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Research Paper

Assessing the Impact of Internet of Things (IoT) on Urban Multi-Modal Mobility for Optimal Routing: A Meta-Review

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Abstract

Intelligent transportation system is an effort to reduce traffic, travel time, thereby reducing environmental pollution. One of the solutions to reduce transportation pollution is to make the transportation system smart for users to find the optimal route, because multi-modal transportation plays an important role in passenger movement. It also manages transportation and reduces travel demand. Intelligent transportation systems have made it possible for different sectors to interact with each other. This paper aims to identify contributions of IoT factors in multi-modal mobility to find the optimal path using an umbrella review method. To achieve this, a set of studies focusing on the Internet of Things in multi-modal mobility in different fields were investigated. The sample includes 14 qualitative and 14 quantitative papers. For qualitative papers, conceptual codes were extracted. Then the significance coefficient of each variable was measured using Shannon entropy coefficient. For quantitative papers, after extracting codes and conducting inferential analysis of data using funnel plot, Egger's linear regression, publication bias and heterogeneity Q test, the effect of each of the independent variables along with the dependent variable was measured. Findings reveal that in qualitative papers, "geographical information and timetable for mobility modes" are ranked first and "the amount of electronic facilities and equipment" and "reducing route length and distance" are ranked second. In quantitative papers, the "time to reach destination", "time and volume of traffic", "number of public and private transportation stations", and "reduction in route length and distance" appeared to have a great effect on mobility.

Keywords: Internet of Things, Multi-modal mobility, optimal routing, Umbrella Review, Meta-review

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1. Introduction

One of the important goals of smart transportation is to find the optimal route for passenger transportation. In fact, the purpose of routing in urban mobility is planning an optimal route that requires an intelligent transportation system (Liu, 2019) Smart mobility system attempts to integrate information and technology with users, transportation infrastructure and vehicles, and the purpose of this integration is to increase safety and security, and reduce accidents, mobility time and fuel consumption. Generally, the smart mobility system is divided into six categories: Advanced Travelers Information Systems, Advanced Traffic Management Systems, ITS-Enabled Transportation Pricing Systems, Advanced Public Transportation Systems, Vehicle-to-Infrastructure Integration, and Vehicle to-Vehicle Integration (Atzori, Iera and Morabito, 2010). As an important element of the smart mobility system, advanced passenger information systems provide passengers with information about transportation (Hull, 2005). Because of dynamic and rapidly changing situations, real-time mobility options are also offered through a dynamic transportation network element (Borgia, 2014).

In many developed countries, facilities, equipment, and infrastructure facilitate private and public transportation sectors role in reducing urban problems such as air pollution (De Souza, 2005). Thus, the multi-modal mobility is increasingly considered in urban planning and development. In developing countries, pollution from transportation sector is as important and significant as industrial pollution. Allocation of considerable urban lands to transportation in cities and high volume of vehicles, have increased fuel consumption and air pollution (Gubbi et al., 2013). Use of modern technologies such as the Internet of Things (IoT) in transportation sector can help with reducing travel time and distance in intra-city movements can contribute to greenhouse gas and particulate matters (Lee, Hancock and Hu, 2014).

Therefore, the present paper aims to identify the IoT factors in multi-modal transportation using an umbrella review method. In doing so, a set of studies was investigated on the subject of the IoT in multi-modal mobility transportation from different fields. In this study, we have attempted to answer the following key questions:

1. What are the key variables studied in the role of the IoT in multi-modal mobility for optimal routing?
2. What are the significace and importance of the key factors affecting the role of the Internet of Things in multi-modal mobility for optimal routing?

2. Theoretical Framework

The term IoT was first used by Kevin Ashton (1999). He envisioned a world in which the physical world was connected to the Internet through real-time sensors and a real-time feedback framework (Sicari et al., 2015)(Collier, 2017). This concept was further developed. According to later (Palavalli, Karri and Pasupuleti, 2016) “The Internet of Things is a smart infrastructure that connects objects, information and individuals through computer networks” (Chooruang and Meekul, 2018). In 2005, the International Telecommunication Union published its first official report on the term IoT and thus a new dimension was added to the world of information and communication technology (Xu and Mcardle, 2018).With the Internet connection everywhere and anytime for everyone, we will now have a connection for everything. The connections will increase and a whole new network of networks will be built - the Internet of Things (Borgia, 2014). Today, every device connected to the Internet is smart and capable enough to perform its tasks independently, without human interventions.

The complexity range of such devices consists of simple interconnected tags that are managed by another smart device (Chooruang and Meekul, 2018). In this way, information about physical processes are collected, transmitted, and processed through sensors and finally used in the digital world (Borgia, 2014).

Connecting different devices to the Internet has increased a large number of new features and applications, especially in the transportation system because the IoT has provided new scenarios of multimodal mobility through sensors that are able to provide reliable information to the mentioned systems (Sundmaeker et al., 2010) Transportation In order to monitor and communicate between different means of transportation, eliminate real-time transportation network interruptions, reliability levels, costs and geographical access are increasingly associated with multiple urban movements (Muthuramalingam et al., 2019).

The layer model of The Schoemaker, Koolstra, & Bovy in 1999 provides a framework for analyzing the urban transportation system.

This model consists of three layers: activities, transportation services and traffic services. (Fig. 1). Multi-modal mobility is related to the transportation services layer (Daisa, 2004) Transportation services determine the overall quality of mobility that is affected by the vehicle, the network, and all features of the service (Dlodlo and Kalezhi, 2015).

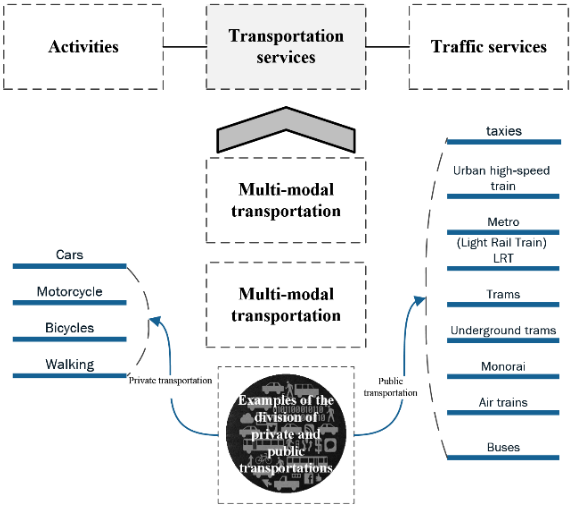

Figure 1. Multilayer model in transportation (source: Adopted from: Van Nes, 2002)

Multi-modal mobility connect different modes of mobility, both public and private, such as walking, cycling, personal transportation, public transportation and etc. (Anand et al., 2015)(Fig. 2). A multi-modal urban transportation system can be represented as a graph in which nodes are stations that can be changed from one mode of transportation to another. The basic elements are nodes, macro nodes, and links. A node is a station for a single transport mode and can only be part of a macro node (Chand Varun and Karthikeyan, 2018). The macro node is an in-network station i.e. a place where individuals can enter or leave the network and / or change the mode of mobility. Thus, a macro node consists of one or more nodes. The link is a one-way route that connects two macro nodes and is assigned to a mode of mobility (Schipper, Fabian and Leath, 2009).

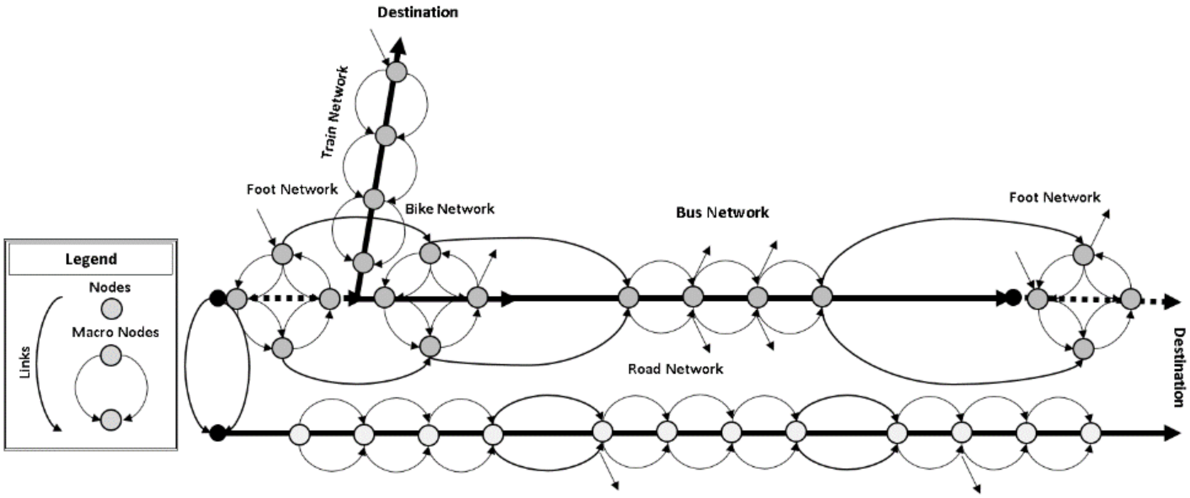

Figure 2. An example of a multi-modal mobility network (source: Adopted from: Zhang, Liao and Harry Timmermans, 2011)

In other words, multi-modal mobility networks are characterized by a combination of dynamic change of conditions and different mobility methods (Lie et al., 2012). For example, the optimal route between two nodes before the peak hours of traffic may include driving to the nearest parking lot to the destination and then walking to the final destination. However, at peak hours of traffic, the shortest route may be to drive to a terminal and continue by bus to the nearest station to the destination and from there walking to the final destination (Mishra, Welch and Jha, 2019).

One of the important parameters for optimal routing is traffic. Heavy traffic causes delays and slows down intra-city movements (Hamrioui et al., 2018). The phenomenon of increasing the amount of traffic reduces the speed of passengers to reach the destination, increases travel time, unnecessary trips and emissions of greenhouse gases, etc. (Blum and Roli, 2003). In online and smart routing, traffic information is provided to the decision-making system immediately.

Then, as the vehicles move along the route, the traffic changes are re-transmitted to the server online, and the routing algorithm in the system sends the required response based on the changes and requests. As a result, passengers get instant information from the transportation and traffic system and choose the shortest and most optimal route according to the current traffic situation. (Ahuja et al., 2002; Chabini and Lan, 2002).

According to Watling & Vuren 1993, the optimal routing system is a tool to improve the efficiency of the urban network and reduce congestion, delays and accidents. (Deflorio, 2003; Hamad and Faghri, 2011).

Yamashita, Izumi, and Kurumatani, 2004 state that in order to monitor and control the urban traffic network, traffic information and influential variables are needed. For this purpose, different sensors are installed at the level of streets and highways to variables such as vehicle density, average speed (average speed of all vehicles passing a certain point in the route and a certain time distance) and average spatial speed (average speed of all vehicles in A certain part of the route, at a certain time interval) are calculated. (Yamashita, Izumi, and Kurumatani, 2004; Zhan, and Noon, 1998).

This is while Liang, 2014 consider optimal routing to depend on the knowledge of parameters such as time interval (time interval between consecutive vehicles passing through a certain point) and spatial distance (distance between the front of one car and the front of the next car) (Manikonda, 2001).

According to Isa, Mohamed, and Yusoff, 2015, there are uncontrolled variables such as accidents, weather conditions, etc. that affect traffic, in their view, these factors should be considered by the central controller (Isa, Mohamed and Yusoff, 2015). The traffic network in different urban areas includes streets, intersections, highways, and in these areas, traffic flow is managed using traffic signs and traffic control equipment, which includes traffic lights, traffic restrictions, speed limits, offering and suggesting alternative routes, estimating the time to reach the destination (Wiering, 2000). If passenger mobility is optimized, it will save fuel consumption and reduce pollution (Chapman, 2007).

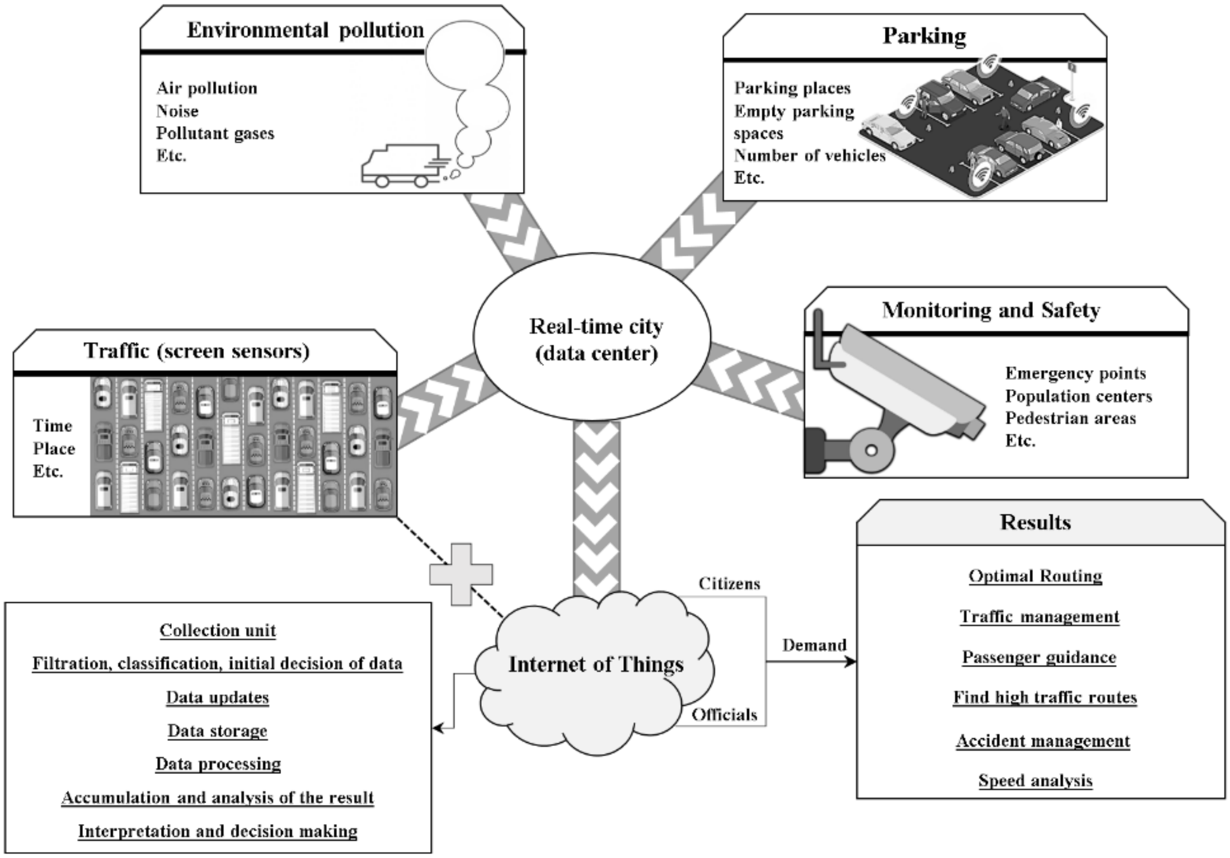

Figure 3. Deployment of sensors (source: Adopted from: Mazhar Rathore et al., 2017)

3. Method

The scientific literature evolves from the review of previous studies (King and He, 2005). Exploration, description, combination, explanation or critique of past scientific literature, or literature review, can independently examine this accumulated knowledge and create independent and original research (Snyder, 2019). Umbrella review is a subset of combined review research (Pieper et al., 2012). This meta-review is a new type of systematic review that combines systematic reviews of a single topic by summarizing, describing qualities, contrasting results, comparing results and strengths and weaknesses of conclusions, and explaining the reasons for inconsistencies of different results and interpretations of the data studied in systematic reviews (Smih et al., 2019). Thus, umbrella review specifically refers to the investigation of convincing evidences from several studies into an accessible and usable document (Papadopoulos, 2007; Pare et al., 2015).

The umbrella browsing method is different from the systematic browsing method (Papageorgiou and Biondi-Zoccai, 2016). A systematic review compares and analyzes the contradictions and similarities of published studies and provides an overview of the information available for a given topic (Hartling et al., 2012). In contrast, umbrella reviews specifically refer to a review that compiles diverse quantitative and qualitative evidences from multiple reviews into one accessible and usable document (Grant and Booth, 2009). Umbrella reviews are designed to incorporate all types of syntheses of research evidence, including systematic reviews in their various forms (Meta-analysis, Meta-synthetic)(Hannes, and Lockwood, 2011).

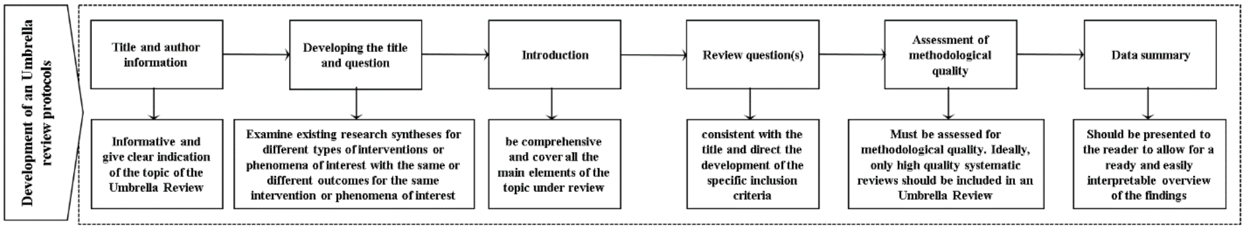

Figure 4. Umbrella review process protocol (source: Adopted from: The Joanna Briggs Institute, 2020)

Given that the subject of the Internet of Things in multi-modal mobility has been investigated from both quantitative and qualitative aspects, we use umbrella review method to summarize their theoretical methods, analyze them, and integrate their results. To conduct this umberalla review, all published papers related to the effect of the IoT on multi-modal mobility were the target population. After extensive search, 60 most relevant papers were selected. The criteria for selecting articles were divided into three categories: IoT and multiple navigation and route optimization. Articles that included at least the following two variables were selected. In the field of Internet of Things, keywords such as, intelligence, smart, information technology, sensors, and interconnected devices, in the field of multimodal mobility, words such as different types of transport, multiple transport, combined transport, combined movement, In the field of optimal routing, terms such as short-term transfer, fast relocation, route shortening, route optimization were used. Majority of the studies have been conducted since 2009. Out od the 60 selected papers, several of them were excluded during the review process if they: a) were not systematically reviewed and / or meta-analyzed, b) no measure of relationships had reported effects, c) no aspect of the Internet of Things or multi-modal mobility was considered and was irrelevant in terms of significance and objectives of this study, and d) journal papers were not completely observable. Finally, 14 quantitative and 14 qualitative studies were selected for indepth umberall review.

For data analysis, theme analysis method (methodical coding) was used. The theme reveals important information about research data and questions and is obtained from continuous rotation between data sets, coded summaries, and data analysis in quantitative and qualitative papers (Braun and Clarke, 2006).(Fig. 5)

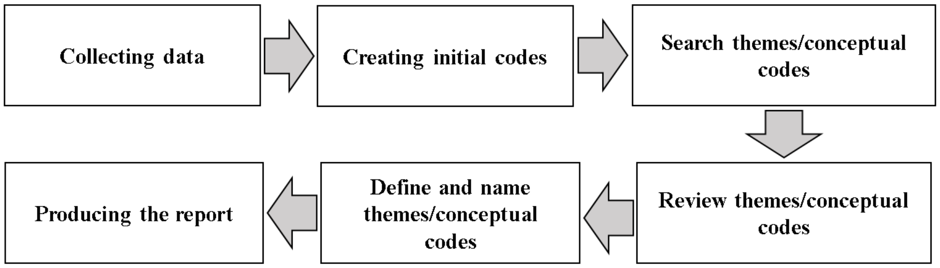

Figure 5. Steps of analyzing conceptual codes extracted from qualitative and quantitative articles (source: Braun and Clarke, 2006)

3.1. Evaluation of the Quality of Qualitative and Quantitative Studies

The quality of the 28 selected articles was evaluated using the JBI Critical Evaluation Checklist by two of the most qualified urban planning experts selected by the Delphi method. The results show that there are no low quality studies and show three studies (10.7%) with medium quality and 25 studies (89.3%) with high quality. The checklist contains ten questions. Each question has a score, and the total relevance score ranges from zero to ten. In this study, studies have been classified to three groups based on their scores (low-zero to four, medium-five to seven and high-eight to ten). Inferential analysis was used to extract conceptual codes and funnel plot, Egger's linear regression, publication bias and heterogeneity Q test were used to analyze the effect of each independent variable on the dependent variable. Cma2 software was used for quantitative analysis.

4. Results

The results of the study are presented in two sections: meta-synthesis and meta-analysis. Meta-synthesis is suitable for studies that are qualitative. Meta-analysis method is used to evaluate quantitative studies.

4.1. Overview of the Sample Publications

Table 1 provides an overview of the 28 studies including type of study, years covered, number of studies identified, and categories extracted in each study. All of the qualitative and quantitative studies published during 2015-2020. This indicates that the level of activity and interest in the role of the Internet of Things in multi-modal transportation is increasing.

Table 1. Characteristics of qualitative and quantitative studies of IoT and multi-modal mobility

Qualitative research						
Rows	**Author (s)**	**Title**	**Journal**	**Method**	**Year**	**Effective factors**
1	H. Abou-Senna E. Radwan Alexander N.Hassan Abdelwaha	Integrating transportation systems management and operations into the project life cycle from planning to construction: A synthesis of best practices	Journal of Traffic and Transportation Engineering (English Edition)	Transportation report	2018	Number of passenger trips per vehicle per hour, Number of passenger trips per vehicle in terms of distance, Number of passengers per stop number of pedestrians, Travel time on the mail transport routes, Delay in reaching destination, Car

Qualitative research						
Rows	**Author (s)**	**Title**	**Journal**	**Method**	**Year**	**Effective factors**
						volume per hour, Traffic duration, Real-time transportation information
2	A. Melis, M. Prandini, L. Sartori, F. Callegati	Public Transportation, IoT, Trust and Urban Habits	International Conference on Internet Science	Literature Review	2016	Geographic information and timetable for different modes of transportation, number of access networks, number of stations, number of accidents per day, population density and passenger
3	S. Porru F. Edoardo Misso F. Eros Pani C. Repetto	Smart mobility and public transport: Opportunities and challenges in rural and urban areas	Journal of Traffic and Transportation Engineering (English Edition)	Literature Review	2020	Travel, Number of vehicles , Air quality , Infrastructure, Real-time transportation information, Passenger information, Passenger support
4	D. Srinivasa Reddy K. V. Ganesh Babu, D. L. N. Murthy	Transportation Planning Aspects of a Smart City	Transportation Research Procedia	Empirical analysis	2016	Transportation demand estimation (daily commutes, peak commuting hours), pedestrian facilities, intelligent transportation system (tracking the location of self-driving cars, electronic roadmaps, instantaneous responses to passengers, electronic parking systems)
5	K. Shubenkova A. Boyko P. Buyvol	The technique of choosing a safe route as an element of smart mobility	Transportation Research Procedia	Theoretical study	2018	Reduction of road length and distance, lane width, time of mobility, number of pedestrian crossings, number of uncontrolled lanes, number of highway lanes at pedestrian crossings, number of ramps, number of underground lanes, rate of road accidents along the route

Qualitative research						
Rows	**Author (s)**	**Title**	**Journal**	**Method**	**Year**	**Effective factors**
6	H. Chand Varun J. Karthikeyan	Survey on the role of IoT in intelligent transportation system	Indonesian Journal of Electrical Engineering and Computer Science	A genetic algorithm and fuzzy control method	2018	Road safety messages, traffic monitoring messages, traffic reports, mobility time, navigation information, 24-hour video surveillance, regular communication of messages between different vehicles
7	J. Sherly D. Somasundareswari	IoT Based Smart Transportation Systems	International Research Journal of Engineering and Technology	Literature Review	2015	Sensors that transmit data to the central server, smart applications in phones, parking lots, monitoring of empty spaces for parking, control of access to traffic-restricted areas, intelligent lighting system
8	T. M. Anand K. Banupriya M. Deebika A. Anusiya	Intelligent Transportation Systems using IoT Service for Vehicular Data Cloud	International Journal for Innovative Research in Science & Technology	Literature Review	2015	Moving time, Reducing the length of the path, communication from vehicles to the cloud, smart parking in the cloud, web server process, vehicle network communications
9	C.Kuster F.Sivrikaya N.Masuch	Toward an interactive mobility assistant for-multi-modal transport in smart cities	International Conference on Service-Oriented Computing	Theoretical study	2018	Moving time, Reducing the length of the path, Population density, different modes of movement, public and private transport, access services in intelligent movements, sharing of motor and non-motor vehicles
10	J. F. Arias Aguilar L. Mendes	Smart Urban Mobility: Conceptual analysis for proposal model	IEEE First Summer School on Smart Cities	Literature review and meta-analysis	2017	Speed control, number of vehicles at different times of the day, traffic duration, average speed, decreasing route length and distance, density and classification of vehicles, facilitating cellular

Qualitative research						
Rows	**Author (s)**	**Title**	**Journal**	**Method**	**Year**	**Effective factors**
						communication to send information in real time, concentration of pollutants in urban areas, Coordination of traffic lights, road infrastructure to reduce the effects of pollution, planning of transportation routes according to the concentration of polluting points
11	A. Asaul I. Malygin V. Komashinskiy	The Project of Intellectual Multimodal Transport System	Transportation Research Procedia	Empirical analysis	2016	Movement time, reduction of path length and distance, number of traffic lights, number of electronic displays, surveillance cameras and recording of violations
12	M. Bouaziz A. Rachedi A. Belghith M. Berbineau S. Al-Ahmadi	EMA-RPL: Energy and mobility aware routing for the Internet of Mobile Things	Future Generation Computer Systems	Literature Review	2019	Traffic time, speed, energy consumption, delay in reaching the destination
13	A. Nikitas, K. Michalakopoulou, E. Tchouamou Njoya, D. Karampatzak	Artificial Intelligence, Transport and the Smart City: Definitions and Dimensions of a New Mobility	Sustainability	Literature Review	2020	Integrated transportation, e-ticketing, transit development, number of hydrogen-powered vehicles, biofuels and alternative fuels, electric hybrid vehicles, car sharing scheme, bicycles, etc., public transportation innovations
14	L. Felipe Herrera-Quintero, K. Banse, J. Camilo Vega-alfonso	Smart ITS sensor for the transportation planning using the IoT and Big data approaches to produce ITS cloud services	8th Euro American Conference on Telematics and Information Systems	Empirical analysis	2016	Number of vehicles, number of traffic lights, road network infrastructure

Quantitative research

Rows	Author (s)	Title			Year	Effective factors
1	Y. Yamada R.Shinkuma Takanori I. Takeo Onishi T. Nobukiyo K. Satoda	Temporal traffic smoothing for IoT traffic in mobile networks	Computer Networks	simulation function in Equ	2018	Delay and transfer time, traffic time, number of stations, number of accesses
2	M. S. Mahdavinejad M. Rezvan M. Barekatain P. Abidi P. Barnaghi A. P. Sheth	Machine learning for internet of things data analysis: a survey	Digital Communications and Networks	Classification/ Regression	2018	Time to reach the destination, waste time, number of parking lots, number of different types of vehicles, travel pattern, Real time prediction, traffic control, public transportation
3	I. M. Hakim, A. Putriandita	Designing Implementation Strategy for Internet of Things (IoT) on Logistic Transportation Sector in Indonesia	International Conference on Industrial and Business Engineering	Regression	2018	Number of public and private transport stations, reduction of route length and distance and speed
4	K. Miraal, A. Manal, M. Hafsa, T. Shanableh, A. R. Al-Ali, A. Al Nabuls	IoT Based Smart City Bus Stops	Future Internet	Regression	2019	Distance, number of stations, time to reach the destination
5	H. Elbehier	Traffic congestion control using Smartphone sensors based on IoT Technology	Journal of Advances in Computer Engineering and Technology	Frequency, obtaining traffic density	2017	Number of different types of vehicles on each route, number of stations, coordination of support infrastructure on a set of routes
6	M. Mazhar Rathore P. Anand H. Won-Hwa S. HyunCheol A. Imtiaz S. Sharjil	Exploiting IoT and Big Data Analytics: Defining Smart Digital City using Real-Time Urban Data	Sustainable Cities and Society	the average speed report of vehicles on a particular road at different times with different traffic intensity	2017	Time to reach the destination, Speed, traffic light control systems, Average level of air pollutant gases, average delay time to reach the destination in terms of passengers, Atmospheric warning systems

Quantitative research						
Rows	**Author (s)**	**Title**			**Year**	**Effective factors**
				levels, i.e., 01–10, 10–20, 20–25, and 25–30 vehicles		
7	M. Marques Da Silva, H. Aurelio De Lima E. Dos Santos, R. Barbosa, C. Fernando Fontana, C. Akio Sakurai, H. Senger	Internet of Things in Urban Mobility: The Case of Bus Rapid Transit of Jose Dos Campos City	International Journal of Transportation Systems	standard rate of BRT systems and priority corridors operating speed of BRT corridors and Priority systems.	2016	Average amount of air pollutant gases, average amount of fuel consumption per day, number of types and combinations of routes, number of stations, distance
8	H. Smih	Smart cities and internet of things	Journal of Information Technology Case and Application Research	Scenario planning	2019	Traffic volume, Time to reach the destination, Number of events per route, Average amount of air pollutant gases, Traffic light control systems, Number of cameras in each route
9	S. Poslad, A. Ma, Z. Wang H. Mei	Transportation network design for maximizing flow-based accessibility	Sensors	Analyse the scenarios expressed in natural language. - Analyse the scenarios for functional versus non-functional requirements. - Analyse the scenario description in order to derive user requirements. - Review that the parts of the complete scenario are	2018	Number of passengers, transportation costs, number of accesses and types of routes

Quantitative research						
Rows	**Author (s)**	**Title**			**Year**	**Effective factors**
				all high priority to be developed for the Living labs (LL) trials (see Section 4). - Review if all major system components requirements are used in the scenarios via analysing that that are then mapped to the system requirements. This confirms how the system supports the user requirements.		
10	A.Waqas, Sh. M. Hizam, I. Sentosa, H. Akter, E. Yafi, J. Ali	Predicting IoT Service Adoption towards Smart Mobility in Malaysia: SEM-Neural Hybrid Pilot Study	International Journal of Advanced Computer Science and Applications	Structural Equation Modeling (SEM) and Artificial Neural Networking (ANN).	2020	The amount of real-time transportation updates on smartphones, the number of different types of vehicles on each route, transportation costs, arrival time
11	A.Riahi Sfar, E. Ntalizio, Y.Challal, Z.Chtourou,	A roadmap for security challenges in the Internet of Things	Digital Communications and Networks	Regression	2018	Number and types of routes, number of stations, rate of real-time traffic updates on smartphones, authentication, confidentiality and access control
12	D. Fitria Murad, M. liana, A. Nizar Hidayanto H. Prabow	IoT for Development of Smart Public Transportation System: A	International Journal of Pure and Applied Mathematics	Meta Analysis	2018	Real-time traffic updates on smartphones, time and volume of traffic, arrival time, average delay time from the passenger point

Quantitative research						
Rows	**Author (s)**	**Title**			**Year**	**Effective factors**
		Systematic Literature Review				of view
13	T.Jan Saleem, M. Ahsan Chishti	Deep learning for the internet of things: potential benefits and use-cases	Digital Communications and Networks	DL versus conventional machine learning	2020	Number of parking lots, public transport stations, number of different types of means of transport in each route, number of types and combinations of routes, distance, transportation costs, time to reach the destination
14	A. Simonetto J. Monteil C. Gambella	Real-time city-scale ridesharing via linear assignment problems	Transportation Research Part C: Emerging Technologies	Regression	2019	Transportation costs, Time to reach the destination, Distance, number of vehicles

4.2. Evaluation of Quantitative Studies

After ensuring the reliability of the sample publications, conceptual codes were extracted. This process continues until a general and comprehensive image of the structure of experience is reached, no new aspect and concept of experience emerge and the researcher reaches theoretical saturation. Through open coding, 38 codes were extracted (Fig. 6) and then the significance coefficient of each variable was measured using Shannon entropy coefficient (Table 2).

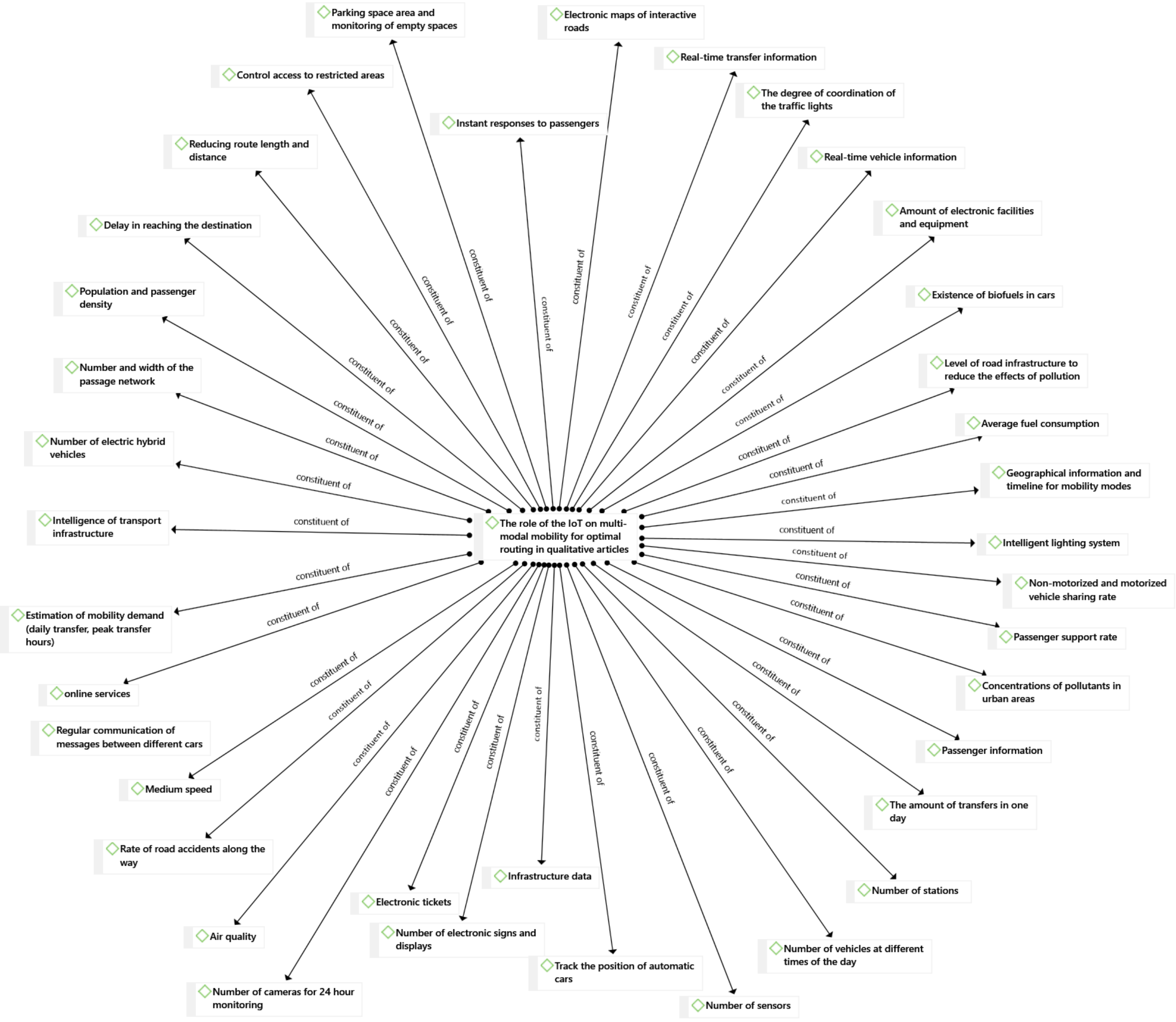

Figure 6. Overview of concepts extracted from qualitative studies

At this stage of the meta-synthesis, the results of the previous stages are presented. Using Shannon entropy method, the level of support of previous studies as well as determining the significance coefficient of each component is shown statistically.

Table 2. Ranking of indices extracted from qualitative studies using Shannon entropy method

Rows	Indicators	Abundance	$\sum P_{ij} * \ln P_{ij}$	Unreliability E_j	Significance factor W_j	Rank
1	Geographical information and timeline for mobility modes	25	-2.2739	0.64211	0.01309	1
2	Number and width of the passage network	13	-1.8462	0.540396	0.01108	10
3	Number of stations	10	-1.8159	0.50331	0.01033	13
4	Population and passenger density	12	-1.8343	0.523403	0.01074	11
5	The amount of transfers in one day	11	-2.0981	0.514809	0.010567	12

6	Air quality	15	-1.9730	0.551666	0.01132	8
7	Online services	14	-1.9396	0.549878	0.01128	9
8	Infrastructure	21	-2.1324	0.605982	0.012431	3
9	Real-time transfer information	19	-2.0806	0.589838	0.01210	4
10	Passenger information	17	-2.0431	0.569142	0.01167	6
11	Real-time vehicle information	17	-2.0431	0.569142	0.01167	6
12	Number of sensors	15	-1.9730	0.551666	0.01132	8
13	Passenger support rate	15	-1.9730	0.551666	0.01132	8
14	Estimation of mobility demand (daily transfer, peak transfer hours)	10	-1.8159	0.50331	0.01033	13
15	Amount of electronic facilities and equipment	23	-2.2049	0.62511	0.012822	2
16	Track the position of automatic cars	12	-1.8343	0.523403	0.01074	11
17	Electronic maps of interactive roads	9	-1.7533	0.480743	0.00986	14
18	Regular communication of messages between different cars	16	-1.9914	0.563238	0.011554	7
19	Instant responses to passengers	12	-1.8343	0.523403	0.01074	11
20	Parking space area and monitoring of empty spaces	15	-1.9730	0.551666	0.01132	8
21	Electronic tickets	17	-2.0431	0.569142	0.01167	6
22	Intelligence of transport infrastructure	15	-1.9730	0.551666	0.01132	8
23	Control access to restricted areas	10	-1.8159	0.50331	0.01033	13
24	Rate of road accidents along the way	14	-1.9396	0.549878	0.01128	9
25	Number of cameras for 24 hour monitoring	14	-1.9396	0.549878	0.01128	9
26	Intelligent lighting system	14	-1.9396	0.549878	0.01128	9
27	Non-motorized and motorized vehicle sharing rate	12	-1.8343	0.523403	0.01074	11
28	Delay in reaching the destination	12	-1.8343	0.523403	0.01074	11
29	Medium speed	16	-1.9914	0.563238	0.011554	7
30	Number of vehicles at different times of the day	16	-1.9914	0.563238	0.011554	7
31	Concentrations of pollutants in urban areas	13	-1.8462	0.540396	0.01108	10
31	The degree of coordination of the traffic lights	17	-2.0431	0.569142	0.01167.	6
33	Level of road infrastructure to reduce the effects of pollution	19	-2.0806	0.589838	0.01210	4
34	Number of electronic signs and displays	11	-2.0981	0.514809	0.010567	12
35	Average fuel consumption	17	-2.0431	0.569142	0.01167.	6
36	Reducing route length and distance	23	-2.2049	0.62511	0.012822	2
37	Existence of biofuels in cars	21	-2.1324	0.605982	0.012431	3
38	Number of electric hybrid vehicles	14	-1.9396	0.549878	0.01128	9

According to Table 2, it can be seen that in qualitative studies, "geographical information and timeline for mobility modes" are ranked at the top and "electronic equipment and facilities" and "reducing route length and distance" are ranked high after them.

4.3. Evaluation of Quantitative Studies

CMA2 software was used to analyze the data and the effect size of each variable was calculated. Cohen's Table was used to interpret the effect size. In the meta-analysis method, statistics are converted to *r* index. For inferential analysis of the data, first the meta-analysis hypotheses were investigated, so that using funnel plot, Egger's linear regression, publication bias and heterogeneity Q test, heterogeneity of the studies was evaluated. Then, using linear and multivariate regressions, first the relationships between each independent variable and then all independent variables with the dependent variable were evaluated (Table 3).

Table 3. Distribution of effect size classes based on statistical estimates (King and He, 2005)

Meaning of effect size	The value of r	The value of d
Low	0.3>	0.5>
Medium	0.3-0.5	0.5-0.8
Large	>0.5	>0.8

As mentioned earlier, after reviewing, 60 studies with the most content relevance to the research topic were selected. After the screening process, 28 papers (14 qualitative papers and 14 quantitative papers) related to the research topic and method were selected. In meta-analysis to check the accuracy of the number of studies, meta-analysts test the differences in studies in terms of effect size. Rosenthal suggested the number of missing studies (with a mean effect of zero) i.e. the number of studies confirming the null hypothesis that, if added to the analysis, a statistically insignificant total effect is obtained, and the result is changed. Cooper calls this number a safe integer N_{fs}.

Table 4. Classic safe N calculations number a safe integer

Z value for observed studies	35.757
P value for observed studies	0.001
Alpha	0.050
Remaining (sequence)	2
Z for Alpha	1.959
Number of studies observed	14
Number of missing studies that bring the P value to Alpha	6637

According to Table 4, another 6637 studies should be reviewed so that the value of the combined bilateral p does not exceed 0.05. This means that another 6637 studies should be conducted in order to make an error in the final results of calculations and analyzes, and this result indicates the high accuracy of the information obtained from this study.

In this section, homogeneity and publication bias of the studies were investigated. Heterogeneity tests were performed to determine the final model and to ensure the existence of moderator variables (Table 5). In this test, provided there is a significant heterogeneity, a random model is selected and in the studies, it is assumed that the nature of the relationship between the independent and dependent variables is affected by the moderator variable. According to the test results (Q = 240.880, P <0.01), it can be said that at 99% confidence interval, the null hypothesis that the studies are homogeneous is rejected and the hypothesis of heterogeneity between the studies is confirmed. Furthermore, square Index I confirms that approximately 92% of distributions are true and result from all present studies and their heterogeneity. Therefore, combining them with the fixed effect model is not justified and a random model should be used to combine the results. In fact, this test indicates that independent variables are different and adjusting variables should be used to determine the cause of variance difference.

Table 5. Q test results

Statistical index	Test value (Q)	Degree of freedom (DF)	Significance level (P-Value)	I-Squared
Results	240.88	19	0.001	92.112

4.3.1. Investigation of Publication Bias Hypothesis

The other part of meta-analysis process is to investigate publication bias. One of the problems that distorts the validity of meta-analysis results is the selection of the articles that have positive and statistically significant effects and do not use other sources whose results are not very satisfactory. For this hypothesis test, funnel plot (the most common method for detecting publication bias, in which the estimated effect of the intervention from each study is plotted against the sample size of that study) and Egger's regression (Fig. 7).

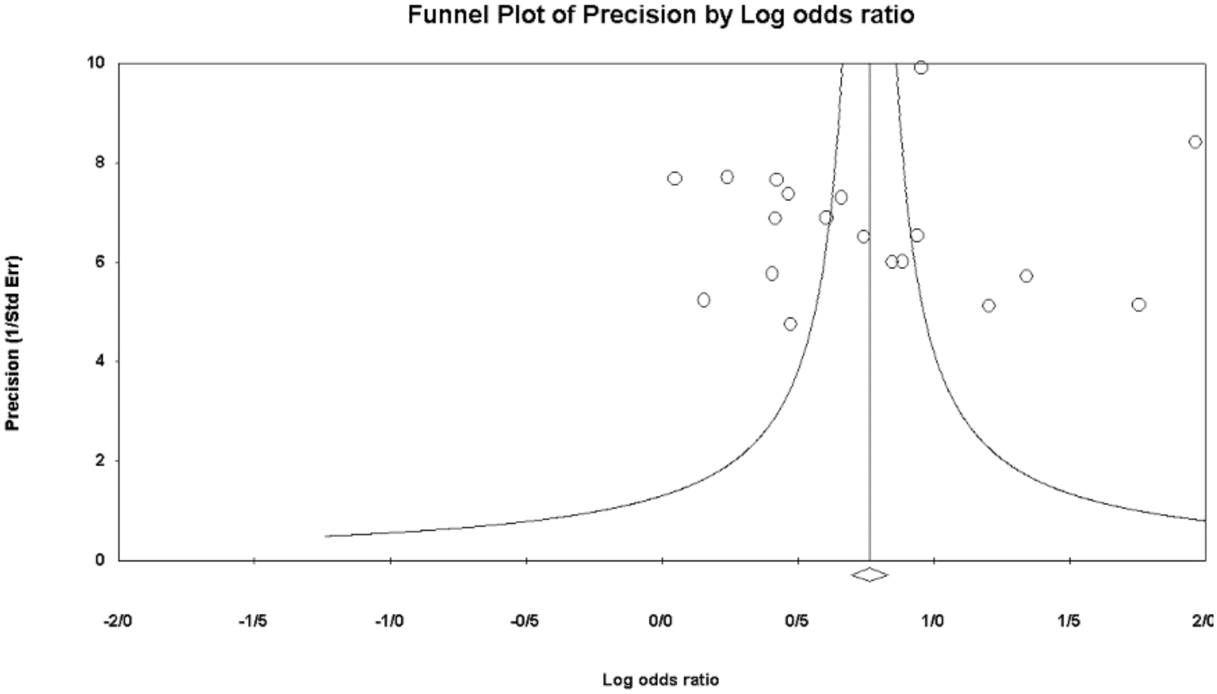

Figure 7. Funnel plot to check publication bias

For the funnel plot interpretation, studies at the top of the funnel had no publication bias; but as the studies drag down the funnel, their standard error increases. The results of the inverted funnel plot almost represent the relative symmetry of the conducted studies. However, in this case, no explicit judgment is made and for more certainty, related tests such as Egger's linear regression should be used. In this method, the null hypothesis H_0 indicates the symmetry of the funnel plot and no publication bias of information and the hypothesis contrary to H_1 indicates the asymmetric funnel plot and publication bias of results.

4.3.2. Results of Egger's Linear Regression

In the absence of publication bias, it is expected to produce a standard regression line effect that is a cut of the main regression line. If the regression line cut differs from the intended surface, it may be due to the publication bias.

Table 6. Results of Egger's linear regression method

Statistical index	Intercept (B)	Standard error(SE)	(T-Value)	Significance level (P-Value)	
Results	3.048	2.163	1.409	One domain	Two domains
				0.112	0.224

According to the results of Egger's linear regression (Table 6), the cut is equal to 3.048 and 95% confidence interval is equal to 1.409, because P value of singlt-range is 0.112 and two-range is 0.224, the null hypothesis is that funnel plot is symmetric and “no publication bias” is not confirmed. According to the results of the heterogeneity of the studies in this section, it is attempted to use a moderator variable to determine heterogeneity in order to determine the difference of variance between the studies. In this study, the variable of the year of research (quantitative variable) has been used as a moderator variable.

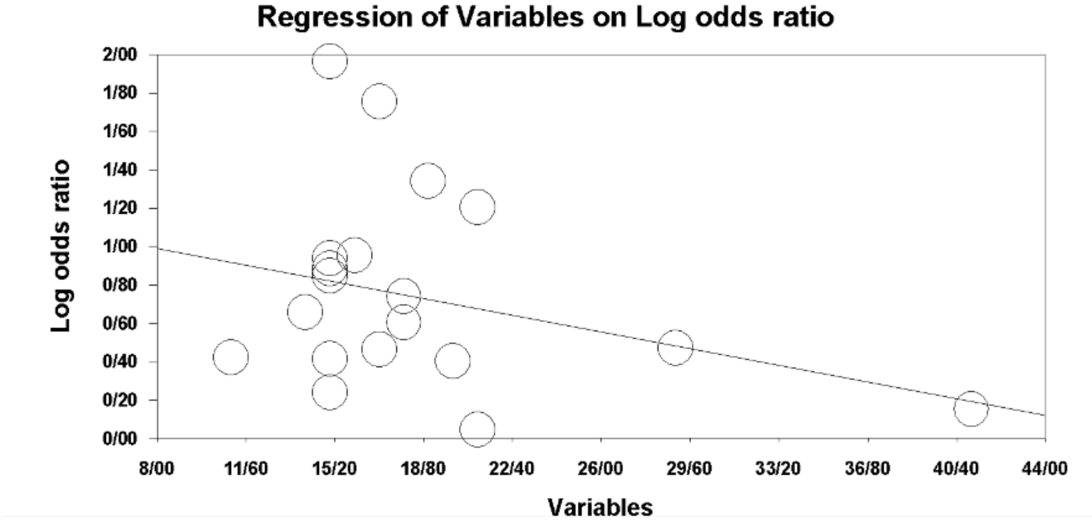

Figure 8. Meta-regression results for each study

Table 7. Meta-regression results are performed based on the moderator variable of the year

Integration with years of research	Estimation of heterogeneity		
	(Q)	(Df)	(P-Value)
	3.592	2	0.166

According to the information in Fig 8 and Table 7, the value of Q of 99% is not statistically significant. With increasing the variable of the research year, the results of Q test show a significant reduction in the value of Q from 240.880 to 3.592 and the effect size is increased and significant. Thus, the temporal change can play a moderating role in the relationship between the Internet of Things and multi-modal mobility.

Table 8 shows that among the 19 variables extracted from quantitative studies, a significant relationship is found at 99% confidence interval. The largest effect size is related to "time to reach the destination" and the smallest effect size is related to the variable "climate warning systems". In the analytical dimension, it can be said that a variable has a low effect, 14 variables have a medium effect, and the variables "time to reach the destination", "time and volume of traffic", "number of public and private transportation stations", and "route less length and distance" had a great effect, respectively.

Table 8. Evaluation of the significance of independent variables (IoT and multimodal mobility) on the dependent variable (Optimal routing) in quantitative articles

Rows	Indexes	Effect size	Low limit	High limit	Z-Value	P-Value
1	Atmospheric alarm systems	0.169	0.072	0.263	3.400	0.001
2	Average amount of air pollutant gases	0.450	0.341	0.547	7.367	0.001
3	Real-time upgrade of mobility on smartphones	0.480	0.397	0.555	9.964	0.001
4	Reduction in route length and distance	0.547	0.474	0.612	12.236	0.025
5	Coordination of support infrastructure in a set of routes	0.388	0.323	0.449	10.757	0.001
6	Number of public and private transportation stations	0.550	0.476	0.616	12.054	0.001
7	Traffic light control systems	0.450	0.358	0.533	8.630	0.001
8	Number of parking lots	0.384	0.295	0.466	7.900	0.001
9	Time and volume of traffic	0.520	0.423	0.605	9.058	0.001
10	Number of different types of vehicles on each route	0.466	0.387	0.539	10.187	0.001
11	Time to reach destination	0.654	0.574	0.722	11.889	0.003
12	Number of types and combinations of routes	0.367	0.324	0.408	15.480	0.001
13	Number of passengers	0.480	0.397	0.555	9.964	0.001
14	Number of events per route	0.353	0.230	0.465	5.383	0.001
15	Number of accesses	0.377	0.287	0.460	7.710	0.055
16	Transportation costs	0.480	0.397	0.555	9.964	0.001
17	Number of cameras in each route	0.356	0.236	0.465	5.535	0.001
18	Speed rate	0.410	0.323	0.490	8.458	0.001
19	Average fuel consumption per day	0.349	0.332	0.367	35.271	0.001

5. Discussion

In qualitative section, by reviewing previous studies, variables that had a high coefficient of importance were extracted. Accordingly, the variables "geographical information and timetable for mobility modes" are in the first rank, and "amount of electronic facilities and equipment" and "reducing route length and distance" are in the second rank; and in quantitative section, the variables "time to reach the destination", "time and volume of traffic", "number of public and private transportation stations", and "reduction in route length and distance" had a great effect, respectively. When the two quantitative and qualitative sections are compared, similarities and differences are seen between the two sections. Thus, in both sections, time has been of primary importance to researchers. The term time includes delay time, time to reach the destination, and arrival time for vehicles, because passengers want to know where they are and how and in what time period they can get where they want to go, whether on foot, by bicycle, or by car or any vehicle. The second common factor is the variable "reduction in route length and distance". One of the main challenges of traffic networks is to direct vehicles to their destinations under dynamic traffic conditions with the aim of reducing the distance traveled during travel and more efficient use of the existing capacities of the network. Also, if routing is done correctly, this will reduce mobility time.

In the process of analyzing papers through umbrella review, several differences also appear between the quantitative and qualitative papers. In qualitative papers, "electronic equipment and facilities is one of the factors that have a great effect on mobility using the Internet of Things." Probably because there is currently no aspect of mobility that is not affected by information technology. Planning a route, finding a way when driving or walking, toll collection, road pricing, traffic management, deciding on different transportation options for a given mobility, reducing time and distance through telecommunications - all are some of the things that IT manages, but to benefit from these advantage, infrastructure should be planned and designed smartly, and the potential of vehicles and infrastructure should be increased.

In quantitative papers, time and volume of traffic are among the factors that have a great effect because by smart transportation, different vehicles of transportation and multi-modal mobility can be related, and by showing and delivering information to the drivers and passengers the level of safety increased, travel time and delay reduced, reception capacity increased and the movement of vehicles smoothed.

The last case is the number of public and private transportation stations. By reducing the distance between public and private transportation stations and increasing the number of stations, users are allowed to navigate according to their priorities, needs and dynamic responses.

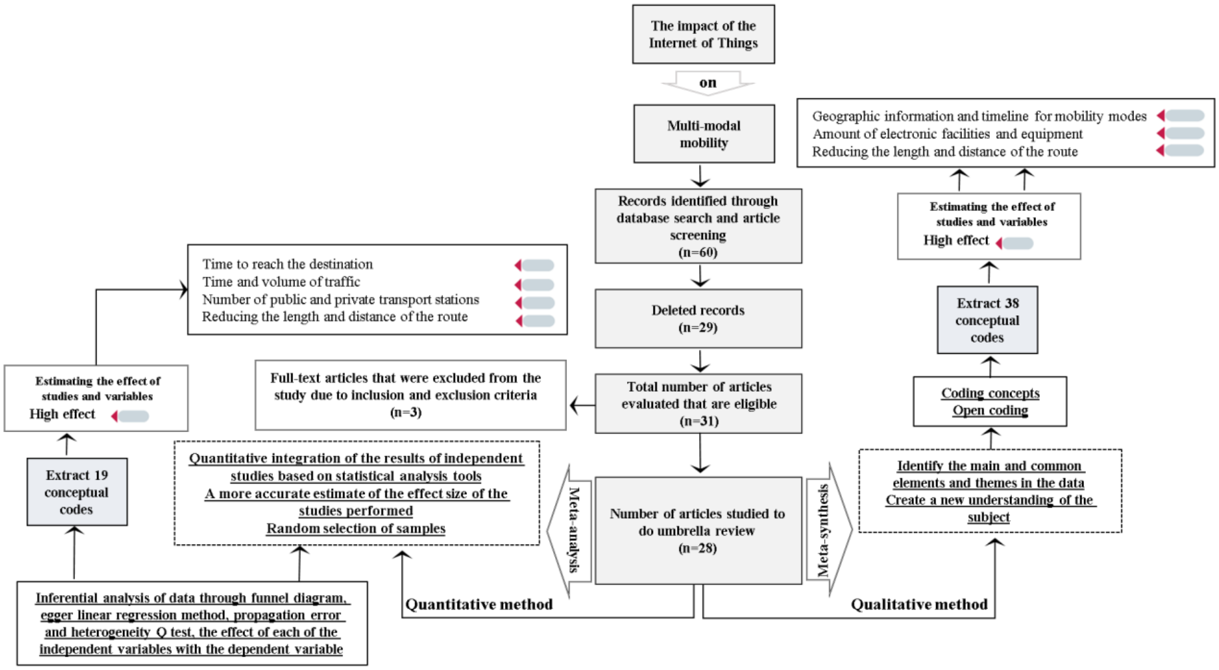

Figure 9. Comparison of qualitative and quantitative research

6. Conclusion

There is an integrated connection between transportation systems and the Internet of

Things, and it is recognized as a factor in the evolution of smart transportation.

Smart transportation systems have an effective role in achieving the optimal route, so to take advantage of this potential, it is necessary to provide a suitable methodology to increase its efficiency and productivity.

Finding the optimal route requires access to more information from vehicles, infrastructure and urban roads, which is created through the integration and interconnection of systems in the field of IoT.

By finding the optimal route by urban users, additional relocation is prevented, which is one of the ways to manage urban transportation by managers and urban planners. Using the Internet of Things, other issues can also be controlled in transportation management:

- View vehicle information by the central server.
- Accurate routing.
- Ability to identify the nearest vehicle
- Ability to check driver behavior.
- Increase vehicle and driver safety by analyzing drivers' behavior while driving.
- Ability to report to manage the daily activities of the transport fleet
- Ability to report to compare and analyze performance over time.
- Plan and manage fleet activities strategically.
- Report unauthorized speeds

All of the above, if controlled in cities, will lead to the development of urban transportation system and optimization of urban mobility by receiving instant information, reducing fuel and energy loss, and thus reducing environmental pollution**.**

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