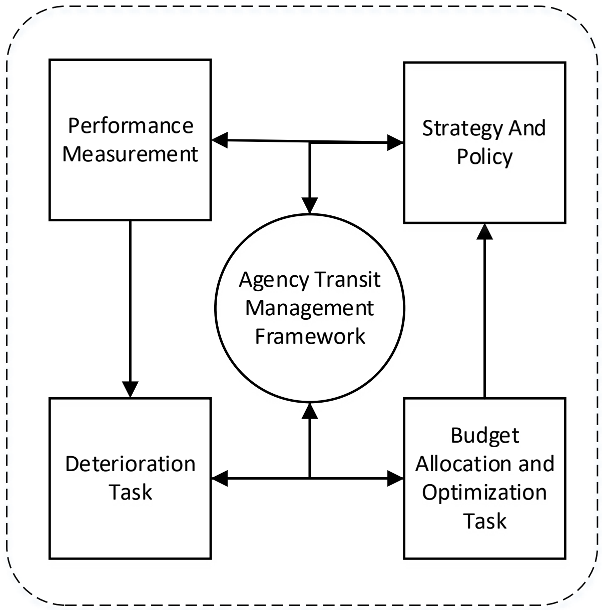

Figure 1. *Proposed framework for transit systems management*

In the next step, discussed issues should be added to framework as it can be seen in figure 2.

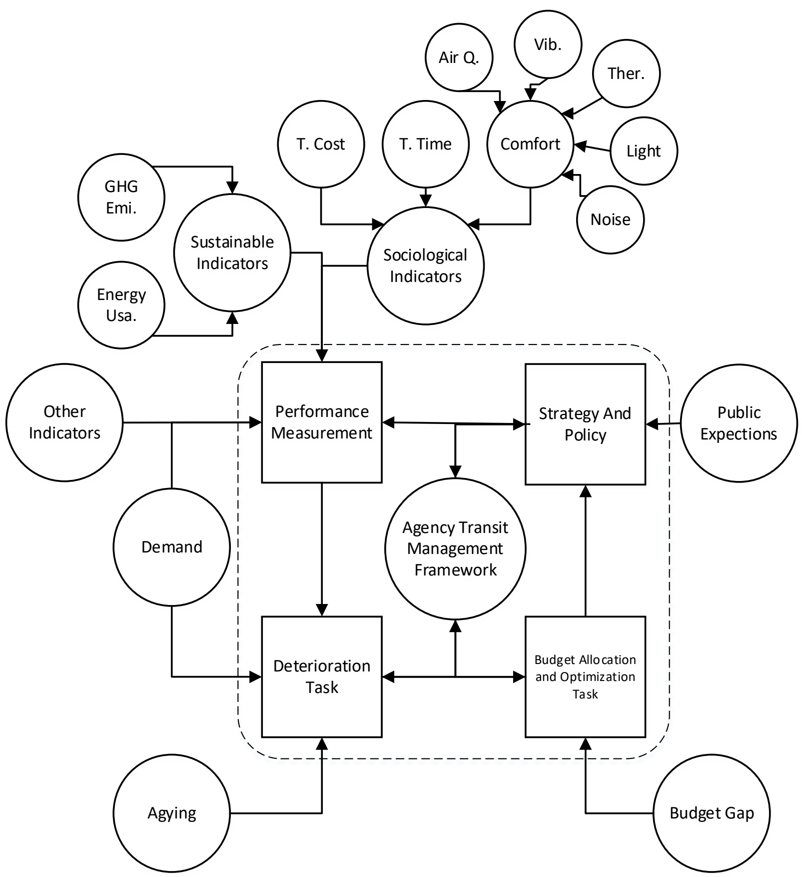

Figure 2. *Recent issues in transit systems management*

4. CONCLUSION:

Although by implementation of new principles, tools, and techniques infrastructure asset management has been improved and expanded rapidly, however, key concerns resulted by new economic, and sustainability issues, still must be taken into account to develop a comprehensive framework for public transit system management. As it was discussed, obvious gaps could be addressed for underground transit asset management framework in terms of demand, ageing, budget limitation, and sustainability. Future maintenance, and rehabilitation plans for subway systems in different level of strategic to operational level should overcome these critical concerns. This proposed a framework to show how sub-models reflecting new issues could be attached to common transit agency approaches. The proposed framework in this research is suitable for any transit agency including Bus-Rapid-Transit, Tramway and suburban trains.

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