Journal of KONBiN 2019
Volume 49, Issue 4
DOI 10.2478/jok-2019-0073

Frehaileab Admasu GIDEBO[1,2], Janusz SZPYTKO[1]
[1] *AGH University of Science and Technology (Akademia Górniczo-Hutnicza)*
[2] *Addis Ababa Science and Technology University*

RELIABILITY ASSESSMENT OF THE TRANSPORT SYSTEM, ADDIS ABABA CASE STUDY

Ocena niezawodności systemu transportowego na przykładzie Addis Abeby

Abstract: *The subject of the article is the method of assessing the reliability of the transport system on the example of Addis Ababa in Ethiopia. The transport system and its technical condition, transport infrastructure, organization of the transport system, environment (users, environmental and climatic conditions), and legal provisions, have a significant impact on the reliability of the transport system. The most common means of transport in Addis Ababa is a car (including: taxis and minibuses). An important problem in public transport is the long waiting time for the vehicles, resulting from random events accompanying transportation processes in a defined infrastructure with limited resources. The article presents also the concept of a transport system availability model for developing countries on the example of Addis Ababa in Ethiopia.*
Keywords: transport system, system reliability, system availability

Streszczenie: *Przedmiotem artykułu jest metoda oceny niezawodności systemu transportowego na przykładzie Addis Abeby. Na niezawodność systemu transportowego istotny wpływ mają środki transportowe i ich stan techniczny, infrastruktura transportowa, organizacja systemu transportowego, otoczenie (użytkownicy, warunki środowiskowe i klimatyczne), przepisy prawa. Najczęstszym środkiem transportu jest samochód (w tym: taksówki i minibusy). Istotnym problemem w komunikacji miejskiej jest długi czas oczekiwania na środek komunikacji zbiorowej, będący skutkiem losowych zdarzeń towarzyszących procesom transportowym w określonej infrastrukturze przy ograniczonych zasobach. W artykule przedstawiono również koncepcję modelu gotowości systemu transportowego dla krajów rozwijających na przykładzie Addis Abeby w Etiopii.*
Słowa kluczowe: system transportowy, niezawodność systemu, gotowość systemu

1. Introduction

Transport is a key critical component that can play a crucial role in economic and social development of any society. The major means of transport in Ethiopia is road transport with many of problems and that can be characterized by very low level of reliability of transport system. Thus, the available forms of transport options are very limited and unattractive to the users [1, 16]. Moreover, the transport system and its technical condition, transport infrastructure, organization of the transport system, environment (users, environmental and climatic conditions), and legal provisions, have a significant impact on the reliability of the current transport system in Addis Ababa, Ethiopia.

The absence of possible alternative routes from various directions, lack of various separate modes of mobility such as pedestrian walkways, bike lanes and motorways are contributing factors for unreliable transport system. The transport means as result of

- maintenance and repair schedule (both technical devices and technological objects),
- fuel supply systems,
- congestion and jams,
- fleet exploitation problems might lack the reliability [3, 16].

Mainly, in the cities like Addis Ababa, access to business activities, education, employment and recreational opportunities can be a challenge due to the expansion of urban population. Another critical factor of the reliability of transport system with respect to user's perspective is capacity of road network and performance of transport vehicles. The reliable transport system can be determined by development of effective transport system capable of increasing network capacity and efficiency without compromising safety, the environment and the economy as well as providing accurate and reliable data for planning and maintenance purposes [3, 10]. There are also much more methods of reliability evaluation in various conditions. One of the most widespread methods of reliability determination is the assessment of transport system behaviour in conditions of congestion [15]. As a result, transportation system reliability refers to the ability that the system operates as planned during the planning horizon. The transport system reliability is used to express the probability of a transportation system to completely fulfill the passenger demand of transportation service without any unwanted events, resulting from failures of vehicles, infrastructure or other transportation facilities [8].

In addition to the above studies, König [7] mentioned that the difficulty of assessment of reliability of transport system is a condition of traffic congestion. Usually users used to make appropriate choice and route depending on real condition. In daily activities, it is important to assess performance of reliability measurements such as travel time reliability and capacity reliability under regular congestions, without a complete loss of network components. Users/passengers should take into consideration the reliability of travel time and reliability of road capacity in a given route [17]. However, in order to ensure reliability of transport system in random events; availability and maintainability of the system should be taken into consideration from planning to operation stage since the exploitation elements of transport system possess various properties in input, process and output sources [9].

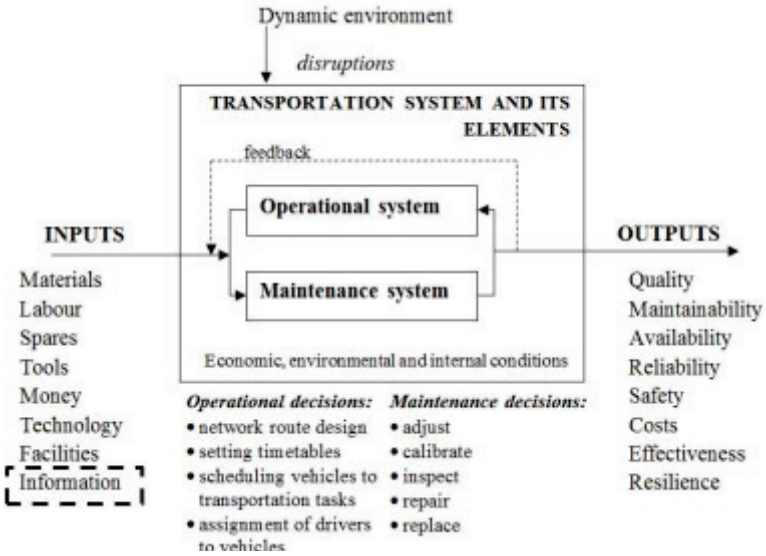

Fig. 1. Transport exploitation elements in random or dynamic environments [9]

The research conducted by Bojda and Tubis [4] indicate that punctuality is also an important parameter to assess the reliability of transport system in terms of proportional travel time, frequency of congestion, the failure rate and the rate of travel time.

This paper mainly tried to address the reliability concerns of Addis Ababa transport system. The most common means of transport in Addis Ababa is a car (including: taxis, minibuses and small cars). An important problem assessed in public transport is the long waiting time for the vehicles, resulting from random events accompanying transportation processes in a defined infrastructure with limited resources. The subject of the article presents the method of assessing the reliability of the transport system on the example of Addis Ababa in Ethiopia. Also, it presents the concept of a transport system availability model for developing countries on the example of Addis Ababa in Ethiopia.

2. Research rationale and methodology

Addis Ababa is a city of diplomacy and the capital with highly increasing number of population. The increasing number of population will lead to city sprawl and low density land use. On the other hand, the growth of demand for transportation services has brought many benefits but also substantial costs in terms of rapidly increasing congestion levels and associated environmental pollution (air and noise), risk of accidents and time wastage during journeys, particularly in urban areas [7]. Therefore, due to the defined problem of the city transportation system, it is difficult to assess the reliability of the transport system.

However, this research tried to assess the mentioned difficulties and identify the possibilities that can increase the reliability of transport system in the city.

The reliable transport system is defined as:

- access to transport means (including multimodal transport means),
- travel and waiting time and
- service quality (proper information to passengers, fleet management, adaptation of technological tools etc.) must be optimized.

In order to address the subject of this research, the existing transport system of Addis Ababa has been assessed. Usage of vehicles like taxi, minibuses and other modes of transport was evaluated to assess the reliability of transport system. Travel time, waiting time, and the distance between stops (mostly unknown or no fixed stops) and transport policy of the city were taken as critical factors of reliability issue of transport system. These factors could also be used to model the availability problems of the transport system in the city [5].

In addition, the difficulty of getting various modes of transport and linked transport system in the city is another subject of reliability. Trams, buses, private public transport services (taxi, minibuses) are not linked with each other to provide the proper service of transportation. The legal provision can play an important role in order to ensure reliability in terms of travel time, frequency of services and service quality.

3. Effect of transport planning on reliability of transport system

Transport planning from inception to operation is a vital activity in transportation process. Planning of proper operation and management of transport system in order to optimize the available resource is a compulsory duty. Transport planning to incorporate all the existing and new modes of transport system cannot be a diluted approach. Lack of integration of land-use and transportation planning can be a reason for unregulated city sprawl and urban growth. At transport planning stage, there is an interest raised from political decision makers and real demand from passengers or transport users. However, government should support transport planners and must give an emphasis on the following critical issues [15]:

- Incorporating urban transport as an important parameter at the planning stage rather than being a consequential requirement
- Reduced travel demand – better integration of land-use and transport planning
- Equitable allocation of road space
- Improved public transport
- Introducing intelligent transportation system (ITS)
- Facilities for use of non-motorized vehicles

- Capacity building – individual and institutional
- Use of cleaner technology, etc.

Fig. 2. Existing transport facility and demand in Addis Ababa city

From government side, the issue of urban sprawl, which is fast and consumes a lot of spaces, is mostly a difficult task for transport planning. The demand for transportation is unexpectedly increasing due to disparity of urban development and limited resources.

4. Effect of environment on reliability of transport system

Transport system is responsible for both the positive and negative impacts on the society in which we live. The immediate concern of the harsh effects of transport is generally the high level of air pollution and traffic noise, which are both harmful to community health and deteriorate the environment. Therefore, it is vital to minimize/ reduce vehicles that highly oil-driven vehicles (old and used cars), and develop a sustainable transportation approach [2]. Transporting people or goods requires energy, and energy, even from 'green' sources, has its costs. Rapid growth of population coupled with numerous economic activities resulted in a substantial demand for energy in all sectors of economy. In this approach, how the available limited natural resources can be optimized for the present and future in order to keep the environment safe [2, 7]. On the other hand, an important reason for the lack of reliability of transportation system in terms of environment is the lack of well-organized public transport system. Addressing the challenges of public transport system is one of the best approaches to ensure a sustainable transport since there is mass transportation and reduction of private cars on the roads and increase in road safety. But due to several reasons such as privacy, comfort, customer satisfaction and technological advancement, public transportation lacks attractive environment and failed due to the challenges. Thus, the need for systems approach in public transportation planning must address Origin to Destination (O-D) travel time effectively and include all modes of transport.

5. Effect of information technology on reliability of transport system

Every day we are witnessing and being a part of new technology and digitalization incidence in transport sector and many industries as well. The today society is easily affected and transformed indirectly or directly by using various technological solutions in day-to-day activities. A transport service is also one of the emerging areas of technological advancement and information system. Nowadays, Intelligent Transport Systems (ITS) has enabled a new approach and implementation of advanced control, and technical as well as technological solutions, achieving greater safety, efficiency and reliability of transport. Evaluating and analyzing the existing information before travel (pre-trip), on trip and route guidance and navigation is an important element of information technology. Though, the reliable information in transport system can be well recognized in case of receiving information from various sources. Moreover, various transport technologies are equipped with vehicles and the same time, vehicles have increasingly effective driver assistance and protection mechanisms. Various onboard controls and information sources allow the driver to customize driving experience and remain up-to-date with the vehicle status; passive safety mechanisms protect the passengers and vehicle against adverse driving conditions [11, 14].

6. Effect of infrastructure reliability on the transport system

It is believed that transport infrastructure plays a crucial role to achieve reliability of transport system. The integrated and connected transport infrastructure can facilitate the positive flow of traffic and mobility. On the other side, the inadequate supply of infrastructure can be reflected by the problem of cost of transportation and degrades population's financial capacity and access to day-to- day activities. The availability of inadequate transport infrastructure can affect the performance of transport network. In the context of Addis Ababa transport system, and transport infrastructure in terms of road length, road width and road side infrastructure are important indicators of efficiency and reliability of transport infrastructure bearing in mind that access to infrastructure creates suitability for passengers from their system entry point to their system exit location in a reasonable amount of the time. Thus, accessibility encompasses the operational functioning of a system for travel.

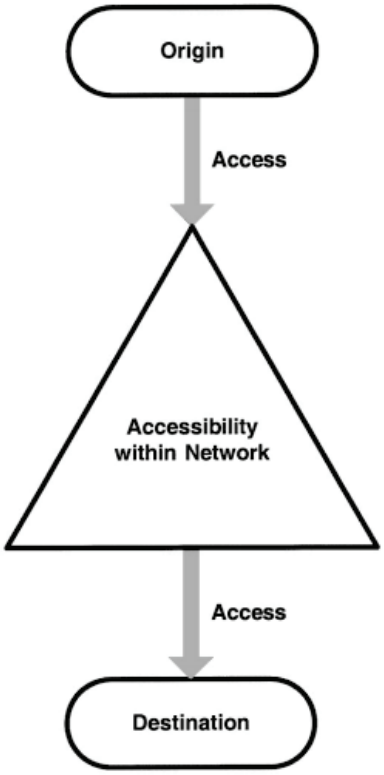

Fig. 3. Transport Infrastructure accessibility model [13]

The major problems regarding infrastructure are:
- high intensity of private vehicles on the roads/ car dependent society
- poor mass transportation facilities,
- inadequate road capacity,
- heterogeneous movement of traffic,
- high volume of traffic congestion and road side accidents.

The problems could be solved by proper planning and integration of various modes of transport services in the city. Minimizing crowded roads and its network through providing public bus transportation and carpooling advantages can be taken into consideration to provide a reliable transport system and effective utilization of the existing road capacity.

7. Results and discussions

Transport is a complex system and a combination of demand and supply as clearly explained in the paper. Basically, demand (interest of finding activities) and supply

(transport infrastructure/networks,services) characteristics must describe the stochastic process of the activities in the transport system. Therefore, the transport systems would possess reliability in terms of:

- walking distance,
- alternative modes,
- waiting and travel time,
- service frequency and available information ,
- as well as suitability for special needs

Fig. 4. Modes of Addis Ababa transport system [1]

The issue in the city is not only concerning reliability but also safety due to the large number of pedestrians walking and the lack of properly connected road networks. It results in the inefficiency and in terms of mobility; urbanization and urban sprawl generate both growing needs and new needs with longer travelling distances. It is essential to make road users feel convenient, secure, comfortable, and healthy while using the transportation system. Since transport systems are designed to let people circulate through the systems; arrive at their destinations; and achieve their trip purposes.

Fig. 5. Some other modes of transportation system in Addis Ababa [4]

Fig. 6. Minibus/taxi dominant transportation system in Addis Ababa

8. Conclusions

Transport system in developing world is a challenging task. To be inclusive and productive economically, providing multiple options to the access to transportation is obligatory. The factors of transport system reliability cannot be neglected. When system reliability is being assessed, various methods of models could be taken into consideration such as multi-state system (MSS) in order to optimize resource allocation and minimize redundancy. In addition to that, ensuring the life cycle of technical objects (cost, design life and efficiency) and ensuring the functionality of technical objects (reliability, availability and maintenance) are essential objectives of the transport system reliability.

Acknowledgement
The work has been supported by the Polish Ministry of Science and Higher Education.

9. References

1. Addis Ababa Road Safety Strategy (2017–2030).
2. Bojda K., Tubis A.: The Selected Aspects of Transport Services Punctuality Measurement Rated By The Carrier and Passengers. Wroclaw University of Technology, Journal of KONBiN 2(38), 2016, DOI: 10.1515/jok-2016-0021.
3. Clark S., Watling D.: Modeling Network Travel Time Reliability Under Stochastic Demand Institute for Transport Studies. University of Leeds, Woodhouse Lane, Leeds LS2 9JT, U.K., 2003.

4. https://use.metropolis.org/case-studies/sustainable-transport -in -addis -ababa
5. König A.: The Reliability of the Transportation System and its Influence on the Choice Behavior. 2ndSwiss Transport Research Conference, Monte Verità / Ascona, March 20-22, 2002.
6. Murrayet A.T. et al.: Public Transportation Access. Australia, Pergamon, Transpn Res.-D, Vol. 3, No. 5, 1998.
7. Nallet C.: The challenges of urban Mobility, The case study in Addis Ababa. Light rail transport, Ethiopia 2018.
8. Nowakowski T.: Problems of Transportation Process Reliability Modeling. Wroclaw University of Technology, 2014.
9. Nowakowski T., Tubis A., Werbińska-Wojciechowska S.: Maintenance Decision Making Process – A Case Study of Passenger Transportation Company. Wroclaw University of Technology, Wroclaw 2015.
10. Ochieng W.Y., Sauer K.: Urban road transport navigation: performance of the global positioning system after selective availability. Department of Civil and Environmental Engineering, Centre for Transport Studies, Imperial College of Science, Technology and Medicine, London 2011.
11. Papadimitratos et al.: Vehicular Communication Systems: Enabling Technologies, Applications, and Future Outlook on Intelligent Transportation. IEEE Communications Magazine, November 2009.
12. Sarkar P.K., Tagore P.: An approach to the development of sustainable urban transport system in Kolkata. School of Planning and Architecture, New Delhi, Current Science, Vol. 100, No. 9, 10 May 2011.
13. Sietchiping R., Permezel M.J., Ngomsi C.: Transport and mobility in sub-Saharan African cities: An overview of practices, lessons and options for improvements. Elsevier science direct, 2012.
14. Šarić S., Peraković D., Kušan I.: Possibility of Improving Passenger Information System in Bus Transport by Using Cloud Computing, University of Zagreb. Faculty of Transport and Traffic Sciences, Zagreb 2012.
15. Verma A., Sreenivasulu S., Dash N.: Achieving sustainable transportation system for Indian cities – problems and issues. Special Section: Sustainable Transport, 10 May 2011.
16. Verseckienėet A. et al.: Urban Public Transport Accessibility for People with Movement Disorders: the Case Study of Vilnius. Elseviere Science direct, 2016.
17. Wu Z.: Measuring Reliability in Dynamic and Stochastic Transportation Networks. University of Nebraska-Lincoln 2015: http://digitalcommons.unl.edu/civilengdiss