



## Research Article

# A comprehensive systematic literature review on traffic flow prediction (TFP)

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## ABSTRACT

Nowadays, traffic congestion is becoming a severe problem for almost every urban area. It badly hampers the economic growth of a country because it has negative effects on productivity and business. Increasing populations and urbanization are the main reasons for traffic congestion in most cities. However, traffic prediction, forecasting, and modeling can help provide appropriate routes and times for traveling and can significantly impact traffic jam reduction. Currently, there is a lot of research being done on traffic flow analysis in all developed countries, and they are planning their future accordingly. The objective of this review paper is to provide a comprehensive and systematic review of the traffic prediction literature, containing 98 papers published from 2010 to 2020. The papers are extracted from four well-known publishers and databases: Scopus, ScienceDirect, IEEE Xplore, and ACM. This article concentrates on the research approaches, directions, and gaps in traffic flow prediction. It also talks about current trends in predicting traffic flow and what might be taken into account in the future.

**Keywords:** SLR; Traffic Flow Prediction; Traffic Congestion; Deep Learning.

## 1. INTRODUCTION

The impact of the transportation system is very important for both people's daily lives and the socioeconomic development of a country (Droj et al., 2021). Nowadays, because of the increasing population and urbanization, the transportation system is badly affected by traffic congestion and jams. The cost of traffic congestion in urban areas is increasing day by day all over the world. The world's worst traffic jam occurs in Jakarta, Indonesia, and the lowest traffic jam is in Tampere, Finland (David, no date).

Traffic Congestion costs 5 million working hours every day and costs an annual loss of 200 550 billion takas in Dhaka city (Traffic jam: The ugly side of Dhaka's development | The Daily Star). Economic loss is very significant in Southeast Asia. This region loses approximately two to five percent of gross domestic product (GDP) due to high traffic (Going the extra kilometer: moving Southeast Asia's cities forward, no date). However, 50 to 70 percent of the losses can be reduced by taking proper actions. Reducing traffic congestion only in the Dhaka city capital of Bangladesh will benefit from the massive economic growth of 35% of the country's GDP (Chakraborty, 2016). Serious traffic congestion can slow down a country's economy, decrease foreign investment, hamper the supply-demand chain and also increase people's mental pressure. As a result, timely and accurate traffic flow prediction is

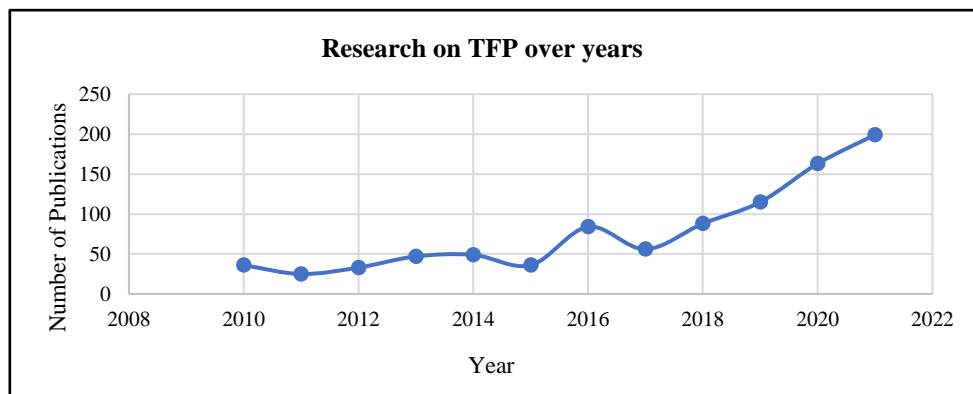


greatly helpful for city dwellers. With the proper traffic flow prediction, travelers can make better travel plans which reduce traffic congestion, fuel consumption, and carbon emissions.

TFP can be regarded as a time series problem where the next traffic flow is estimated based on historical data using various prediction/estimation models and/or statistical models. Various traditional parametric models such as ARIMA and different versions of ARIMA are used to predict traffic flow. But because of the non-linear and stochastic nature of traffic flow, these models are unable to provide an accurate prediction. Therefore, non-parametric models (k-NN, ANN, SVR, etc.) are more suitable for traffic flow prediction (Liu et al., 2017; Yi et al., 2017; Tian et al., 2018; Luo et al., 2019; Mackenzie et al., 2019; Yang et al., 2019). Although these models provide a better performance, they failed to handle a huge amount of traffic data on time. To solve this problem, deep learning architecture such as CNN, RNN, and LSTM is used in TFP to provide better prediction which uses multiple layers to extract more features. Moreover, the combinations of parametric and deep learning are also used in traffic prediction research.

Currently, TFP attracts researchers' attention because of its impact on people's lives and the solution to this problem involves many emerging domains.

As a result, the number of publications in this field is increasing day by day as shown in Fig. 1. Research on TFP has grown significantly since 2010. Since then, the number of research papers published every year has been increasing. This suggests that researchers from around the world have come to appreciate the importance of traffic prediction. In addition, the solution of TFP includes many emerging domains such as Intelligent transport systems, big data, the Internet of things, Advance machine learning, etc.



**Fig. 1.** Publications of TFP over the years (2010 to 2021).

Systematic literature review (SLR) is a tool for summarizing the already published research work and also helps to find the research gap (Linde and Willich, 2003). It follows a specific protocol and search strategy to add or remove research work from the list (Introduction - Systematic style literature reviews for education and social sciences - Library guides at Griffith University). SLR aims to build a knowledge base on a specific topic. The knowledge base will help to find research direction, assist with research gap analysis, and give a strong platform to direct original research to address any gaps and support the hypothesis (Szvetits and Zdun, 2016).

It focuses on the literature on TFP. This study concentrates on the methodology, approaches, keywords, and related research domains used for predicting traffic flow. From this analysis widely used approaches, research gaps, and research direction can be identified.

The rest of the paper is organized as follows. Section 2, Methodology describes our search strategy and the criteria for adding or removing research publications to our list. Section 3 presents the Result and Interpretation of our studies. After extensive review and experiments, we find some research questions that are described in section 4. Section 5 describes our experiment's outcome and section 6 briefly concludes our studies.

## 2. METHODOLOGY

As mentioned before, this SLR mainly focuses on already published literature on TFP. Our main objective of this study is given below.

1. Propose an easy way of searching and selecting research papers from different databases on TFP.
2. Find out the top most cited publications, publishers, organizations, countries, and relevant topics of TFP.
3. Identify the most used method in TFP and also find the reason.
4. Identify the research gap in TFP.

Maintaining the procedure, principle, and evaluation of SLR the study was introduced with the improvement of an extensive review protocol. (Borrego et al., 2014). This includes background studies, search strategy, data collection, finding research questions, and quality assessment criteria for the selection of the study and data analysis.

We have to follow a process so that there is no irrelevant paper on the list and only add the publication which is related to this topic. We have included papers from journals, conferences, workshops and symposiums. For this SLR we considered papers which are published from 2014 to 2022. We use Publish or Perish, Mendeley, Vosviewer, Ms excel software for searching, finding duplicates, prepare different types of diagrams. We use Publish or Perish for searching, our primary search finds total 1000 papers of different types of publication. We exclude papers from our list based on publication citation score and publication type. Knowledge development is a very important issue when starting research on any new topic. In this case, it is important to read some of the Benchmark papers. We have given more priority in our list to those papers which have higher citation score.

After the selection based on citation, we are now read the title and abstract of the papers. First of all, we read the title and find some irrelevant papers that are network traffic congestion-related papers so we exclude those papers. Then we read the abstract and try to understand the main objectives of the research work. We have removed from our list all the papers which we have not been able to understand the original objective by reading the abstraction of. Then we read the abstract and try to understand the main objectives of the research work. We consider only those paper that is written in English. We find some papers whose title is written in English but the rest of the papers are written in other

languages. We exclude those papers. Also, articles were turned down if they were duplicates, didn't have a full-text version, or were not related to any of our study topics. We also use manual search, where we use forward and backward referencing to gain previous and subsequent knowledge. There is some limitation to finding the full text of a research paper. Some need licenses or subscription and some paper's full text are not available. So we exclude those papers that have this kind of problem. We use Publish or Perish software for automatic search. This software allows search from different database. We search scopus, IEEE Xplore, ACM database and found 1000 search result. This search result consists of journal, conference, workshop, symposium published research paper. First of all, we find the publishers citation rate per year, paper citation and impact factor and make a condition for paper selection. If the publication citation is above 10 and publisher impact factor is above 2.0 then we add the paper to our list and exclude rest of them. We have received 565 papers which satisfy the conditions of our election. Now in the most exhausted work is read the title manually and find irrelevant papers and exclude them. We found some paper that are mainly on network traffic congestion related. After analyzing title and remove some irrelevant papers we read the abstract and try to find the main objectives of the research. Some paper gives very clear idea about their work in the abstract. We add them to the list. We exclude 386 papers after manually reading the title and abstract. We search the full text of our selected papers. We do not find the full text of some papers. There are some papers that have limited access, for this kind of paper is removed from our list. Finally, we find 104 papers and remove those papers from our list.

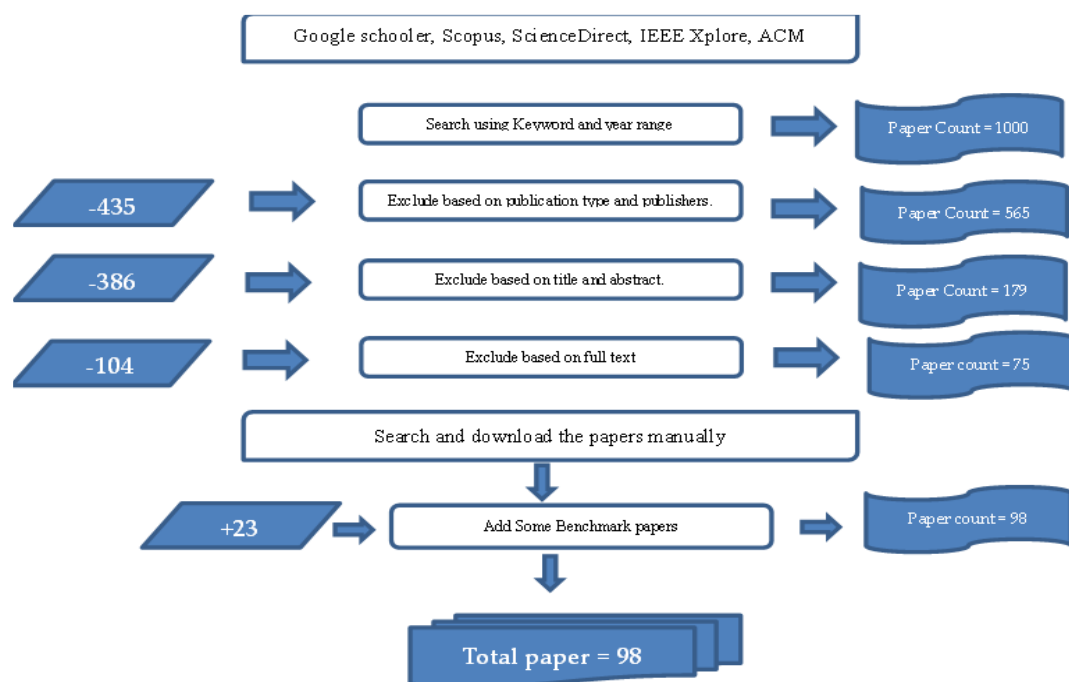


Fig. 2. Complete overview of studies selection procedure for SLR.

Now we manually search in google scholar and find some benchmark papers whose citation is above 200 and those are very related to TFP. We add those papers to our list and finally, after an exhaustive search and selection procedure, we find 98 papers that are highly

related to TFP and those papers will help the researcher to gather knowledge about this topic. In Fig. 2 we give a complete overview of the study's selection process.

### 3. RESULTS AND INTERPRETATION

In this section, we will show our bibliometric analysis outcomes on TFP. Based on the data obtained, descriptive analysis was done by publication type, distribution of publishers, find benchmark papers that have more than 100 citations, research collaboration among different countries, author keyword analysis, prediction model used in TFP, and we also find the top 10 most journals for TFP and top 10 most productive institution for TFP in the world.

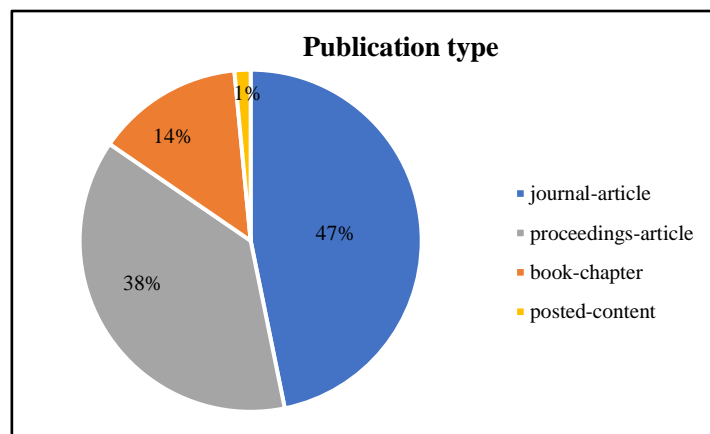


Fig. 3. Pie chart of publication type

In Fig. 3 we can see the publication type statistics. Here we find that almost half of the publications published as journal articles from the number of total publications on TFP. We already know that publication on TFP is increasing over the years. And the rate of journal publication is also increasing.

In Fig. 4 we represent the distribution of databases of TFP. The weight of the IEEE database is higher than all other sources. Elsevier and springer databases are growing at a very high rate on TFP.

In table 1 we find the top ten journals for TFP. Those journals have high impact factors and citation rates. Those journals play an important role for develop the research trend on TFP. Those journals are also very well-known journals on TFP.

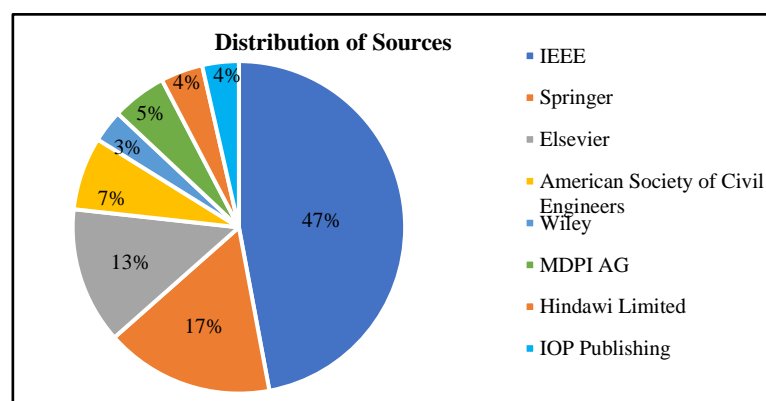


Fig. 4. Pie chart of Distribution of databases of TFP.

**Table 1.** The top 10 most Journal for TFP.

| Rank | Sources  | Citation | No. of Documents |
|------|--|----------|------------------|
| 1    | Transportation research part c: emerging technologies                    | 130      | 54               |
| 2    | Physica a: statistical mechanics and its applications                    | 92       | 48               |
| 3    | Transportation research part b: methodological                           | 50       | 25               |
| 4    | Journal of transportation engineering part a: systems                    | 20       | 22               |
| 5    | IEEE transactions on intelligent transportation systems                  | 224      | 53               |
| 6    | Sustainability (switzerland)   | 34       | 45               |
| 7    | Accident analysis and prevention   | 72       | 22               |
| 8    | Applied sciences (switzerland)   | 42       | 30               |
| 9    | Journal of physics: conference series                                    | 6        | 35               |
| 10   | Journal of transportation systems engineering and information technology | 9        | 28               |

In table 2 we give a list of some benchmark papers on TFP. Those papers have more than 100 citations. One paper has 2543 citations which is the maximum among all papers. This paper title is "Traffic Flow Prediction with Big Data: A Deep Learning Approach". This list will help the new researchers to develop their knowledge of TFP.

The top 10 countries that published the most publications on TFP are given in Fig. 5. Only China published 4 times more publications than any other country on TFP. We also see that only three countries from Asia are in the top ten list. Recently Indian researchers grow their interest in TFP and do research on this topic. We also see the countries' collaborative work on TFP in Fig. 6. In the Fig. 6 node size represents the number of collaborative research publications. China, the United States, the United Kingdom, India, and Australia are the topmost countries in collaborative research on TFP. We observe that only developed countries and large economic countries are doing research on TFP.

**Table 2.** Research publication which have more than 100 citations.

| No. | Title of the papers  | Citations | Year | Ref                     |
|-----|--|-----------|------|-------------------------|
| 1   | Traffic Flow Prediction with Big Data: A Deep Learning Approach.   | 2543      | 2015 | (Lv et al., 2015)       |
| 2   | A hybrid deep learning-based traffic flow prediction method and its understanding.                       | 432       | 2018 | (Wu et al., 2018)       |
| 3   | Deep learning for short-term traffic flow prediction.  | 733       | 2017 | (Polson et al., 2017)   |
| 4   | Using LSTM and GRU neural network methods for traffic flow prediction.                                   | 782       | 2016 | (L et al., n.d.)        |
| 5   | Traffic flow prediction for road transportation networks with limited traffic data.                      | 310       | 2015 | (Abadi et al., 2015)    |
| 6   | Short Term Traffic Flow Prediction for a Non-Urban Highway Using Artificial Neural Network.              | 234       | 2013 | (K. Kumar et al., 2013) |
| 7   | Traffic Flow Prediction using Kalman Filtering Technique.  | 110       | 2017 | (S. V. Kumar, 2017)     |
| 8   | Short-term traffic flow prediction with Conv-LSTM.   | 174       | 2017 | (Yipeng et al., 2017)   |
| 9   | Short-time traffic flow prediction with ARIMA-GARCH model.   | 150       | 2011 | (Chen et al., 2011)     |
| 10  | Privacy-Preserving Traffic Flow Prediction: A Federated Learning Approach.                               | 152       | 2020 | (Yi Liu et al., 2020)   |
| 11  | An effective spatial-temporal attention based neural network for traffic flow prediction                 | 110       | 2019 | (Do et al., 2019)       |
| 12  | Traffic flow prediction using LSTM with feature enhancement  | 180       | 2019 | (Yang et al., 2019)     |
| 13  | Research on Traffic Flow Prediction in the Big Data Environment Based on the Improved RBF Neural Network | 169       | 2017 | (Cao, 2017)             |

| No. | Title of the papers   | Citations | Year | Ref                       |
|-----|---|-----------|------|---------------------------|
| 14  | Spatiotemporal traffic flow prediction with KNN and LSTM  | 132       | 2019 | (Luo et al., 2019)        |
| 15  | An evaluation of HTM and LSTM for short-term arterial traffic flow prediction                           | 101       | 2018 | (Mackenzie et al., 2019)  |
| 16  | Deep architecture for traffic flow prediction: Deep belief networks with multitask learning             | 922       | 2014 | (Huang et al., 2014)      |
| 17  | Improving Traffic Flow Prediction with Weather Information in Connected Cars: A Deep Learning Approach. | 280       | 2016 | (Koesdwiady et al., 2016) |

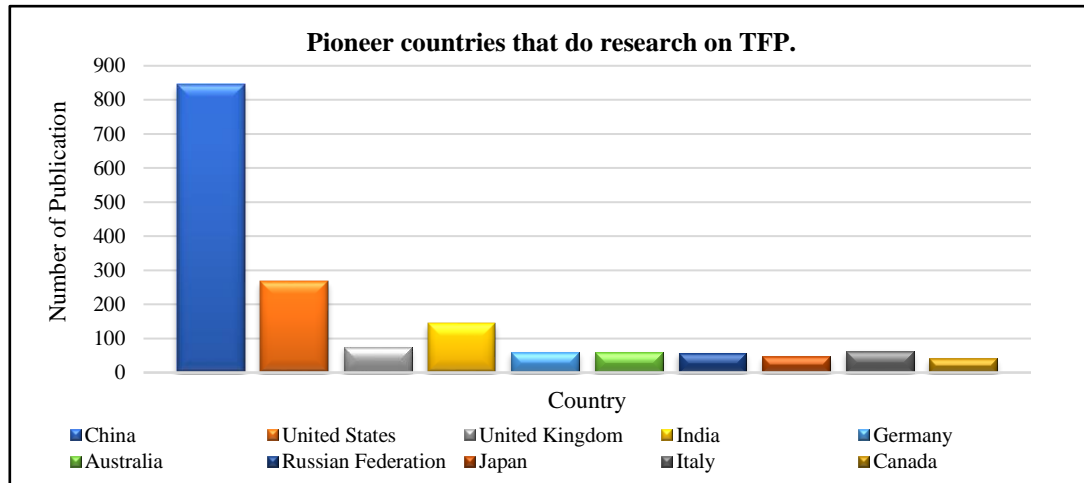


Fig. 5. Top ten pioneer countries that do research on TFP.

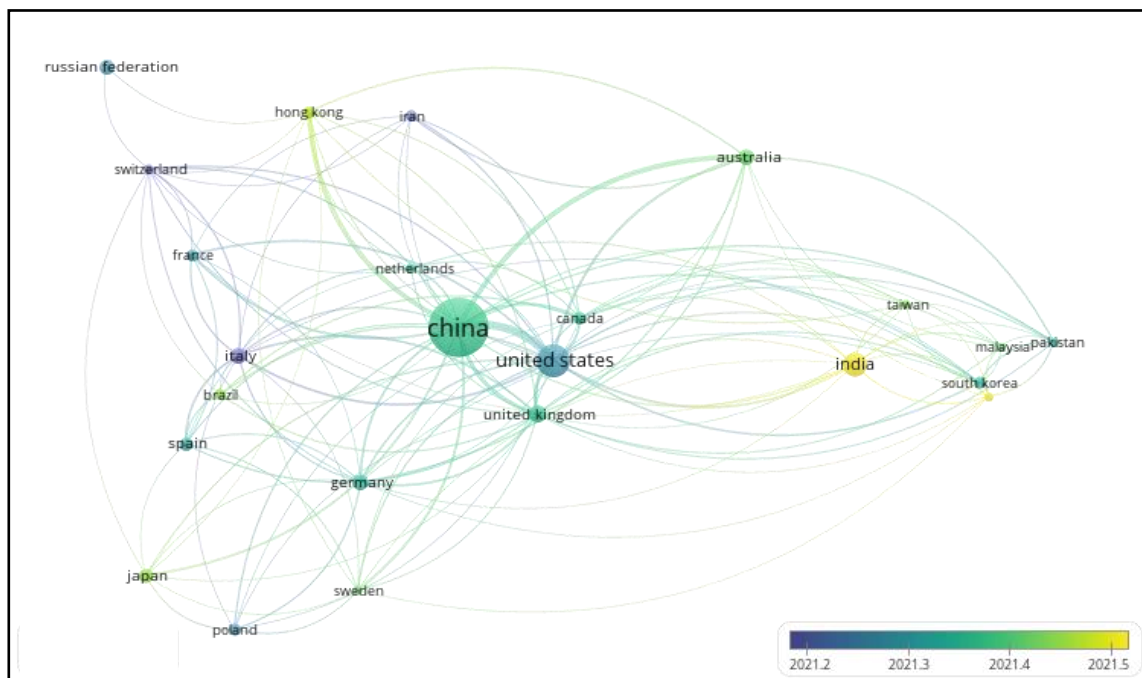


Fig. 6. Research collaboration among different countries.

Developing and underdeveloped countries are lagging behind in this area. But the traffic problem is the biggest problem in developing countries. In developing countries, there is no infrastructure to capture traffic data and other facilities are absent. Developed countries spend more on traffic flow research. For this reason, they nearly solved the traffic problem.



Through author keyword analysis, we can know the other relevant field that is closely related to TFP. In Fig. 7, we can see that ITS, big data analysis, the Internet of things, traffic engineering, and vehicle dynamics are very closely related to TFP. From this, we also know that machine learning, deep learning, clustering, and artificial intelligence techniques are widely used in predicting and analyzing traffic flow.

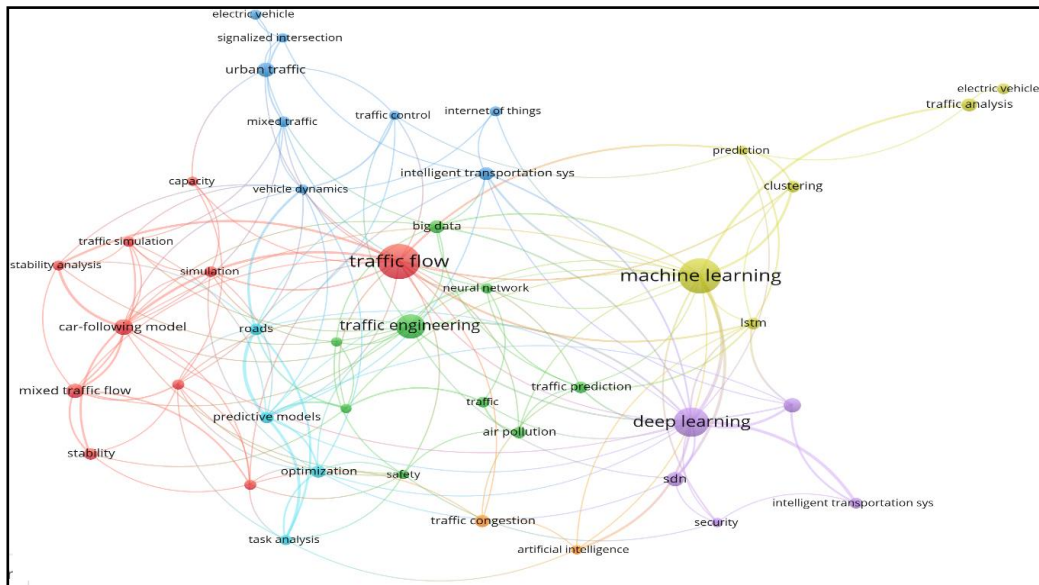


Fig. 7. Author keyword analysis.

Fig. 8 shows the method or model used in TFP. We noticed that 51% of our selected publications used neural networks to predict traffic flow. Because NN is very popular and this method has been widely used since 2010 or earlier. Fig. 8 shows the method or model used in TFP. We noticed that 51% of our selected publications used neural networks to predict traffic flow. Because NN is very popular and this method has been widely used since 2010 or earlier.

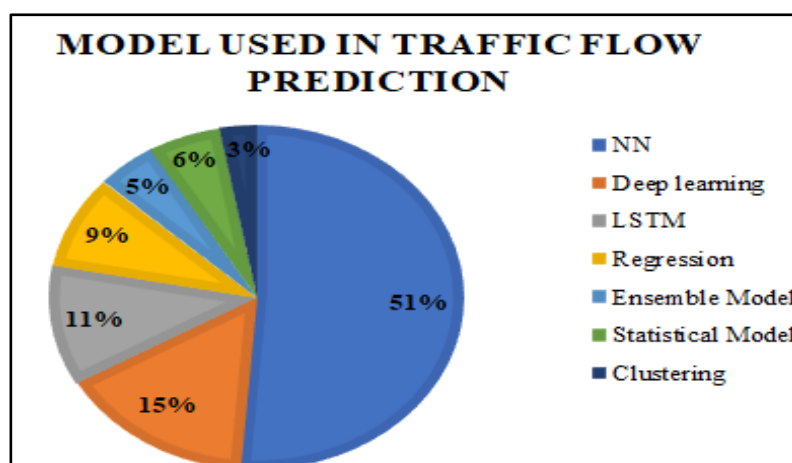


Fig. 8. Pie chart of model used in TFP.

Recently LSTM and ensemble method are used in short term and long-term prediction respectively. LSTM can run on very low data and provide satisfactory accuracy. It is very efficient that's the main reason we believe.



In table 3 we also list the top ten organizations that do research on TFP. We observe that all ten institutions are Chinese. In all aspects, Chinese researchers and institutions are more focused on research than other countries.

**Table 3.** The top 10 most productive institutions

| Rank | Institution  | Citation | No. of publication |
|------|--|----------|--------------------|
| 1    | Faculty of Maritime and transportation, Ningbo University  | 19       | 17                 |
| 2    | Jiangsu Province collaborative innovation center for modern urban traffic technology   | 15       | 6                  |
| 3    | School of transportation science and engineering, Beihang university   | 13       | 5                  |
| 4    | Business school, University of shanghai for science and technology, Shanghai   | 21       | 5                  |
| 5    | School of traffic and transportation, Beijing jiaotong university  | 13       | 11                 |
| 6    | School of traffic and transportation, Beijing jiaotong university  | 70       | 5                  |
| 7    | Beijing Key laboratory of traffic Engineering, Beijing university of technology  | 10       | 5                  |
| 8    | University of chinese academy of sciences, Beijing   | 12       | 5                  |
| 9    | School of highway, Chang'an university   | 5        | 5                  |
| 10   | Key laboratory of transport industry of big data application technologies for comprehensive transport, Beijing jiaotong university | 3        | 5                  |

## 4. RESEARCH QUESTIONS

The Research question plays a vital role in selecting the research goal. It also influences the search keyword selection or search query in SLR that will be used to explore research publications. We've chosen some research questions that help experienced researchers and new researchers who enter the domain of TFP to understand where research in this field stands today.

### 4.1. HOW TO DEAL WITH NOISY AND MISSING DATA ?

In TFP there is a need for spatiotemporal data. This data can collect from different sensors. This data can be missing or noisy due to sensor failure, communication error, storage loss, and environmental situations (Zhang et al., 2021). This problem has existed since the beginning of TFP research. Already many researchers looking forward to solving this problem. Some solutions already exist. But there is no solution that can solve the problem efficiently and work in every situation. Missing data can hamper the live traffic prediction on a short-term basis. Today Intelligent traffic systems have one challenge that is missing and noisy data (Chan et al., 2021; Tang et al., 2021).

### 4.2. WHICH METHOD ARE APPROPRIATE FOR TFP IN SHORT TERM AND LONG TERM BASIS?

Different model is used to predict the traffic flow. In Fig. 8 we also see this. Neural networks, machine learning approaches, statistical methods, and ensemble methods are already used in TFP. But there is no absolute model for all circumstances. Model's performances can vary in terms of short-term and long-term predictions. Performances can also vary for the others parameter related to traffic congestion. Population density, flexible working hours, poor infrastructure, alternate routes, and the number of public transport are the

main reason for traffic congestion (Thakur, 2016). when we select an area for TFP that area has different parameters so which model is appropriate we have to find out.

#### **4.3. HOW DO FEATURE REDUCTION TECHNIQUES AFFECT PREDICTION ACCURACY?**

Today's world wants perfection and efficiency. Lower features improve the efficiency but there is a risk of decreasing accuracy. Sometimes short-term TFP needs to reduce some features. Also, some methods only work with limited features. But which feature reduction method is appropriate for TFP is needed to find out. We think this is a new research domain in the future.

#### **4.4. HOW CAN WE COLLECT DATA FOR DEVELOPING COUNTRIES AT A LOW COST?**

For accurate and timely traffic prediction, we need historical and real-time traffic data. These data can be collected from sensors, loop detectors, cameras, speed cams, mobile GPS crowdsourcing, etc. There are some limitations in developing countries specially in TFP. In particular, there is no infrastructure through which spatiotemporal data can be collected and vehicles can be monitored on every road or in every cross section. Developing countries need a process or way to collect traffic data at a low cost. Some researchers try to collect data from different maps available in their country and then apply the TFP model(Hossain et al., 2022 ).

### **5. DISCUSSION**

TFP has gained more attention after the introduction of ITS (Paul et al., 2016). Accurate and timely information about traffic is needed to improve the transportation system. TFP experienced substantial growth in the publication science 2010 and it's still growing. This type of research will help the individual travelers, government and non-government services organizations, reduce carbon emissions, minimize fuel consumption, and also planners plan for the future. From the experiment, we find some exciting and interesting knowledge about TFP. Our findings reveal that China has done more research on this topic and is still continuing the process. China (846), the United States(266), and India (144) are the top three countries that are doing research on TFP. Transportation research part c: emerging technologies is the top most journal on TFP. This study also introduces top-cited publications. Using co-authorship analysis we also find the top collaborative countries on TFP. China, the United States, the united kingdom, and Germany are the most collaborative countries on TFP. Using author keyword analysis we also find the hot topics or areas related to TFP. ITS, sustainability, traffic engineering, vehicle dynamics, optimization, traffic control, and simulation are the most relevant topic to TFP. We find the most used model in TFP. We also find that above 50% of publications use NN for their prediction. NN is a very popular model and used since 2010 or earlier. But it has also some limitations, it needs quite a lot of historical data, and it is very time-consuming also. Most recent publications used LSTM for short-term prediction. The ensemble method also draws attention to the researcher for TFP. We also suggested some areas for further research direction.

## 6. CONCLUSION AND FUTURE WORK

TFP is very important in today's world. Developed countries are already doing very good research on TFP, but developing countries are lagging behind. For economic progress, every country that suffers from traffic congestion needs to focus on research. We search the databases using the "traffic flow prediction" keyword. This study aimed to present a general overview of the publication trend over a specific time period. Instead of just giving a general overview and figuring out what the emerging themes and hot topics are in TFP, future studies could look at a certain method and type.

### Author Contributions:

"Conceptualization, Md. Mahbubul Alam Joarder; Methodology, Md. Moshir Rahman.; software, Md. Moshir Rahman; validation, Md. Moshir Rahman, Md. Mahbubul Alam Joarder and Naushin Nower; formal analysis, Md. Moshir Rahman; investigation, Naushin Nower; resources, Md. Moshir Rahman; data curation, Md. Moshir Rahman.; writing—original draft preparation, Md. Moshir Rahman; writing—review and editing, Naushin Nower; visualization, Md. Moshir Rahman; supervision, Naushin Nower; project administration, Md. Mahbubul Alam Joarder; All authors have read and agreed to the published version of the manuscript.

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### Conflicts of Interest:

The authors declare no conflict of interest.

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