PERFORMANCE MEASUREMENT IN NETWORK INDUSTRIES: EXAMPLE OF POWER DISTRIBUTION AND ROAD NETWORKS

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Abstract: The performance of network industries has a great effect on the wellbeing of the society. Planning of such networks balances different social goals, industry trends and investment capabilities. This paper explores the possibility of developing an overall performance index to assess the performance of network industries as a whole in the example of power distribution and road networks. In this paper, performance is seen as a broader concept than the traditional quality of supply or quality of service, embracing the requirements of consumers in relation to the service provided by network authorities. The proposed overall index concept would be an additional regulatory tool to evaluate wider view of performance, to comply with consumers’ requirements.

Key words: network industries, road network, power distribution network, performance indicators, system architecture.

1. INTRODUCTION

Network industries can be defined as entities where the institution or its product consists of many interconnected nodes and where the connections among the nodes define the character of commerce in the industry [1]. A node in this context can be an institution, a unit of an institution or its product.

Examples of network industries are power supply, telecommunications and inland roads. Majority of the services provided by network industries are services of general interest. Network industries providing these services have a significant impact on competitiveness as they account for a large part of every country’s gross domestic product (GDP). The products and services they offer represent a sizeable input for their economy and have an impact on economic development [2].

Governments have stressed that evaluating network industries providing services of general interest is necessary due to the fact that these sectors are undergoing important structural reforms because of regulatory, technological, social and economic changes.

Therefore, it is necessary to evaluate and measure the performance of these sectors, to ensure that the current structural changes do not prevent those social and public policy objectives being attained [2].

There is currently considerable interest in performance measurement. The topic of performance measurement has generated much coverage over two decades in many disciplines within the private and public sectors [3].

The main objective of this research is to:

• explore the possibility of developing a general performance index (GPI) to evaluate the performance of network industries covering power distribution and road networks;

• propose high-level conceptual Information and Communication Technology (ICT) architecture reference model to allow timely data collection, prediction and analysis to support GPI calculation across network industries.

In order to limit the number of parameters affecting performance, and maintain conciseness, cognition and clarity, it is
important to find new ways to combine parameters systematically into GPI-s. Latest developments in ICT sector, such as Big Data and analytics in conjunction with novel user interaction design patterns, pave the way to measure all important performance parameters, create radically better understanding of the problem domain, and translate that knowledge into management decisions.

2. PERFORMANCE MEASUREMENT FUNDAMENTALS

2.1. Definition
Performance measurement is the use of statistical evidence to determine progress toward specific defined social or organizational objectives (see Fig. 1).

![Fig. 1. Performance measurement system](image)

The National Performance Review of the U.S. Federal Highway Administration provides a complimentary definition of performance measurement that is applicable in the context of network industries: “A process of assessing progress toward achieving predetermined goals, including information on the efficiency with which resources are transformed into goods and services (outputs), the quality of those outputs (how well they are delivered to clients and the extent to which clients are satisfied) and outcomes (the results of a program activity compared to its intended purpose), and the effectiveness of government operations in terms of their specific contributions to program objectives.” [1].

Every performance measurement system (PeMS) requires developing and reviewing at a number of different levels as the situation changes. The PeMS should include an effective mechanism for reviewing and revising targets and standards and should be used to challenge the strategic assumptions [7].

2.2. Performance indices
The performance index is a management tool that allows multiple sets of information to be compiled into an overall measure [8]. Chapter 2.3 contains examples of indexes used to evaluate performance of power distribution and road networks. The “real time” data collection gives new possibilities for performance monitoring and management since the services in road or power distribution industries are "consumed" at the same time they are "produced" [2]. Performance indices provide information to stakeholders about how well that bundle of services is being provided. Performance indices should also reflect the satisfaction of the users, in addition to those concerns of the system owner or operator [6, 9].

The procedure of combining data into indices is necessary to present simultaneous information from several related areas and data sources. This process provides a statistical measure that describes the change of performance over time.

![Fig. 2. Conceptual model for performance indices in network industries](image)

Fig. 2 proposes a generic conceptual model for performance indices. It can be exploited in network industries to evaluate performance of different network locations,
elements, and their performance trends over time.

A performance indicator (PI) defines the measurement of a piece of useful information about the performance of a program or a work expressed as a percentage, index, rate or other comparison which is monitored at regular intervals and is compared at least to one criterion. The use of PI-s goes beyond simply evaluating the degree to which goals and objectives have been achieved [4, 12].

2.3. Examples

In road industry, PI-s is defined for different types of pavements and highway categories. In the first level several single PI-s describing the characteristic of the road pavement condition are assessed [12]. The next step is the grouping of single PI-s into key performance indicators (KPI-s) and finally into representative combined performance indices (CPI-s) as:

- functional performance indices (demands made on road pavements by road users);
- structural performance indices (structural demands to be met by the road pavement);
- environmental performance indices (demands made on road pavements from an environmental perspective).

Fig. 3. Performance indices in road industry as proposed by COST354 and EVITA [4, 13, 14]

Finally, based on the CPI-s a GPI (see Fig. 2 and Fig. 3) is defined for describing the overall condition of the road pavements, which can be used for general optimization procedures [1]. Attempts had been made [15, 16, 17, 18] to create overall quality of supply and reliability indexes for power distribution network performance evaluation. However, the index systems are not yet as comprehensive as for road networks. This remains as a topic for further research.

Emerging Smart Grid developments are putting more emphasizes to understand the performance of the power network not only from power quality and grid reliability aspects, but also as a whole. A lot of effort has been put into voltage quality research. Several indices have been taken by standardization bodies to implement [19, 20, 21]. The commercial quality, quality of service, safety of operations, socio-environmental impacts of power distribution network operations has not been investigated thoroughly.

Fig. 4. Performance indices in power distribution industry [15, 18, 22]

Fig. 4 attempts to combine different sources [15, 18, 22] of information into single GPI that can be visualized and hierarchically combined for substations (areas), feeder lines, phases and metering points in distribution network.

3. SYSTEM ARCHITECTURE

3.1. Data context

The process of unlocking additional value from the existing data and combining it with new data sources (e.g. sensors, Smart Meters, Internet of Things) will have a
transformative impact on the management of network industries. More effective and therefore lower cost data communication, storage, and presentation that have better data processing mechanisms will allow the handling of the data with higher velocity, variety and volume in near future.

The proposed system architecture reference model is developed to provide high-level view of the functional components in the platform allowing processing of the technical parameters and to combine them into understandable indexes also visualizing them for the end-user. By dividing layers of responsibilities between different functional components of the platform, we can get a clear view of the roles and responsibilities and lay the foundation for a common understanding.

The diagram on Fig. 5 shows the high-level overview of the system and specific functional layers of the platform. The reference model is based on the work done by Tallinn University of Technology \[4\] and TM Forum \[23\].

**3.2. Reference model layers**

The purpose of the reference model is to provide high-level view of the functional components in the Performance Evaluation System.

All layers have clear responsibility borderline. Only a subset of the functionality may be needed to satisfy the requirements of a particular performance evaluation scenario.

Data communication layer is responsible for transporting the data from data sources into the processing platform. The amount and creation speed of data will play the key role in choosing the communication technology.

Data ingestion layer is responsible for integrating various data sources and importing the technical parameters into the platform. The main importance of this layer is to handle the volume, velocity and variety of the data coming into the platform. Modules of this layer must be capable of scaling out in order to accommodate the data input bandwidth and speed.
When data is missing, prediction algorithms can be applied to estimate the missing values [14]. Validation of values is also done in data processing layer. The other responsibility of this layer is to ensure data quality. Data management layer accommodates processes to perform format transformation towards uniform domain data model, correlation of events, enrichment manipulation. Batch queries over the large historical dataset using the Map-Reduce algorithm is to provide the functionality to implement scenarios that do not require real-time processing. Complex Event Processing (CEP) layer in another hand controls the processing of streaming data, and the calculation of indices in on-going basis. In the context of big data, both of the abovementioned layers can be implemented by massively parallel-enabled data processors. Data aggregation layer carries the responsibility of combining the results of CEP and queries into PI-s and combined indexes. The visualization layer is often forgotten but it is the key to make the collected data easily understandable and meaningful to the end-users. Common functions, Geographical Information System (GIS) and data Repository are required functions to implement each of the layers.

4. CONCLUSION

Constant performance evaluation of network industries enables more effective and efficient lifecycle management. For that purpose in mind, a lot of research and standardization efforts have been made. Road networks have comprehensive indices systems available. Power distribution systems indices focus today more on the voltage quality side and do not provide real end-to-end support for decision-makers. Unifying and combining the different aspects of different indices into common network industries’ performance index remains as further research. However, performance of both of the industries can be analysed and visualized using the existing evaluation concepts with the ICT systems built based on the proposed performance evaluation reference architecture. Emerging Smart Grid networks combine communication and power networks, Smart Road systems require the existence of nearby power distribution networks, real-estate development includes new roads, power and communication networks etc. The same performance evaluation conceptual model as a system covering network industries as whole should be used to understand the performance of Smart Infrastructure.

5. REFERENCES


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