VII International Symposium
NEW HORIZONS 2019
of transport and communications
29 - 30 November, 2019
www.novihorizonti.sf.ues.rs.ba

GRAPHS IN MODELING LOCAL ROAD NETWORKS: A PRELIMINARY LITERATURE REVIEW

GRAFOVI U MODELOVANJU MREŽA LOKALNIH PUTEVA: PRELIMINARNI PREGLED LITERATURE

Jelena Stojanov[a], Goran Jauševac[b], Zeljko Stojanov[a], Ilija Hristoski[c]

[a] *University of Novi Sad, Technical faculty 'Mihajlo Pupin', Zrenjanin 23000, Serbia, jelena.stojanov@uns.ac.rs, zeljko.stojanov@uns.ac.rs*

[b] *University of East Sarajevo, Faculty of Traffic Engineering, Doboj, Bosnia and Herzegovina, goran.jausevac@sf.ues.rs.ba*

[c] *'St. Kliment Ohridski' University - Bitola, Faculty of Economics, Prilep, Macedonia, ilija.hristoski@uklo.edu.mk*

Abstract: *Graphs have been proved as efficient tool for modeling and analyzing issues in different types of networks in socio-technical systems. Different issues and properties related to locations and distances in road networks can be presented and analyzed by using graphs. Since it is evident that local roads have a significant impact on everyday life, it is necessary to identify issues that affect their more efficient use. This paper presents preliminary literature review on using graphs for modeling and inquiring issues related to local road networks. The literature review protocol is outlined, followed with the discussion of research findings, constraints and benefits. Implications of the research are also presented, which is the main contribution of this study.*

Key words: *graph, mathematical model, local road network, literature review*

Apstrakt: *Grafovi su efikasan alat za modelovanje i analizu problema u različitim mrežama koje se koriste u socio-tehničkim sistemima. Različiti problemi i svojstva vezana za lokacije i udaljenosti u putnim mrežama mogu se predstaviti i analizirati pomoću grafova. S obzirom na očigledan uticaj koji lokalni putevi imaju na svakodnevni život, neophodno je identifikovati probleme koji utiču na njihovu efikasniju upotrebu. Ovaj rad predstavlja preliminarni pregled literature koja se odnosi na upotrebu grafova za modelovanje i istraživanje problema mreža lokalnih puteva. Prikazan je protokol koji se koristi za pregled literature, a potom je prikazana diskusija nalaza istraživanja. Implikacije za buduća istraživanja su takođe prikazana, što predstavlja ključni doprinos ovog rada.*

Ključne riječi: *graf, matematički model, mreža lokalnih puteva, pregled literature*

1. INTRODUCTION

Hierarchy of roads, starting from the highest level of traffic frequency, includes the following levels: highways, main roads, regional or collector roads (collect traffic from local roads to main roads), and local roads. The lowest level relates to tertiary roads, or local roads with the smallest traffic volume. These roads include urban roads and rural roads, and enable access to local objects. Despite the fact that local roads comprise more than 80% of total road network in majority of countries, more attention and investments relates to the primary roads at national and international level (Cvetanović & Banić, 2013). The importance of local roads, especially urban roads is in the fact that more than 55% of all roads are in this class of roads, while the expectation is that 85-90% off all roads in Europe and America will be urban roads (Dueñas, 2018).

Increasing traffic volume affects the deterioration of the state of local roads, leading to decreased performance and reliability of these roads. Financial constraints in maintaining and monitoring local roads' networks result with their decreased operational characteristics, leading to a large number of traffic accidents on them (Cvetanović & Banić, 2013). In addition, there is a lack of information related to characteristics of these roads, as well as information about available facilities.

Road networks are usually interpreted by using structures such as trees, graphs or grids, but there is always some selective consideration of what is being presented for the given context (Marshall, 2016). Graph theory is mathematical discipline aimed at studying graphs as mathematical structures that are commonly used

for modeling relations between objects. Graphs are made of vertices (also called nodes or points) and edges (also called links or lines) that connect the vertices. In traffic engineering, graphs are used for analyzing traffic networks, where exists obvious relationship between the links and nodes in transport networks and the edges and vertices in graphs (Ducruet & Lugo, 2013; Bagdasar, 2013; Marshall, 2016). Based on previous considerations there is evident need to systematize knowledge on using graphs for analyzing issues related to local roads. A common way for systematizing knowledge on selected phenomena in a selected field is to use literature reviews, which enable identification of the research trends and propose issues to be inquired in future research. This study aims at presenting a preliminary literature review that addresses issues on using graphs as a mathematical concept and tool in local road traffic.

The paper is organized as follows. The next section presents our approach to literature review, with presentation of the findings, while the third section presents discussion of the study benefits and constraints. Concluding remarks and future research directions are considered in the last section.

2. LITERATURE REVIEW STUDY

Integrative literature reviews, as a form of research that reviews, critiques, and synthesizes representative literature on a topic, have been recently adopted in many fields with the intention to address two general kinds of topics - mature topics or new and emerging topics (Torraco, 2005). Findings of literature reviews can be presented in different form such as research agendas, frameworks, taxonomies or metatheory (Doty & Glick, 1994). However, data analysis and the form of the findings should be aligned to the proposed review objective.

Based on the proposed objective of the literature review, stated in the introduction section (inquiring issues on using graphs as a mathematical concept and tool in local road traffic) this study fits into a typology proposed by Rowe (2014) as a study aimed at understanding a specific theme by using systematic approach for searching literature. For this study is adopted a light version of a systematic literature review (SLR) method (Okoli & Schabram, 2010), with the following constraints:

- Only Google Scholar is used as a database for searching literature, while repositories of leading academic publishers are excluded from the search (e.g. Wiley, ScienceDirec, Springer).
- This search includes only the first 50 publications listed at Google Scholar. Other literature sources listed in Google Scholar will be considered in the next detailed SLR study.
- The simplest set of keywords for searching literature sources is used. Additional keywords will enable constructing more complex search strings, resulting in the identification of many more studies.

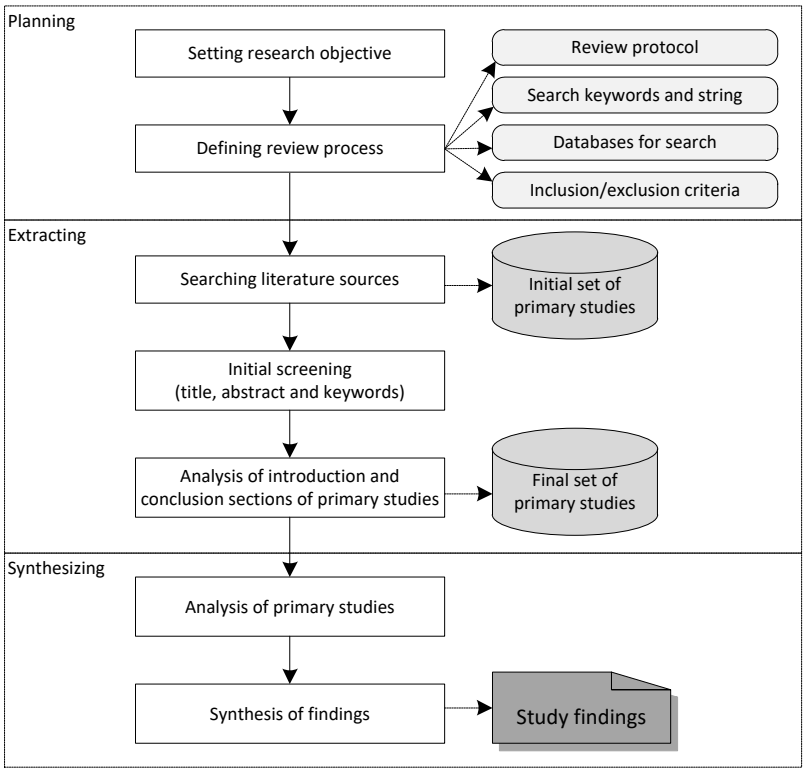


Figure 1. The approach to preliminary literature review used in this study

Due to the stated constraints, we call this approach preliminary literature review (PLR), and in discussion section we analyze the constraints of this study and propose potential improvements and further work. The presented PLR approach does not strictly follow the guidelines for conducting systematic literature review, and design of the study is presented in Figure 1.

2.1 Planning phase

Planning activities include proposing the research objectives and determining relevant parameters for conducting a literature review, such as a review protocol, a database to search, the keywords for searching, and the criteria for including or excluding identified studies.

The research objective of this literature review is to identify empirical studies related to using graph theory for analyzing different issues related to local roads, and to systematize findings of these studies.

The protocol for conducting the literature review includes the following steps: (1) identification of potential studies, (2) screening of studies based on the title, abstract and keywords, (3) additional analysis of the study introduction and conclusion sections in order to determine the final set of primary studies - detailed screening, (4) detailed analysis of the selected primary studies, and (5) synthesis of findings. The second and the third steps include judging about the studies based on proposed inclusion/exclusion criteria.

Google Scholar was selected for searching literature sources, because it provides access to studies published by a variety of publishers, including both journal articles and papers published at conferences' proceedings. The full text of listed studies was accessed either through Google Scholar or by accessing the authors' web pages and Research Gate Web portal.

The keywords used for the search were extracted from the proposed study objective: "graph", and "local road". However, in order to point out that review relates to graphs as a mathematical concept, an additional keyword was included - "mathematical model".

Inclusion/exclusion criteria ensure that only studies relevant for the proposed objective will be selected for the data analysis. For this review study these criteria are:

- The study is published in a journal or a conference proceeding with a recognized review process.
- The study deals with using graphs for analyzing different issues related to local roads.
- The study is published in English language.
- The study is published in the period from 2009 to 2019.

Planning activities are important for determining the research process that should be followed during the literature review.

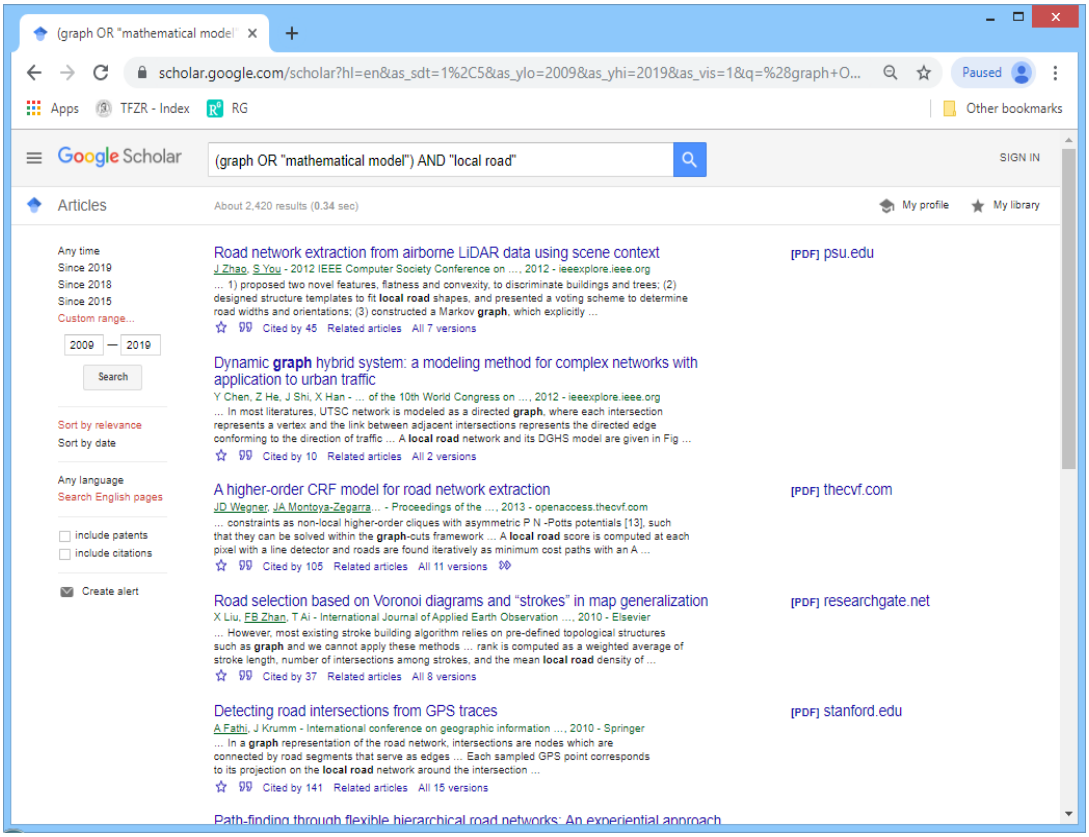
2.2 Extracting relevant studies

The literature search was conducted at Google Scholar, which is a freely accessible web search engine for academic literature, accompanied by bibliographic data. Google Scholar enables setting parameters for search, among which are the search keywords, the period and the relevance (see Figure 2).

The search string was constructed by using the selected keywords. The search string used for searching literature on Google Scholar is:

(graph OR "mathematical model") AND "local road"

Totally 2420 literature sources are detected by Google Scholar, which are sorted by relevance for the selected keywords. From this 2420 literature sources, the first 50 sources were selected for this preliminary literature review. The reason for including only the first 50 sources in analysis is that after the 20th article, most articles were excluded.



Slika 2. Searching relevant literature at Google Scholar

The analysis of the first 50 sources was conducted in two phases. The first phase is called "initial screening" and it includes judging about including or excluding the study based on the analysis of the title, abstract and keywords. During the initial screening 24 literature sources were excluded from the data analysis. The second phase includes screening the introduction section, conclusion section, and where it is necessary the whole text to check if the studies should be included or excluded. During detailed screening additional seven literature sources were excluded. After detailed screening 19 literature sources were included in the detailed analysis, and these sources are marked as "primary studies" and labeled as PS#, where # denotes the number of the included primary study (PS). The list of primary studies included in the literature review is presented in Table I.

Table 1. The list of primary studies included in the literature review

Study No.	**Study citation**
PS02	Chen, Y., He, Z., Shi, J., & Han, X. (2012, July). Dynamic graph hybrid system: a modeling method for complex networks with application to urban traffic. In Proceedings of the 10th World Congress on Intelligent Control and Automation (pp. 1864-1869). IEEE. DOI: 10.1109/WCICA.2012.6358180.
PS06	Li, Q., Zeng, Z., Zhang, T., Li, J., & Wu, Z. (2011). Path-finding through flexible hierarchical road networks: An experiential approach using taxi trajectory data. International Journal of Applied Earth Observation and Geoinformation, 13(1), 110-119.
PS07	Wang, X., Wu, X., Abdel-Aty, M., & Tremont, P. J. (2013). Investigation of road network features and safety performance. Accident Analysis & Prevention, 56, 22-31.
PS09	Szottka, I. (2013, October). Particle filtering for lane-level map-matching at road bifurcations. In 16th International IEEE Conference on Intelligent Transportation Systems (ITSC 2013) (pp. 154-159). IEEE.
PS10	Avila, M., Begot, S., Duculty, F., & Nguyen, T. S. (2014, October). 2D image based road pavement crack detection by calculating minimal paths and dynamic programming. In 2014 IEEE International Conference on Image Processing (ICIP) (pp. 783-787). IEEE.
PS12	Walker, R., Arima, E., Messina, J., Soares-Filho, B., Perz, S., Vergara, D., ... & Castro, W. (2013). Modeling spatial decisions with graph theory: logging roads and forest fragmentation in the Brazilian Amazon. Ecological Applications, 23(1), 239-254.

PS13	Pan, X., Wu, L., Hu, Z., & Huo, Z. (2014, September). Voronoi-based spatial cloaking algorithm over road network. In International Conference on Database and Expert Systems Applications (pp. 273-280). Springer, Cham.
PS14	Toplak, W., Koller, H., Dragaschnig, M., Bauer, D., & Asamer, J. (2010, September). Novel road classifications for large scale traffic networks. In 13th International IEEE Conference on Intelligent Transportation Systems (pp. 1264-1270). IEEE.
PS15	Lou, Y., Zhang, C., Zheng, Y., Xie, X., Wang, W., & Huang, Y. (2009, November). Map-matching for low-sampling-rate GPS trajectories. In Proceedings of the 17th ACM SIGSPATIAL international conference on advances in geographic information systems (pp. 352-361). ACM.
PS16	Bastani, F., He, S., Abbar, S., Alizadeh, M., Balakrishnan, H., Chawla, S., ... & DeWitt, D. (2018). Roadtracer: Automatic extraction of road networks from aerial images. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (pp. 4720-4728).
PS18	Wu, T., Xiang, L., & Gong, J. (2016). Updating road networks by local renewal from GPS trajectories. ISPRS International Journal of Geo-Information, 5(9), 163.
PS19	Qian, Y. S., Wang, M., Kang, H. X., Zeng, J. W., & Liu, Y. F. (2012). Study on the road network connectivity reliability of valley city based on complex network. Mathematical Problems in Engineering, 2012.
PS20	Zhu, Q., & Mordohai, P. (2009, September). A minimum cover approach for extracting the road network from airborne LIDAR data. In 2009 IEEE 12th International Conference on Computer Vision Workshops, ICCV Workshops (pp. 1582-1589). IEEE.
PS29	Eisenstat, D. (2011, January). Random road networks: the quadtree model. In 2011 Proceedings of the Eighth Workshop on Analytic Algorithmics and Combinatorics (ANALCO) (pp. 76-84). Society for Industrial and Applied Mathematics.
PS31	Zhu, C. J., Lam, K. Y., & Han, S. (2015). Approximate path searching for supporting shortest path queries on road networks. Information Sciences, 325, 409-428.
PS35	Han, X., Chen, Y., Shi, J., & He, Z. (2012, September). An extended cell transmission model based on digraph for urban traffic road network. In 2012 15th International IEEE Conference on Intelligent Transportation Systems (pp. 558-563). IEEE.
PS42	Demiryurek, U., Pan, B., Banaei-Kashani, F., & Shahabi, C. (2009, November). Towards modeling the traffic data on road networks. In Proceedings of the Second International Workshop on Computational Transportation Science (pp. 13-18). ACM.
PS46	Fortin, P., Morency, C., & Trépanier, M. (2016). Innovative GTFS Data Application for Transit Network Analysis Using a Graph-Oriented Method. Journal of Public Transportation, 19(4), 2.
PS49	Freiria, S., Tavares, A. O., & Pedro Julião, R. (2015). The multiscale importance of road segments in a network disruption scenario: A risk-based approach. Risk analysis, 35(3), 484-500.

After two-phase screening, totally 31 studies were excluded from the analysis. The main reasons for excluding the studies from further analysis is that they do not deal with local roads and/or do not use graphs. In many cases graphs relate to graphs of mathematical function used for modeling specific issues. The details about the reasons for exclusion of literature sources from the data analysis are presented in Table II.

Table II. Reasons for study exclusion from data analysis in two-phase screening process

	Graph	**Local road**
Initial screening	23	10
Detailed screening	6	2
Total in screening	29	12

Table II revealed that there are 41 reasons for exclusion, while 31 studies were excluded from the further analysis. In 10 cases the studies were excluded because they do not deal with graphs and local roads. In addition, the studies were mostly excluded during the initial screening.

2.3 Synthesizing literature review findings

The first classification of the primary studies relates to the use of graphs in them. Two types of studies can be distinguished: (1) the studies aimed at constructing graphs from other data sources (images, maps, etc.) , and (2) the studies that upgrade or enhance graphs as starting point for analyzing issues related to local road networks. The distribution of the primary studies regarding these two types of the graphs' use is presented in table III.

Table III. Distribution of primary studies according to the type of the graphs' use

Graphs' use	**Primary studies**
Constructing graphs	PS09, PS10, PS16, PS20
Upgrading and enhancing graphs	PS02, PS06, PS07, PS09, PS10, PS12, PS13, PS14, PS15, PS18, PS19, PS20, PS29, PS31, PS35, PS42, PS46, PS49

Based on data presented in Table III, majority of studies upgrade or enhance graphs for inquiring different issues related to local roads. Three studies (PS09, PS10 and PS20) presents approaches for constructing graphs from different sources and after that upgrade constructed graphs for analyzing issues related to local roads. Only primary study PS16 presents an approach for constructing graphs of local road networks.

The second classification of the primary studies relates to the aspects of local road networks inquired by graphs, which is presented in Table IV.

Table IV. Aspects of local road networks inquired by using graphs

Aspects of local roads	**Primary studies**
Signal control in urban traffic	PS02
Road hierarchy and path planning	PS06
Structural properties of road network	PS07, PS46
Map matching	PS09, PS15, PS18
Detecting road pavement cracks	PS10
Space decisions	PS12
Anonymization of a location	PS13
Link level time prediction	PS14
Road network extraction from data sources	PS16, PS20
Reliability of connectivity	PS19
Traffic flow	PS29, PS35, PS42
Supporting path search	PS31
Risk management	PS49

Totally 13 aspects of local road networks were identified in the primary studies. Four were inquired in more than one study, while nine aspects were inquired in only one study. Map matching and traffic flow are the most interesting issues because they are inquired in three studies.

3. DISCUSSION

This section outlines a discussion of the constraints and the benefits of the study, which is necessary for increasing the validity of the study and the findings (Yin2009).

3.1 Constraints

Despite obvious contribution related to systematization of knowledge in the field of using graphs for presenting and analyzing local road issues, presented literature review certainly has several constraints.

The first constraint relates to the selection of keywords, which should be improved by using more keywords and constructing more comprehensive search strings that will result in more precise identification of primary studies. With additional keywords, new aspects of graph use can be identified.

The second constraint relates to using only Google Scholar database for searching for studies. More comprehensive search and identification of a larger set of studies assumes use of databases of leading academic publishers such as ScienceDirect, Springer, Wiley, IEEE, etc.

The third constraint relates to the synthesis of findings, which is presented at the rudimentary level. A more detailed analysis of findings assumes identification of much more primary studies, which will be objective of a future systematic literature review.

3.2 Benefits

The benefits of the presented literature review are: (1) literature review process is presented in way that enables repeating this study or implementing the process in other literature review studies, and (2) identified knowledge is systematized and can be used as starting point for future research projects.

In addition, the authors gained experience and improved literature review skills, which can be used in future systematic literature reviews.

4. CONCLUSIONS

Presented study is the initial work of the authors in the field of using graphs for modeling and inquiring local road networks. Although the study suffers from the stated constraints, it is important because it presents a systematized state of the research, which is useful for profiling future research directions. The following research direction can be distinguished: (1) detailed systematic literature review on more specific graph use for local roads modeling and analysis, and (2) selection of the most attractive theme for empirical research based on the identified research trends in literature.

5. REFERENCES

Bagdasar, O. (2013) Elements of Graph Theory. In: Concise Computer Mathematics: Tutorials on Theory and Problems, 73-80. Springer Briefs in Computer Science. Springer Cham. doi: 10.1007/978-3-319-01751-8_9.

Cvetanović, A., & Banić, B. (2013) Local roads. Akademska misao. Beograd, Serbia. [in Serbian]

Doty, D., & Glick, W. (1994). Typologies as a Unique Form of Theory Building: Toward Improved Understanding and Modeling. The Academy of Management Review, 19(2), 230-251.

Ducruet, C. & Luqo, I. (2013). Structure and dynamics of transportation networks: models, methods and applications. In J. RodrigueT. Notteboom & J. Shaw The SAGE handbook of transport studies (pp. 347-364). London, UK: SAGE Publications. doi: 10.4135/9781446247655.n20.

Dueñas, D.E.M. (2018) Effects of road-network circuity on strategic decisions in urban logistics. Ph. D. Thesis. Massachusetts Institute of Technology, School of Engineering. Cambridge, MA, USA.

Marshall, S. (2016) Line structure representation for road network analysis. Journal of Transport and Land Use, 9(1), 29-64. doi: 10.5198/jtlu.2015.744.

Rowe, F. (2014) What literature review is not: diversity, boundaries and recommendations. European Journal of Information Systems, 23(3), 241–255. doi:10.1057/ejis.2014.7.

Okoli, C., & Schabram, K. (2010) A Guide to Conducting a Systematic Literature Review of Information Systems Research. Sprouts: Working Papers on Information Systems, 10(26). http://sprouts.aisnet.org/10-26.

Torraco, R.J. (2005) Writing Integrative Literature Reviews: Guidelines and Examples. Human Resource Development Review, 4(3), 356-367. doi: 10.1177/1534484305278283.

Yin, R. K. (2009). Case study research: Design and methods (4th ed.). Thousand Oaks, CA: Sage