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ROAD SAFETY AUDIT FINDINGS ON TWO-LANE ROAD: CASE STUDY IN GREECE

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ABSTRACT

Greek legislation (Presidential Decree104/2011) in line with the European Directive 2008/96/EC plans to implement Road Infrastructure Safety Management (RISM) for the road network of Greece. The procedure of Road Safety Audit (RSA) is one of the main RISM procedures as a means for preventing accidents. This paper addresses the RSA findings on a national 2-lane, 2-way road network in Greece, as a reactive approach to identifying safety issues and infrastructure deficiencies. The examined road network is a typical road in Greece and the presented approach analysis may operate as a report to roadway authority officials to gain a better understanding on the current state assessment of the typical type of road. The RSA conducted by a team of auditors who was experienced in road design as well as in road safety engineering and user driving behaviour. The RSA team developed checklists for the specific roadway, according to the Greek legislation, checking the conformity of road layout to Road Design Specifications, potential violations of driver expectancies related to roadway design, and risk potential accidents points. The findings were categorized into groups taking into account the analysis of human factors. The proposed remedial measures are based on behavioural studies and they presented in qualitative evaluation. However, cost-benefit and cost-effectiveness analyses combined with the specifics in each case are imperative for the key issues to be addressed.
Keywords: 2-lane road, accidents, human factor, road safety audit.

1 INTRODUCTION

In recent years, the road safety approaches as Vision Zero, Sustainable Safety and Safe System, proposed by developed countries like Sweden, the Netherlands and Australia, were based on the fundamental principle of the long-term vision for a developed society, where no one is killed or seriously injured in a road transport. In 2008, ITF/OECD published a research report "Towards Zero: Ambitious Road Safety Targets and the Safe System Approach", an international attempt to present a new framework for road safety policies [1]. The main ambitious target was to progressively eliminate all fatalities and seriously injured. The basic principles of achieving this main target are shared responsibility, between road users and providers of the elements affecting the safety of system and prevention. The stakeholders and the main authorities of the road transport system are responsible to road safety level in the long term. The typical "blame the road user" view has been replaced. It is recognized that road users make mistakes that may lead to road accidents. A road transport system has to support human error, making the road environment more forgiving and self-explaining. A more pro-active than re-active approach to road infrastructure design and construction is desired, where road safety is taken into consideration in all the stages of a road life cycle [2,3].

In the European Union, the Directive 2008/96/EC legally specified tools and procedures for a pro-active approach to Road Infrastructure Safety Management (RISM), providing policy guidance to improve the road safety of a road network [4]. OECD [2,3] and Persia et al. [5] present ten RISM procedures that support a road authority in decision making related to road safety improvement of a road network. These procedures are aimed to enhancing road

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safety at the different stages of a road infrastructure life cycle; some of them can be applied to existing infrastructures (a more re-active approach) and other are used in the early stages, i.e. planning and design (a more pro-active approach). Among the ten RISM procedures, the road safety audits, road safety inspections, management of high-risk sites and road impact assessments are the main procedures for identifying safety issues and providing measures in all stages of design, construction and operation.

Road safety audit (RSA), as procedure for preventing accidents, originated in Great Britain and is now being spread in several countries around the world [6]. RSA is a formal safety performance examination of an existing or future road by an independent, multidisciplinary team. RSA has been broadly recognized as a successful preventive tool for minimizing future accident occurrence and is a part of Safe System approach to road safety. Austroads (2009, 2018) includes the examination of existing roads in RSA as well as, noting that it is a reactive approach finding any potential hazards the design may unwittingly hide [7,8].

However, the Directive 2008/96/EC was amended in 2019 with the Directive (EU) 2019/1936 which will apply to roads not only which are part of the trans-European road network but to motorways and to other primary roads, whether they are at the design stage, under construction or in operation [9].

This paper addresses the RSA findings on a national two-lane road network in Greece, as a re-active approach to identifying safety issues and infrastructure deficiencies. It is mainly focused on providing the general framework of RISM and a general description of the identified road safety problems based on human factors approach.

2 METHOD

Internationally, the main RSA guidelines are those published in the USA (2006) by Federal Highway administration (FHWA) [10], in Britain (2008), published by British Institution of Highways and Transportation (HIT) [11] and in Australia (2009) published by Austroads [7]. The RSA carried out by a multidisciplinary auditing team comprising two or more well-trained and accredited road safety engineers who are not part of the design team. It is worth noting that the independence of the auditor team performing the RSA is absolutely necessary. The identification of potentially dangerous features of the roadway environment and potentially misleading or missing information points are the main principles of the procedure.

In Greece, for the implementation of integrated RISM, Presidential Decree 104/2011 defines: “specific procedures related to the training and responsibilities of auditors, the data which are collected and utilized, as well as the relevant good practices that should be used to tackle the road safety issues that have been identified”. RSA is one of the proposed measures of the Strategic Plan to improve road safety in Greece 2011–2020 and is considered mandatory for the Trans European Road Network. Regarding to the training of auditors, there was an official effort for the training and certification of highway engineers, working in the private and public sector, from an organized RSA training program in order engineers to be certified as road safety auditors [12].

The training of auditors was based on the implementation of the Safe System approach and human factors in road design. Human factors are stable psychological and physiological threshold limit values that influence the performance and safety of technical systems used by humans, as typical limitations of the perception system, information processing, learning or decision making of all human beings [13,14]. It is important, in the framework of RSA, the auditor has to take into consideration the natural laws of human perception, the processing of information and the regulation of action programs whenever an onsite safety evaluation is made. Auditors have to understand how the road design influences driving behaviour and how the environment contributes to driver errors and collisions [15]. Numerous studies have been conducted worldwide to examine specific risky behaviours of drivers, which can be directly related to the occurrence of traffic accidence. The reason for conducting these studies is the fact that 90%–95% of traffic accidents occur due to human factors [16–18]. Driver behaviour is a very complex matter that is influenced by one's knowledge, abilities and skills on the one hand and personality traits such as volition, values and motives on the other [19,20]. It is a combination of both typical behaviour and maximal performance in demanding situations. There are several theories and models of driver behaviour or performance in order to predict typical behaviour or the limits of maximal behaviour [21]. Although the driver behaviour is governed by several factors and their interactions, and many of these operate at subconscious level, theories and model of driver behaviour are essential to understand how changes in vehicle, roadway, social and legal environment can affect driver behaviour [21].

PIARC's reports [22,23], mention that there are three classes of human factors in the man-road interface that trigger accidents: (a) the 6-s rule: the design and construction of the layout of the road should give the driver enough reaction time (4–6 s) to adapt to a new driving requirement, (b) the field of view-rule: a good quality field of view effectively keeps drivers over his lane and (c) the logic rule: the road has to follow drivers' expectation and orientation formed by their experience and recent perceptions.

The above principles can be used in the quality planning and design process or investigation and completion the on-the-spot checklist during the RSA procedure.

The examined road in this study is a national two-lane road network in Greece. The team of auditors was experienced in road design as well as in road safety engineering and user driving behaviour. The findings were categorized into groups taking into account the analysis of human factors. The examined road network is a typical two-lane two-way road in Greece and the presented approach analysis may operate as a report to roadway authority officials to gain a better understanding on the current state assessment of the typical type of road.

3 CASE STUDY

The case study examined in this paper is the roadway "Amphipoli-Drama", a 50 km interurban road, located in the Northern Greece. It is the main connection of Egnatia Odos Highway with town of Drama (Fig. 1). Mainly, it is a two-lane, two-way road network, without separated directions and 0.5–1.2 m. shoulders. Along the network of the road, there are 19 unsignalized intersections. The roadway course is passing through seven built-up areas, as shown in Fig. 1. The speed limit is 90 km/h except the area of built-up areas where the speed limit is 50 km/h. The importance of the provided connection of this road is high as it facilitates the high volume of traffic. An average traffic volume is about 35,000 heavy vehicles per year.

The safety data of the part of 20 km of this road, near the town Drama, is presented in Table 1. The data of the other part of the road was not available from the Traffic Office. The main causes of the accidents were the excessive, over-limit speeding, the absence of lighting in intersections, the restricted field of view of driver and other causes based on human factors. The RSA was carried out by an independent team of road safety engineers with appropriate experience and qualifications in road safety. Specifically, one member of the team is certified road safety auditor. All the members have experience in road design and construction, basic principles of traffic operation and human factors knowledge. Before the field inspection, data for traffic volumes, traffic accidents and high risk sites, the design standards that were used, ortho photomaps, road design software were examined and analysed.

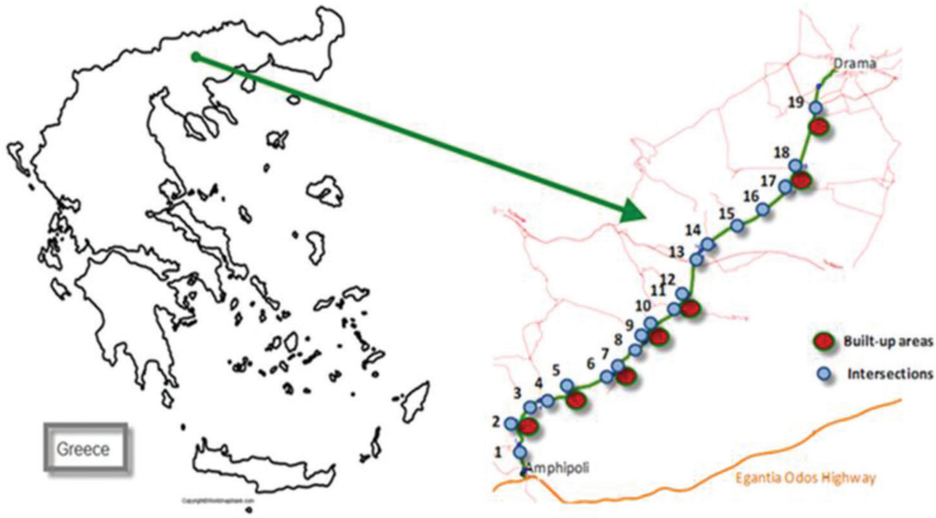


Figure 1: The interurban road Amphipoli-Drama in northern Greece.

Table1: Road safety data of 20 km of Amphipoli-Drama roadway.

	2014	2015	2016	2017	2018
Traffic accidents	23	22	28	23	19
Fatalities	1	1			3
Injuries	11	8	3	4	7
Only damages	13	16	25	19	11

The inspection of the road was carried out in daylight and at night-time, in wet and dry conditions, from the point of view of all road users and included all movements at each interchange. The RSA team developed checklists for the specific roadway, according to the Greek legislation, checking the conformity of road layout to road design specifications, potential violations of driver expectancies related to roadway design and risk potential accidents points.

4 RESULTS

The RSA team identified several safety issues. In the inspection process, auditors took emphasis on how drivers might perceive the road environment, adjust their driving behaviour to the geometric characteristics of the roadway or the geometric layout of roadway might provide wrong information to drivers. The main safety issues were categorized in groups, considering human factors analysis, in specific topic areas and are presented as following:

4.1 Road function

A critical situation in respect of road safety is the mixture of functions of roads. Road classification provides a categorization of roads design in order roads to cater for a defined function. The examined road, a national interurban road, has a flow function which allows efficient

Figure 2: Road with mixed functions.

throughput of long-distance motorized traffic. The critical areas where the road passes through villages creates situations of mixture of functions (Fig. 2). There is no clear distinction between the flow function of the interurban road and the access function of urban road. In case the road geometry, from one environment to another, keeps unchanged, the driver behaviour has to be changed as may cause serious problems in road safety with conflicts with vulnerable road users.

4.2 Access control

Along examined road strong access control is the basis of road safety. Access control is the planned and regulated interaction between the roadway network and property access (Fig. 3). Different local traffic activities allow actual access to properties alongside the road overwhelming the trough route function of the road. These activities along the road such as public and private transport of goods and people, shopping, parking decrease the level of road safety and increase the accidents figures especially in vulnerable road users such as pedestrians and cyclists.

The appropriate management has main goal to limit and separate conflicts points between property access and efficient transport system. The limitations of access points reinforce the flow function of the main road and the concentration of uncontrolled turning movements at a single junction which can be properly designed for such movements upgrade the level of safety.

4.3 Consistency in road horizontal and vertical elements

From the review of road design plans, it is remarked that the design of horizontal and vertical element is not compatible with the road design principles. In the horizontal alignment, an inconsistent alignment with a combination of large with small radius horizontal curves makes the road course to be not predictable. Drivers are surprised by sudden changes of the curvature and they misinterpret the poor coordination of the horizontal and vertical curvature (Fig. 4). Unexpectedly tight horizontal curves may lead to drivers to drive through them at speed higher than that of the dynamic equation of the curve especially after a long straight section. There is no sufficient sight distance, in many cases, for overtaking or breaking and stop in case of obstacle. It may be difficult for a driver to estimate the sight distance on a curve crest and he may overtake when he does not have sufficient length to do so safely.

Figure 3: Uncontrolled access points.

Figure 4: A combination of small radius vertical crest with horizontal curve.

4.4 Excessive speed

Long straight sections of the road course encourage drivers to drive at higher speed than is safe for that location according to design and operational speed of the road. The combination of straight sections with low gradients along the road and low level of horizontal and vertical curvature encourage speed and lead to a rise in accidents (Fig. 5). Moreover, the cross-section profile plays significant role; the width of lanes or shoulders greater than the limits of the design specifications also encourage speed.

In residential area, where the interurban road functions as urban road, the type of cross-section should be different. The main problem is that a driver when enters in area with lower speed limit, generally underestimate his speed, especially after a higher speed driving period. This fact makes him unable to reduce his speed enough to comply with the lower speed limit. Appropriate engineering infrastructure measures can help to indicate the transition from one traffic environment to another, and thus help drivers adjust to the lower speed.

4.5 Maintenance of the road

Maintenance of the road in full profile impacts the safety situation. Adequately maintaining road assets is essential to preserve and enhance the provision of safe and efficient travel of people and goods. There are many critical positions where it is remarked a deterioration and

Figure 5: A combination of small radius vertical crest with horizontal curve.

Figure 6: Lack of maintenance of pavement and signing.

defects on pavement; low skid-resistance, asphalt cracks, potholes and deformation. Some main reasons for that is the harsh weather condition, the lack of appropriate maintenance and heavy daily traffic which may cause adverse impacts on pavement condition (Fig. 6).

The road marking was faded at many locations while old markings controlling temporary traffic had not been removed effectively. Poorly signed positions do not clearly inform drivers about dangerous road conditions. Many signs are obscured by overgrowing vegetation and the driver has no opportunity to take notice of the instruction given by the sign. Many signs are not visible at night because of poor illumination, lack of maintenance, inappropriate position. Signs should be sited far enough in advance for drivers to react in the required way (Fig. 6).

Concerning the lighting system, there are many positions where there is no lighting. In locations where there are high proportions of vulnerable users (in built-up areas) or in areas of intersections have to provide lighting. Careful attention needs to be paid to the sitting of lamp posts as they can be hazardous for an errant vehicle and it should be protected by barriers system.

Well designed and located barriers systems reduces the number and the severity of traffic accidents. Many accidents on rural roads involve accidents leaving the road and colliding with hazardous obstacles. There are many positions where there are damaged barriers or missed barriers or barriers which are a series of unconnected short pieces or with faulty connection or termination (Fig. 7).

Figure 7: Damaged restrained systems.

Figure 8: Roadside obstacles.

4.6 Roadside features

A roadside is defined as the area beyond the edge traffic lanes of roadway. Different single fixed or continuous obstacles at the edge of traffic lanes create potential danger of collisions leading to accidents or increasing accident severity. Some of these obstacles are trees or other vegetation, utility poles, sign and lighting posts and supports, abutments, overpasses, rocks on the nearside, drainage features, embankments and slopes, ditches, kerbs, canals (Fig. 8). Consideration all these roadside obstacles as a component of the driver's field of view, which governs the driver's behaviour is crucial. According to PIARC Human Factors Guidelines, a well-designed field of view helps enhance road safety.

4.7 Intersections

A junction is required wherever two or more roads cross, so that vehicles can pass through the junction in ways that are safe and understandable for all road users. According to the inspections of all the 19 intersections, many findings were recorded. Recognizing road user's limitations in capabilities and the point of view of driver in all directions, the auditors considered how the potential for a collision can be reduced and in which locations there are misleading or missing information (Fig. 9).

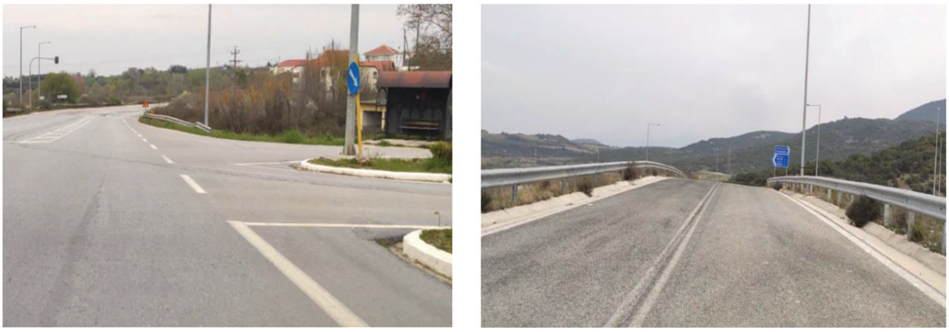


Figure 9: (a) Uncontrolled intersection and (b) intersection in vertical crest curve; limited visibility.

5 DISCUSSION

In order to the main safety issues to be addressed, recommended measures for improvement and upgrading the level of safety are presented. The effectiveness of the methods that take into account the user's driving behaviour and the forgiving road namely a safe and self-explanatory design consistent with the expectations of road users while recognizing their needs, limitations and capabilities of information has to be examined.

The proposed remedial measures are based on behavioural studies [24–27] and they presented in qualitative evaluation. Behavioural studies consider the medialization of users' choice with behavioural theory [28].

5.1 Road safety infrastructure investments

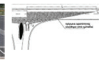
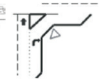
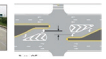
- Although the road course, inside built-up areas, fulfil mixture of functions, a clear distinction between flow function of interurban road and the function of connection, access and stopover has to be implemented. As the construction of by-pass road around the built-up area is an expensive solution, the implementation of different countermeasures is significant for upgrading the level of road safety. Some of them are full space separation of traffic with local activities, well-designed intersections, separation of pedestrian lanes (pedestrian bridges or protected pedestrian zones), separation of the shoulder by barriers, different calming traffic measures (islands in the centre of the road, roundabouts, narrowing of the lanes) in order to reduce the level of speed.
- Closing of direct access to main road and the uncontrolled turning movements to minimize the possibility for accident is important. However, the connectivity to the surrounding land has to be examined.
- Inspection for keeping the sufficient sight distance for drivers. Improved signing, warning signs, chevron signs in sharp curves, overtaking forbidden by suitable road markings and signs, improved marking are low cost solutions. Moreover, it is important to improve the sight distance in curves removing obstacles or vegetation.
- Concerning the speed management, local improvements in the most dangerous locations it is imperative. Some measures are signing about speed limit, separation of traffic travelling in opposite directions using median barriers (where there is enough space), speed cameras,

shoulder or centreline rumble strips (tactile warning devices). In built-up areas the implementation of many physical engineering restrictions encourages drivers to slow down; gates at the entrance of the village, central traffic islands, roadside refuges, narrowing the width of the lanes, speed humps, small roundabouts.

- An important aspect for cost-effective maintenance over the pavement life cycle is the selection and timing of maintenance activities. Using the right maintenance treatment at the right time, depending the condition of the pavement, will get the maximum benefit.
- Replacement of new signing with modern signs, reflectorized that provide excellent visibility in all weathers. It is recommended variable message signs in critical positions where it is absolutely necessary.
- Improved and clean road markings provide appropriate information to the drivers. Centrelines indicate locations where overtaking is forbidden. Where it is necessary, it is recommended centre and edge lining reinforced using studs or reflective glass beads.
- Lighting is expensive to install and maintain but usage of cheaper LED lighting and solar power lighting system or any other energy saving system may reduce costs. Proper maintenance is needed (changing and cleaning lamps). Protection of the lamp posts via installation of appropriate barrier systems (according to EN-1317 specifications).
- Appropriate restrained barrier system installation, along the two sides of the road, according to European Standards EN1317 (Greek guidelines Road Restraint Systems OMOE-SAO) is imperative. According to the technical guideline OMOE-SAO, the installation of safety barriers on the road requires the consideration of the relevant study to determine the obstacles at the edge of the pavement, the critical distance of each obstacle, the required containment level depending on the degree of danger and the permitted speed. Special consideration should be taken in end-treatments of barriers, transition from one category of barrier to another, appropriate length before and after obstacles, crush cushions at dangerous locations.
- The main approach for the management the roadside obstacles is to design a forgiving roadside in order to reduce the consequences of an accident caused by driving errors, vehicle malfunctions or poor roadway conditions. The main categories of management of roadside obstacles the removing or relocation of potentially dangerous roadside objects, the modification of objects and the shielding of objects. Thoroughly examination is needed in each dangerous point.
- Redesign and reconstruction of intersections is imperative to be safe and understandable for all road users. Proposed countermeasures for the examined intersections are presented in Table 2 to prevent future accidents. The road specifics of each case combined with cost-benefit and cost-effectiveness analyses determine the priority of the implementation of these measures. In Table 2, the priority of each measure implemented in each intersection is presented taking into account the low cost of measure combined the effectiveness.

The proposed measures are: enhanced sign (I.1), improved maintenance of stop signs (I.2), enhanced pavement marking (I.3), flashing beacons at stop-controlled intersections (I.4), splitter islands on the minor road approach (I.5), transverse rumble strips (I.6), clear sight triangles on stop or yield controlled approaches (I.7), right turn lanes at intersections (I.8), left turn lanes at intersections (I.9),offset left-turn lanes at intersections (I.10), realign skewed intersection (I.11), improve visibility by proving lighting (I.12), roundabouts (I.13), delineation in islands (I.14), illumination signs at night.

Table 2: Proposed intersection countermeasures to prevent future accidents.

Intersection	Proposed countermeasures														
	I.1	I.2	I.3	I.4	I.5	I.6	I.7	I.8	I.9	I.10	I.11	I.12	I.13	I.14	I.15
															
1	X		X		X	X									
2	X		X										X		X
3			X									X			
4			X	X		X								X	X
5	X	X	X	X				X	X				X	X	
6	X		X		X	X		X	X						X
7	X	X	X	X	X	X		X	X						X
8	X		X	X		X		X				X		X	X
9			X	X				X		X			X	X	X
10	X		X	X				X		X		X		X	X
11	X		X	X		X				X				X	X
12	X		X	X		X						X		X	
13			X			X		X						X	X
14			X	X		X		X						X	X
15	X		X									X		X	X
16	X		X	X				X	X					X	
17			X	X		X					X			X	X
18	X		X	X	X	X			X		X	X			X
19			X	X	X	X	X								X

The locations of the intersections 1–19 are predicted in the map of Figure 1.

	Top high priority
	High priority
	Medium priority

Table 3: Cost-effectiveness evaluation of infrastructure measures.

Measure	Cost-effectiveness evaluation/cost
Design of horizontal and vertical element	Not expected to be cost-effective in most cases, due to the increased implementation costs.
Engineering infrastructure measures-speed management	Expected to be >1:1 due to low implementation costs
Road marking	2.76:1 7,500 € per km
Signs	8.6:1 50,000€–300,000 € per junction
Lighting system	7:1 to 9:1
Barriers systems	8.7:1–32:1 130,000 €–220,000 € per km
Roadside features	7:1
Redesign and reconstruction of intersections	2.5:1 to 1 3.8:1 from 1,100,000 €

5.2 Cost-effectiveness assessment of measures

The selection between various infrastructure safety measures is usually based on economic evaluation. As budgets for road safety policies and activities are not infinite, politicians have to make decisions regarding the best implemented policies. The criteria used in most countries, when deciding about policies and budgets, are mainly suitability, lawfulness, legitimacy and efficiency [24]. Cost-effectiveness is a technique used for the evaluation of road safety investments. The cost-effectiveness ratio of a road safety measure is defined as the number of accidents prevented by the measure per unit cost of implementing the measure [29,30]. In Table 3, the cost-effectiveness evaluation of the proposed infrastructure safety measures are presented based on data of literature review. The suitability of an investment depends on the high safety effect with the low implementation cost.

6 CONCLUSIONS

The results of RSA were carried out on the 50 km long interurban road, "Amphipoli-Drama", with the aim of identifying features of the road network operating environment that may be potentially dangerous. The importance of the provided connection of this road is high as it facilitates the high volume of traffic. Emphasis was placed on the principles of positive guidance, forgiving road and self-explanatory design consistent with road users' expectations while recognizing their information needs, limitations and capabilities. The proposed improvement measures can be implemented to address various road safety issues raised. Road safety issues can rarely be solved with a single measure in general, a combination of measures covering different elements of the road system is required. Since there are no "magic recipes" for infrastructure related to road safety measures, cost-benefit and cost-effectiveness analyses combined with the specifics in each case are imperative for the key issues to be addressed.

The proposed procedure of RSA in a national road is a guide method identifying points that present high levels of accidents and areas that can improve on level of safety by addressing deficiencies concerning signalling, barriers and pavement condition.

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EVALUATION OF STRUCTURAL FACTORS IN A THIRD-GENERATION PORT: METHODS AND APPLICATIONS

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ABSTRACT
UNCTAD identified the structural factors of commercial ports and introduced the general definition of 'port generation'. Third-generation ports were born with the container revolution in the last decades of the 20th century. The container became the main unit for the transport of goods, both intermediate and finished, between production and consumption regions. Containerization allowed the globalization of the economy and ports became the nodes of the global supply chain.
The paper proposes a methodology, based on consolidated theoretical models, to ex-ante evaluate the current and future scenarios of an international commercial port. The methodology has been applied to the container port of Gioia Tauro, with the aim to verify its ability to become a third-generation port as a generator of value added, rather than only a centre of cost. The results of the application allowed to identifying the development direction and the planned interventions in the port, as far as concerns general transport, agri-food logistics and mechanical logistics.
Keywords: agri-food sector, case study, general logistics, mechanical sector, port of Gioia Tauro, third-generation ports.

1 INTRODUCTION

UNCTAD described the ports' evolution according to the concept of generation (see [1]-[3], and the references included). The first-generation of ports was built close to the cities and the port-city was the dominant model for centuries. Ports of the second generation characterized the second part of the 20th century. They were built in proximity to industrial areas to supply the industrial plants of raw materials and final products. The third-generation of ports emerged after 1980s with the world-wide diffusion of container, combined with the growing requirements of the international trade. The ports became integrated transport centres and logistic platforms for international trade. From the economic point of view, third-generation ports increase the added-value of goods that transit through them, due also to the manipulations that are placed in the goods. In broad terms, it is possible to associate the exchange of final products to the first-generation ports, the exchange of raw materials (e.g. oil, chemical, steel and coke) to the second-generation ports; and the exchange of intermediate products mainly belonging to mechanical-automotive and agro-industrial sectors to the third-generation ports. New generations of ports raised in the last two decades ([4], [5]), but their description is out of the scope of this paper.

The paper presents a methodology, based on consolidated theoretical models, to ex-ante evaluate the current and future internal structural factors of a third-generation port (see references [6]-[12]). In other words, the methodology supports the evaluation of the internal

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characteristics of a third-generation port, considered as a 'fabric with its internal production processes' operating inside port areas ([13], [14]).

The port production is based both on physical (material) components, such as transport and logistic infrastructures, and on intangible (or immaterial) components, such as the research ones (segmented in research component inside each firm, inside an economic district, and inside the universities and the research centres). This paper does not consider the external interactions of the port with the closer urban areas and the strategic lines for their sustainable development ([15]-[19]).

The methodology has been applied to the container port of Gioia Tauro, with the aim to verify its ability to become a third-generation port as a generator of value added, rather than a centre of cost. The strategic development directions and the planned interventions for the port of Gioia Tauro have been defined inside the Regional Transport Plan of Calabria [20] and the strategic report of the Integrated Logistics Area of Gioia Tauro [21]. Detailed descriptions have also been recently published in [6]-[12]. The port of Gioia Tauro is specialized today in container transhipment operations, which need to be consolidated and strengthened; together with the connections to the European railway networks and the attraction of investments in the port hinterland.

The remaining part of the paper is articulated as follows. Section 2 presents a literature review on existing general methodologies to support the analysis and evaluation of transport and logistics operations inside a port. Section 3 reports the proposed methodology to analyse and evaluate the current and future scenarios of an international commercial port. Section 4 presents the current situation of the port of Gioia Tauro (Italy), and of the leading sectors of Calabria Region: mechanical and agri-food. Section 5 reports the scenarios and the planned transport interventions inside the port. Finally, the conclusions and the perspectives.

2 LITERATURE REVIEW ON EXISTING METHODS

The methodologies and models existing in large literature to support the analysis and evaluation of transport and logistics operations inside a port may be broadly classified into three main categories:

- *Transport Systems Models (TSMs)* ([22]-[25], and the references included), to estimate freight costs and flows on transport networks;
- *Logistics Models (LMs)* ([26]-[29], and the references included), to estimate logistics costs and flows of products along the supply chains;
- *Economic Impact Models (EIMs)* ([30]-[36], and the references included), to estimate freight flows and economic impact (e.g. value added, employment) generated by port operations (e.g. handled freight) and by investments (e.g. transport infrastructure).

The great variety of methods and models of each of the above categories may belong to one of the following three components (see Table 1). The Supply (S) component estimates the performances resulting from users (e.g. transport or logistics operators), infrastructures and services. The most common approach used is the topological one, given by a network model, with links, nodes and costs. The Demand (D) component estimates users' choices resulting from activities (production, consumption, trade) and infrastructure and service performances. The most common approaches used may be classified among behavioural, or micro-economic founded (e.g. random utility models); and not-behavioural, or not micro-economic founded (e.g. entropic-gravitational). The Demand-Supply (D-S) interaction component estimates the

Table 1: Classification of methods and models: outputs for each category ([23], [24], [26]).

Component/ Model	*Supply(S)*	*Demand(D)*	*D-S interaction*
TSMs	Transportation costs on transport network	Freight flows between trip origin-destination	Freight flows and costs on transport paths and links
LMs	Logistic costs on supply chain (distribution network)	Freight flows between the logistic nodes	Freight flows and costs in logistic nodes and distribution channels
EIMs	• Financial costs on value chain • Urban land for residential and service activities	• Financial flows between production-consumption regions • Urban population and employment generated by port	• Interregional trade flows and costs and economic impact in transport nodes • Urban flows of people (e.g. from residential areas to workplaces)

mutual interaction between users' choices and the performance of the infrastructures and the services. The approaches used may classified between equilibrium (e.g. user equilibrium/ system optimum [23] for TSMs, Computable General Equilibrium [33], [34] for EIMs) and not-equilibrium (e.g. network loading [23] for TSMs, Multi-Regional-Input-Output (MRIO) [29], [31] and Lowry [35] for EIMs, …)

Table 1 provides the outputs of each modelling component belonging to every category of models. As far as concerns the TSMs, the (S) component provides the costs on transport network, the (D) component the freight flows between the trip origins-destinations, the (D-S) interaction component the freight flows and costs on paths and links of the transportation network. As far as concerns the LMs, the (S) component provides the logistic costs on the supply chain (distribution network), the (D) component the freight flows between the logistic nodes of the supply chain, the (D-S) interaction component the freight flows and costs in logistic nodes and along the distribution channels. As far as concerns the EIMs, the (S) component provides the financial costs on the value chain; the (D) component the financial flows between production-consumption regions, the (D-S) interaction component the interregional trade flows and costs.

It is worth noting that freight flows are commonly expressed in units of load (e.g. container, swap body) or in vehicles between trip origin-destination inside TSMs, in units of load or in quantities between logistics nodes (e.g. warehouses, distribution centres, …) in LMs, and in monetary value between production-consumption regions inside EIMs. It is not univocally defined how to convert vehicles/units of load into quantities, or to convert quantities into monetary value and vice versa in order to change from one category of model to another.

3 METHODOLOGY

The methodology proposed in this paper allows to analyse and evaluate the current and future scenarios of an international commercial port according to the theoretical background presented in the previous section.

As far as concerns TSMs, the following analysis of transport variables related to a commercial port have been considered in this paper:

- supply: aggregated estimation of current handling capacity of the port, both on the sea-side (docks, quays, ….) and on the land-side (railway and road last-mile connections, …); and identification of critical elements of the existing infrastructures and services;
- demand: aggregated estimation of current and forecasted freight traffic, both on the sea-side (transhipment container traffic) and to the land-side (imported-exported freight via railway and road) according to existing sources, in order to determine the reference market of the port;
- identification of the strategic development directions and of the planned transport interventions.

The comparison of transport variables, by means of TSM, between different ports is executed according to the cost reduction minimization, as long as ports are considered a mere place of transit for goods (first- and second-generation ports). Given a port *a* and a port *b*, eq. (1) certifies that port *b* is more competitive than port *a* (transport costs are in absolute value):

$$transport\ costs\ in\ port\ b\ < transportcosts\ in\ port\ a \tag{1}$$

As far as concerns LMs, the general elements a supply chain, which include the maritime shipping service, are the following ([16], [18]):

1. production/processing area, where the freight is produced, and eventually processed;
2. consolidation centre, where the freight is consolidated into a container, or a swap body;
3. port of origin, where the container (swap body) is loaded on a container, or on a ro-ro, ship;
4. port of destination, where the container is unloaded and transported;
5. distribution centre, where the freight is unpacked from the container and distributed in smaller parcels;
6. selling /consumption place, where the freight is sold by retailer and/or finally consumed.

The third-generation port incorporates the activities 2 and 3, regarding respectively the consolidation and the deconsolidation (distribution) of freight (see Fig. 1).

The functional structure of a distribution centre is described in Fig. 2. The distribution centre receives the freight, consolidated in one cargo unit (e.g. container), from the port of destination and deconsolidates it into several smaller parcels (e.g. pallets) to be delivered to one (or more) selling/consumption area(s), where retailers (consumers) are present.

The distribution centre has some inputs and provides some outputs. The input of the distribution centre is the container, which arrives at the port of destination from abroad. The output is a

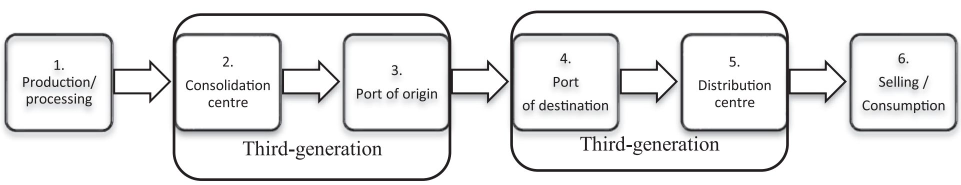

Figure 1: Main components of a supply chain.

Figure 2: Schematic representation of a distribution centre.

set of pallets (of freight), which are delivered to a number of retailers/consumers. Each retailer generally demands a small amount of freight: the minimum quantity is generally one pallet.

The following analysis of logistics variables related to a commercial port have been considered in this paper (see also [8], [11], [12]):

- current characteristics and critical elements of the existing supply chains connected with the examined port;
- potentialities of the existing supply chains, in order to determine the reference market of the port;
- strategic development directions and planned logistics interventions and estimation of the future logistic capacity of the port.

The estimation of logistics variables of a port, by means of LMs, is executed according to the criterion of transforming the port from a centre of cost to a centre of value added generation, as long as a port is considered a third-generation port. Given a port *a*, eq. (2) certifies that *a* is a third-generation port if (transport costs are in absolute value):

$$\textit{transport costs in port a} < \textit{added value in port a} \tag{2}$$

As far as concerns EIMs, a common method to estimate the economic impact of a commercial port relies on the MRIO approach (see [29], [30], [31]). MRIO models allow to estimating the direct, indirect and the induced impact, through the identification of inter-sectoral linkages. Recent studies allowed on MRIO provide an assessment of the port embeddedness inside the maritime trade network and inside the global supply-chains [32]. Some limitations of MRIO models (e.g., fixed production technology) could be solved in spatial computable general equilibrium models. The model of Norwegian economy [33] includes an explicit production function for the transport sector.

The following analysis of economic variables related to a commercial port have been considered in this paper:

- current economic impact (e.g. value-added, employment) generated by transport/logistic operations inside the port;
- potentialities of the port in order to determine its reference market;
- estimation of the future economic impact of the port.

The comparison of economic variables between different ports, by means of EIMs, is executed according to the criterion of the value-added maximization, as long as a port is considered a third-generation port. Given a port *a* and a port *b*, eq. (3) certifies that (third-generation) port *b* is more competitive than (third-generation) port *a*:

$$\textit{added value in port b} > \textit{added value in port a} \tag{3}$$

4 APPLICATION TO GIOIA TAURO PORT: CURRENT CONDITIONS, SCENARIOS AND PLANNED INTERVENTIONS

The port of Gioia Tauro, located in Calabria (Italy), is the first container transhipment port and one of the most important port for the automotive logistics of Italy ([6], [7], [8], [12]). The container traffic was 2.55 million of TEUs (Twenty-Equivalent Units) and the number of handled vehicles was 213,000 in year 2019; while in 2020 the container traffic increased of +26% respect to 2019.

Two terminal operators currently operate in the port:

- Terminal Investment Limited (TIL), belonging to Mediterranean Shipping Company (MSC) Group, which operates in container transhipment with lo-lo services;
- Automar, which operates in the automotive logistics with ro-ro services.

The port has a great expansion capacity to become a third-generation port, in terms of increasing added-value connected to the transit and manipulation of goods. On the other hand, there is a demand for logistics in Calabria related to different sectors of the regional economy. The most important sectors in Calabria are the mechanical and the agri-food ones.

The following paragraphs present the current transport infrastructures in Gioia Tauro (Section 4.1), a description of mechanical and agri-food sectors in Calabria Region (Sections 4.2 and 4.3).

4.1 Current Situation

4.1.1 Transport infrastructures

The strong infrastructural equipment of the port of Gioia Tauro makes it a competitive transhipment container port, in relation to other existing ports in the Mediterranean basin. Its second strength is represented by its advantageous location with respect to the intercontinental maritime routes, crossing the Mediterranean basin from Suez to Gibraltar.

The connection of the port of Gioia Tauro with the Italian and European railway networks is an element of weakness. Today the port is connected to the national railway network through

Figure 3: View of the port of Gioia Tauro (source: www.portodigioiatauro.it)

the single track and electrified line Rosarno -S. Ferdinando. The line has a double track, but only one is operational, since the terminal section necessary for connection with the Rosarno railway station is missing on the other track.

From the port of Gioia Tauro, through the Rosarno station, up to 20 weekly block trains were sent to the intermodal ports of Nola (Naples), Bari, Frosinone, Padua, Melzo (Milan), Bologna and La Spezia, for then in 2008, due to the continuing loss of competitiveness of the railway system compared to the road system, to the almost total cancellation of activities by train.

Road accessibility to the port area is guaranteed by the 'Mediterranean Motorway' Salerno-Reggio Calabria (connected to the port via a ring road) and by the SS 18.

From the point of view of performance characteristics, the railway network belonging to the national railway company Rete Ferroviaria Italiana (RFI), has a fairly heterogeneous configuration in terms of shape of the tunnels, maximum admitted train lengths and loads.

As regards the shape of the tunnels for combined transport, the Battipaglia (Praia) - Paola, Rosarno-Reggio Calabria, Sibari-Catanzaro Lido and Reggio Calabria lines have a P/C32 shape; while the Paola-Rosarno and Rocca Imperiale – Sibari -S. Antonello - S. Lucido has a P/C45 shape.

As regards the maximum axial mass, heterogeneous bounds exist, which are variable from category C3 (with limitations) to category D4 (with limitations) along the most relevant directions. In particular, the entire network is already characterized by category D4 (22.5 tonn/axle) with limitations. The Metaponto-Sibari-S. Antonello corridor has an axial mass of category C3 (20 tonn/axle) with limitations, while between S. Antonello and S. Lucido the axial mass category is C3 (20 tonn/axle). A further element of weakness is represented by the absence of a homogeneous double-track layout.

The road connections of the port with the motorway A3 Salerno-Reggio Calabria, that is subject to an ongoing structural modernization, is need to be maintained in order to allow to increase the level of service.

4.1.2 Mechanical sector

The mechanical sector in Calabria does not have high specialization indices in terms of the number of companies and employees, if compared to the rest of Italy. However, it is important in the regional economy, especially if evaluated in relation to three characteristics: capital intensity, highly qualified workforce, strong presence of engineers and high-level technical personnel [37].

The sector weights about one-third on the value of regional exports. It has local production units of world-leading multinational groups and presents interactions with universities and research centres of the area, but yet not fully structured.

The structure of mechanical production in Calabria is similar to the rest of Italy: some settlements of large leading companies are flanked by small and medium-sized manufacturing units. The sector's specializations, both in terms of number of firms and of employees, are that of metal products manufacturing, in particular of large metal carpentry

In Gioia Tauro there is one of the most dynamic mechanical firm of Calabrian territory, De Masi Industrie Meccaniche, which operates in the construction and trade of agricultural machinery. The firm invests massively in research and development to create and develop high-tech devices and products.

However, there are also other mechanical poles in the Calabrian territory, where the leading firm belongs to a multi-national leading company, are centred around of Nuovo Pignone in Vibo Valentia, and around of Hitachi Rail (ex-Ansaldo Breda) in Reggio Calabria ([38], [38]).

There is a high demand for mechanical logistics in Calabria, but this demand remains unsatisfied due to the following critical elements:

- the lack of some transport and logistics infrastructures allows the growth of the main existing activities in the port: transhipment and automotive logistics, and
- the presence of isolated large mechanical firms in Calabria region, linked with several small and poorly structured ones.

4.1.3 Agri-food sector

The agri-food sector is one of the most important in Calabria and it is a distinctive element of regional productions. The specificities of agri-food production in Calabria concern the olive oil and citrus sectors, as well as the cereal and bakery, and viticulture sectors. Calabria produces, if compared to the total production in Italy, more than 50% of clementine, more than 30% of oranges, more than 25% of mandarins, all the bergamots and cedars, about 25% of table olives and of fresh figs ([38], [39], [40]).

The positive trend of production and export of Calabria has recently affected the increase in the agricultural sector in the Southern Italy. The value of regional agricultural production has recorded an annual increase of +10.6%. The performance from Calabria was mainly determined by the positive trend of olive growing, citrus fruits and vegetables. The production of olive oil in 2019 doubled, thanks above all to the province of Reggio Calabria; Calabria, together with Campania and Puglia, contributed to the growth of olive oil production at the national level, which, with an increase in the volume of production of 27.6% and in the added value of 29.6%, represents the agricultural product that recorded the best performance in 2019. Moreover, among the most representative fruit and vegetable products of the Calabrian territory, fennel is also worthy of note: the district of Crotone stands out nationally for the production of this vegetable [39].

Among the most important industries in the agri-food sector, there are: Callipo and Intertonno (tuna), VegItalia and GIAS (frozen food), Liquirizia Amarelli (licorice), Capua1880 (citrus) which are well-known all over the world [38]. Other important agri-food industries are: Mangiatorella (mineral waters), Ilcar (meat processing), Fattorie Del Sole and Calabrian Milk Associations, Fattoria della Piana (dairy products), Distilleria F.lli Caffo (liqueurs), OP Interpiana and Agrumaria Reggina (citrus fruits), Antiche Vigne di Pironti, Ceraudo, Librandi, Statti, Tenuta del Conte, Tramontana, Val di Neto, Zagarella (wine).

The agri-food sector and the related logistic infrastructures present several critical elements [39]. In most cases, they have few employees, and have a poor degree of horizontal and vertical integration. The production chains are sometimes incomplete and companies are forced to import local products (figs, citrus fruits, olive oil) from outside the Region, due to the high prices deriving from the regional production and the inefficiencies in the primary sector [39].

The limited availability of dedicated transport and logistics infrastructures does not allow to respond to the needs of the regional agri-food production. In particular, there are no cold-poles for the logistics, with refrigerated warehouses that allow the storage and the manipulation at different temperatures. The lack of specific infrastructures, that guarantee the cold chain, does not allow to manage large quantities of perishable products, which characterize the production of Calabria, nor to manage seasonal products deferred over time, as in other Italian regions (e.g. port of Salerno in Campania).

4.2. Scenarios and planned interventions

The container transport market of the Euro-Mediterranean region is constantly increasing, even if there is a strong competition between the Mediterranean ports. Some estimates, indicate for 2025 a number of containers handled between 78 (instability case) and 84 million TEU (recovery case) in the Mediterranean basin ([41], [42]).

The completion of Gioia Tauro as third-generation port could meet the demand of transport and logistics of mechanical and agri-food companies, on one side; and boost the growth of these sectors in the economy of Calabria, on the other side. The strategic development scenarios, defined in ([20], [21]), aim to support the development and the integration of existing supply chains, to enhance the Gioia Tauro hinterland in order to attract mechanical and agri-food factories, operators, transport and logistics companies, encourage mechanical and agri-food production for the local and the international markets.

This section proposes the set of planned transport interventions (Section 4.1) and the interventions for the realization of the mechanical and agri-food logistics scenarios (Sections 4.2 and 4.3).

4.2.1 Planning transport interventions

Strategic development directions towards third-generation port of Gioia Tauro are proposed and based on three general objectives defined in [20]:

- objective five, which concerns the logistics system and the port system;
- objective six, which concerns the core system of Gioia Tauro;
- objective seven, which concern network integrations;
- objective nine, which concerns specific measures to improve safety and security in ports.

The objective five is finalized to increase and improve the quality and competitiveness of the logistics services provided through an approach of synergy and coordination, which guarantees functional and managerial integration of the port systems, starting from the integration of the nodes in the European core network with the nodes of the comprehensive European network. Specific measures must be envisaged to increase regional GDP, starting with the advanced engineering, agri-food, mechanical and automotive cruise and tourist port sectors [20].

The objective six is finalized to the economic development of Calabria, related to the development of the economic and transport macro node of Gioia Tauro in the Euro-Mediterranean and intercontinental context. The overall promotion of the area must be developed at a unified regional level, through communication channels for the presentation of the overall supply of services and infrastructures in the area. Specific measures are envisaged for the simplification and attraction of investments, giving impetus to the development of the hinterland, starting with the establishment of a special Economic Zone (SEZ) and of an Integrated Logistics Area [21]. The transhipment in Gioia Tauro must be consolidated and strengthened, including through the activation of a gateway, and specific node interventions, supported by research and operational applications [20].

The objective seven is finalized to aim at an overall improvement in the performance of the infrastructural system for the different types of traffic, starting with the TEN-T infrastructures. It is necessary to act on the recovery and modernization of the existing infrastructural capital, on the bottlenecks of rail and road connections for short and long-range accessibility, on the existence and quality of last-mile connections, on regional and local linear and nodal infrastructures, on pedestrian and cycling systems. An observatory must be provided for monitoring the costs and times of construction of the infrastructures.

The objective nine is finalized to development of a mobility system with the vision of zero victims on the road as a reference target by 2050; safety must be expressed in terms of safety and security, with specific references to safety in the port area.

The different actions should allow increase added-value in the sectors mainly connected to the port: general logistics [8], agri-food logistics [11], mechanical and automotive logistics [12].

The general logistics interventions are composed of interventions aimed to:

- the expansion of the port infrastructure (sea-side), and
- the increase of the railway and road infrastructure (land-side).

The planned interventions related to smart town, research and development are respectively proposed in [9] and [10].

4.2.2 Scenario and interventions in the mechanical logistics

Global firms currently operating in the mechanical sector (e.g. automotive), whose intermediate and final productions are generally distributed among several plants, look for a third-generation port as a generator of value-added, rather than a centre of cost. This could happen when the port is equipped with:

- material infrastructures, such as logistics and storage areas, intermodal centres, last-mile connections with railway and road networks;
- immaterial infrastructures; concerning tax incentive tools, research and training centres, ICT (Information Communication Technology).

The above dotation of infrastructures ensures the third-generation port to be embedded inside the maritime trade network and inside the global supply-chain.

The port of Gioia Tauro aims to add a ‘third-generation function’ by enhancing the role of the large industrial agglomeration of about 1,500 hectares present in its hinterland, destined to industrial, production and service activities ([43], [44]).

Given the current situation presented in the previous section, the scenario aims to achieve the following objectives:

- favour the development of connections and the strengthening of the logistic capacities of the international groups settled in the port of Gioia Tauro;
- enhance the port hinterland to attract businesses, operators, local and international transport and logistics companies, which carry out entrepreneurial, commercial or handling activities, storage of goods related to the logistical processes of mechanical and automotive.

The scenario of mechanical logistics will be implemented through the design and, therefore, the implementation of interventions in the Integrated Logistic Area of the port of Gioia Tauro [21].

The cluster of planned interventions is located within the industrial area of the port of Gioia Tauro, inside the municipalities of Gioia Tauro, Rosarno and San Ferdinando (Fig. 4).

The decision to locate the interventions in this area is closely linked to the necessity to guarantee the connections determined by the proximity to the motorway network and the availability of areas already partially equipped with material and immaterial infrastructures.

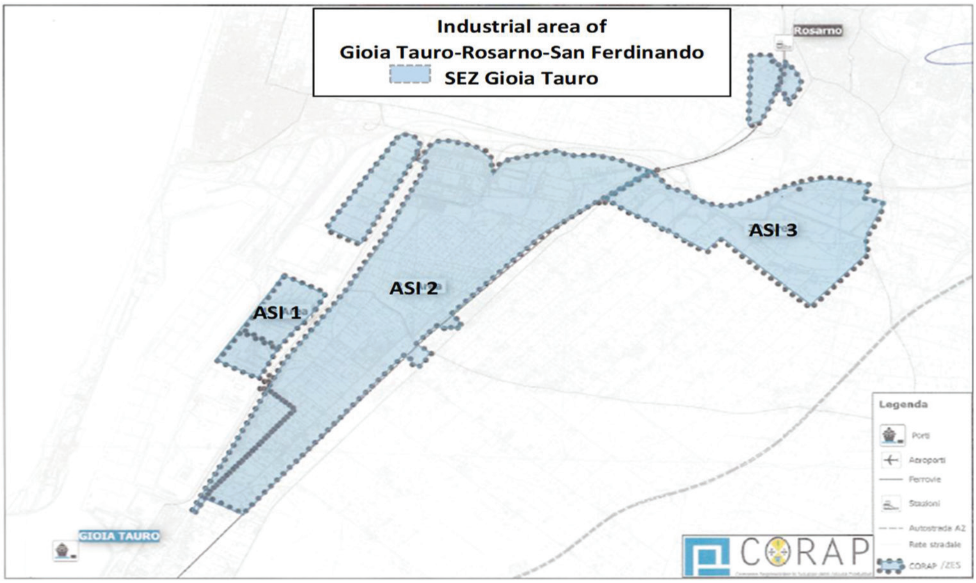

Figure 4: Industrial area of port of Gioia Tauro (source: [43]).

The cluster of interventions in mechanical logistics is composed of three sub-groups (see a detailed description in [12]):

- automotive logistics: multi-floor terminal for cars, retraining of yards and complementary areas, special connecting roads;
- light maintenance: dry dock, container repairing and cleaning, light mechanical platform;
- general infrastructures, for increasing level of service and security of the port.

4.3. Scenario and interventions in the agri-food logistics

Firms and logistic companies currently operating in the agri-food sector tend to locate their consolidation/distribution centres (Fig. 1), which are mainly refrigerated warehouses, inside port areas, in order to reduce or eliminate the transport costs connected to the trips from to consolidation centre to the port of origin, and to the trips from to the port of destination to the distribution centre. They look for a third-generation port as a generator of value-added, rather than a centre of cost. If the port is adequately equipped with material infrastructures and immaterial infrastructures, the port is candidate to become fully embedded inside the (containerized) supply-chain, in other words to become a third-generation port.

The agri-food logistics scenario (see [20], [21]) is based on the development of a cold-pole, considering the current conditions and potentialities of the agri-food sector of Calabria.

The scenario, moreover, foresees the definition of a logistic network inside Calabria, that is based on several logistic platforms that will include (Fig. 5):

- intercontinental nodes, complementary to the European nodes active in the Northern Range (Gioia Tauro);
- international nodes, for international production, such as tuna, and for international distribution (Lamezia and Sibari);

Figure 5: Schematic representation of the potential locations of the agri-food logistics nodes at intercontinental, international and national scale (source: [20]).

- national nodes, for regional or interregional productions in Southern Italy and for national distribution (Vibo Valentia, Locri, Crotone);
- regional nodes, for regional or interregional productions and for regional or interregional distribution.

The realization of agri-food logistics scenario takes place through different planned interventions, that are located in the industrial area close to the port of Gioia Tauro to guarantee their connection with the road and the railway networks.

The planned interventions for agri-food logistics in Gioia Tauro port are: cold-pole, transport and energy supply, general infrastructures (see a detailed description in [20] and [11]). The cold-pole is the core intervention and includes: refrigerated warehouses, railway tracks and road connections to the national motorway and rail networks, yards and service areas; expropriation of areas. Transport and energy supply concerns the realization of plants for the production of renewable energy from sea waves [45], from wind and solar energy, from the closer dam along the Metramo river, from the regasification. General infrastructures concern the extension of the level of service and level of security in port area.

5 CONCLUSIONS

The paper presented the methodology, based on consolidated theoretical models, to evaluate the current and future scenarios of an international commercial port. The methodology proposed some general criteria (equations) that allow to certify if a commercial port belongs to a third-generation port category. The goods manipulated inside a third-generation port belong mainly to the following sectors: mechanical and agro-food logistics, and general cargo.

The methodology has been applied to the container port of Gioia Tauro, with the aim to verify its ability to become a third-generation port as a generator of value-added, rather than a centre of cost. The strategic development directions and the planned interventions as far as concerns general transport, mechanical and agro-food logistics, have been defined inside the

Regional Transport Plan of Calabria [20] and the strategic report of the Integrated Logistic Area of Gioia Tauro [21].

The general transport interventions aim to achieve the following specific objectives:

- strengthen transhipment, increasing the infrastructural sea-side supply to support the activities of settled terminal operators, and to encourage the settlement of new terminal operators;
- enhance the combined transport (ship-to-rail and ship-to-road), by means of the gateway and of the increased accessibility of A2-Motorway.

The planned sea-side port interventions aim to:

- maintain the level of service of the quays and yards to the standards required by the container and ro-ro terminal operators;
- increase the capacity of the port in order to receive and handle last-generation container and ro-ro ships;
- settle further operators in the port.

The above sea-side transport interventions could increase the transhipment handling capacity of the port by at least 1 million of TEUs; the capacity of the deep sea e ro-ro services of at least 100.000 cars, and the capacity of the short-sea ro-ro service of 200.000 trucks of articulated lorries.

The land-side port interventions aim:

- the composition of trains of 750 meters, which is the current standard in Europe, allowing to reduce the travel cost on the railway mode;
- the improvement and the realization of the road last-mile connections between the port and the Italian A2 Motorway; thus, incrementing the accessibility to the domestic freight production areas and consumption markets.

As far as concerns the agri-food logistics, the interventions allow the establishment and consolidation of regional agri-food productions, which is one of the pillars of the regional economy. The core set of interventions concerns the realization of a cold-pole with two refrigerated warehouses for rail-road, and two refrigerated warehouses for all-road transport.

The estimations about their storage capacity is 40,000 pallets for the ‘rail-road warehouses’ and 40,000 pallets for the ‘all-road warehouses’.

As far as concerns the mechanical logistics, the planned interventions aim to:

- boost the logistics related to the automotive sector, currently present in the port;
- support the development and consolidation of regional mechanical productions, which is one of the pillars of the regional economy.

The core intervention is the multi-floor terminal for assembling and storing cars, in line to the development trajectories observed in the main European ports manly dedicated to automotive logistics, such as Hamburg and Zeebrugge.

The planned interventions in the port of Gioia Tauro are identified according the methodology defined, in order to overcome the above criticalities and to create a specific industrial area inside the port-hinterland.

The presented methodology is suitable to be applied in other ports, that are experimenting a similar evolution towards the third-generation nature.

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PREDICTING TRAFFIC ACCIDENTS AND THEIR INJURY SEVERITIES USING MACHINE LEARNING TECHNIQUES

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ABSTRACT

Traffic accidents are among the most censorious issues confronting the world as they cause numerous deaths, wounds and fatalities just as monetary misfortunes consistently. According to the world health organization (WHO) reports, 5,18,3626 accidents took place in India in the year 2019. Factors that contribute to these road crashes/ traffic accidents and resulting injuries include inattentive drivers, unenforced traffic laws, poor road infrastructure, driving in bad weather conditions and others. This investigation effort establishes models to select a set of influential factors and to build up a model for classifying the severity of injuries. Machine learning models can be applied to model and predict the severity of injury that occurs during road accidents. One such way is to apply unsupervised learning models such as Apriori, Apriori TID (transaction id), SFIT (set operation for frequent itemset using transaction database) and ECLAT (equivalence class clustering and bottom-up lattice traversal) which analyze the unlabeled traffic accidents dataset and determine the relationship between traffic accidents and injury. This research work is helpful for traffic departments to decrease the number of accidents and to distinguish the injury's seriousness extensive simulations were carried out to demonstrate the unsupervised learning algorithms for predicting the injury severity of traffic accidents. Apriori algorithm predicts the patterns in 962 milliseconds, Apriori TID (transaction id) algorithm predicts the pattern in 557 milliseconds, SFIT algorithm predicts the pattern in 516 milliseconds and ECLAT algorithm predicts the pattern in 124 milliseconds. ECLAT algorithm took less time compared to all the other algorithms.

Keywords: Apriori, ECLAT, machine learning, traffic accidents

1 INTRODUCTION

Traffic accidents cause considerable economic, monetary and social losses to individuals, families and the nation as a whole. As indicated by the death approximation provided by the world health organization (WHO), there is an alarming increase in the number of traffic accidents [1][2]. Each year the lives of approximately 1.2 million are lost with 50 million individuals injured [1].

Road traffic accidents have reached alarming levels every year across the world. Every year, roughly 1.2 million people are dies due to road traffic crashes worldwide. A similar trend can be seen in countries with the most traffic accident-related death rate per 100,000 namely Zimbabwe (61.90), Liberia (52.03), Malawi (51.62), Gambia (47.51), Togo (46.62), Tanzania (46.17), Rwanda (45.90), Sao tome (45.52), Burkina Faso (44.94) and Burundi (44.94) [3]. The public is suffering from many major injuries even after many years of the accident [4]. Consequently, road crashes became the main source of human death and injuries all around the world.

There are several factors due to which accidents occur. These are: rear-end collisions, side-impact collisions, side swap collisions, rollover, hit and run, head-on collisions, single-car accidents, multiple vehicle pile-ups and drunk and drive. There are two types of accidents namely: Major accident injury and minor accident injury. Major accident injury is one in

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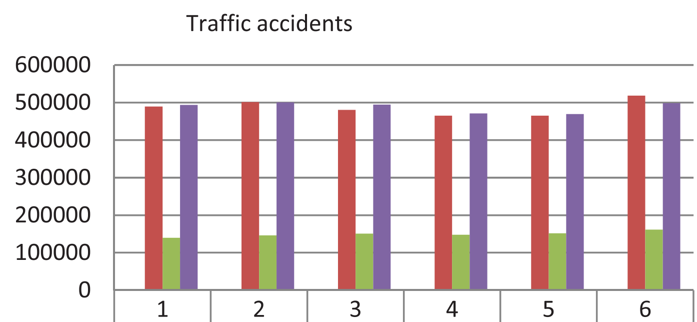
which at least one casualty endures genuine injury requiring hospitalization. Minor accident injury is one in which the victim(s) doesn't require hospitalization.

Figure 1 represents the graph of traffic accidents categorized by three parameters i.e., road accidents, the person dies and injuries that happened on roadways from 2014 to 2019, the data provided by the Government of India (ministry of road transport and highways research wing, New Delhi). The descriptive model was developed using clustering techniques and association learning techniques [5][6]. Around 140 lives have been lost across the country due to road crashes. Different states which recorded maximum traffic accidents are Delhi, Maharashtra, Gujarat, Assam, Kerala, Karnataka, Rajasthan, Punjab and Tamil Nadu [9][10].

Figure 2 represents the different traffic accidents with related injuries. For example, being drunk and driving may lead to some fractures or may lead to death. Different types of injuries are brain injuries, spine fracture, pelvic fracture, back and spinal cord trauma, skull and maxillofacial, rib fracture, broken bones, whiplash, scrapes and cuts, internal bleeding, and herniated disc, knee trauma, soft tissue injuries, etc. The existing system used some of the machine learning algorithms like the random forest (RF), K-nearest neighbor and decision tree to identify the accidents, accidents vehicles, and injuries which provides less accuracy [7][8].

The proposed work is a real-time application that is helpful for the government sector to decrease the number of traffic accidents and its injuries severity. Unsupervised learning is a machine learning technique, which helps to discover the hidden patterns and information in the given datasets. Mainly unsupervised learning algorithm needs only data sets without trained or labeled and tested which does not consume time for calculating, analyzing and predicting accidents severities. We use association rule mining which predicts the severities of road crashes [11][14]. Association rule mining is used to discover the relationships between data items within large datasets. Association rule uses support and confidence to identify the most important relationships of data items in less amount of time. The main idea of this work



Year	2014	2015	2016	2017	2018	2019
Road accidents	4,89,40	5,01,42	4,80,65	4,64,91	4,64,91	5,18,32
Persons Death	1,39,67	1,46,13	1,50,78	1,47,91	1,51,41	1,61,51
Persons injured	4,93,47	5,00,27	4,94,62	4,70,97	4,69,41	4,98,40

Figure 1: Trends of traffic accidents, the person dies, and injuries by road category from 2014 to 2019.

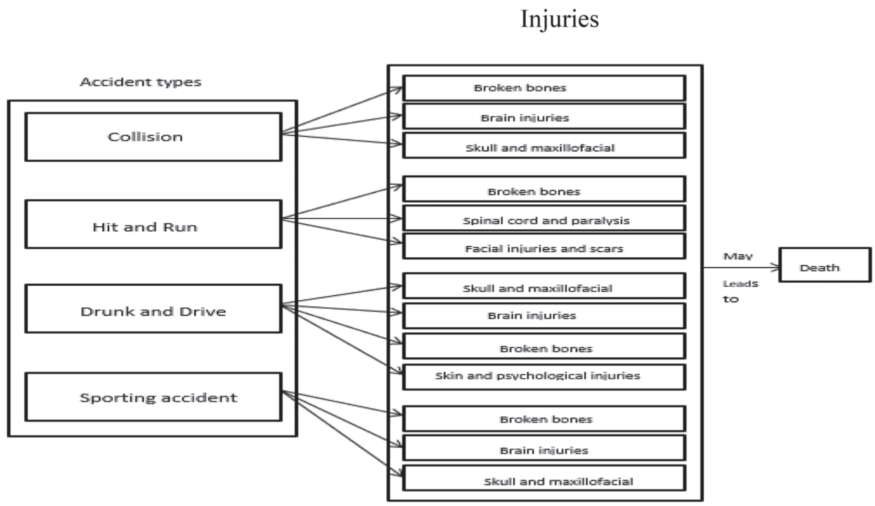


Figure 2: Different traffic accidents with injuries.

is to minimize traffic accidents and their injuries because the public is suffering from many major injuries even after many years of accidents [17][18]. We took four machine learning algorithms i.e., Apriori, Apriori TID (transaction id), SFIT (set operation for frequent itemset using transaction database) and ECLAT (equivalence class clustering and bottom-up lattice traversal) which analyze the unlabeled traffic accidents dataset and determine the relationship between traffic accidents and injury.

This finding of the paper is as follows:

- Identify the correlation between the accident types i.e., drunk and drive may lead to hit and run, etc.
- Discovering the relationship between the different categories of injuries i.e., brain injury may lead to spinal cord injury, etc.
- Identifying the correlation between accident types with injuries i.e., collision may lead to brain injury, broken bones, etc.

Our work can be helpful in several future scenarios to save people's lives by early prediction of the type of accidents with related injuries to get proper treatment because so many people are suffering from major injuries even after many years of the accident. The paper is organized as follows: section 2 represents related work, section 3 describes proposed work, section 4 presents a comparative analysis of existing methodologies, section 5 shows the results and section 6 presents a comparative analysis of proposed methodologies. Finally, we concluded this paper.

2 RELATED WORK

In this section, we briefly discussed existing methodologies and their contributions. We also acknowledge the limitations of existing methodologies.

Xiao Li, et.al, [11] identify the impact of traffic accidents and injury severities which is dependent on three angles, example, daily travelers (included age, sex, and so forth.), vehicles (included vehicle type and number, vehicle transmission and so on.) and street (included pavement condition, cross-area type and so forth.).

Siddharth Tripathi, et.al, [12] proposed a model called CBIT (cloud-based intelligent traffic system) to detect traffic accidents and alerts the traffic authorities of the location of an accident. They took three principle targets: examining emission, accident detection and unique vehicle ID. The proposed model used some sensors i.e., NO_X, SO_X, CO and temperature sensors like MQ135, MQ3 and LM35 for detecting the emission. Accelerometer (ADC MCP3008) and force resistive sensors are used to detect accidents. Unique vehicle ID will be assigned to all the vehicles which are helpful for traffic authorities to monitor the vehicle. GPS (UBLOX G7020) and GSM (SIM 900) modules are used for sharing the location of accidents with traffic authorities. The WiFi port of raspberry pi is used to aggregate the information and then it is stored in the cloud.

Naji Taaib Said Al Wadhahi, et.al, [13] proposed a model for the detection of accidents and prevention system to lessen traffic hazards utilizing Arduino boards (Atemga 328) and some sensors such as IR. This framework includes two stages: detection and prevention of traffic accidents. Here is a sensor (IR) that helps to identify the accidents and alarm the individuals by sending messages. Messages are sent through GSM (SIM 900D) module. These sensors notify the driver about accidents.

JIAN ZHANG, et.al, [14] compared injuries severities predictions using statistical methods and machine learning algorithms. The accident seriousness, street geometry and traffic status were gathered at road separate territories in Florida [24]. They assessed the two most utilized statistical methods which are the multinomial logit model and the ordered probit (OP) model. They have used machine learning algorithms i.e., K nearest neighbor (KNN), decision tree, RF and support vector machine (SVM) to predict the accident injury severities. The RF method is best for large and extreme accidents while the OP model was the most fragile one.

Guang Yu, et.al, [15] proposed a strategy for taking gander blockage and controlling traffic accidents. Speed and lane changing control systems are used to reduce traffic accidents. They took a portion of the countermeasures to keep away from the auto collisions through administration of path, controlling rate of crashes, adjusting of speed and traffic data.

Fabio Galatioto, et.al, [16] proposed a model i.e., MAIA (model and methods for accident prediction and its impact assessments) toolkit for predicting traffic accidents and their injury severities. The authors in this paper concentrated on three different problems: accident rate prediction, estimation of both injury and non-injury collisions and estimation of collision security level. Finally, we discussed existing works and their contributions. We surveyed so many papers and their solutions which are related to our work. There are so many issues in existing work, so we compare these solutions with our proposed solutions. Our work has made more contributions to these issues.

3 PROPOSED WORK

Road traffic accidents and their injuries are the leading cause of death. The proposed research work is a real-time application that is helpful for traffic departments to decrease the number of traffic accidents and distinguishes the injury severities. This application is also helpful for doctors to give better treatment. The proposed system makes use of association learning methods to discover the hidden patterns between traffic accidents and related injury severities.

Figure 3 shows the design for anticipating traffic injury severities. The system predicts the traffic accidents and their injury severities dependent based on old datasets. The users here will be the Admin, Member (City Traffic In Charger, Doctors) and Visitor (Public). The administrator maintains the entire system. The administrator is responsible for the city in charge of creating and uploading the necessary data for processing. Member (City Traffic In

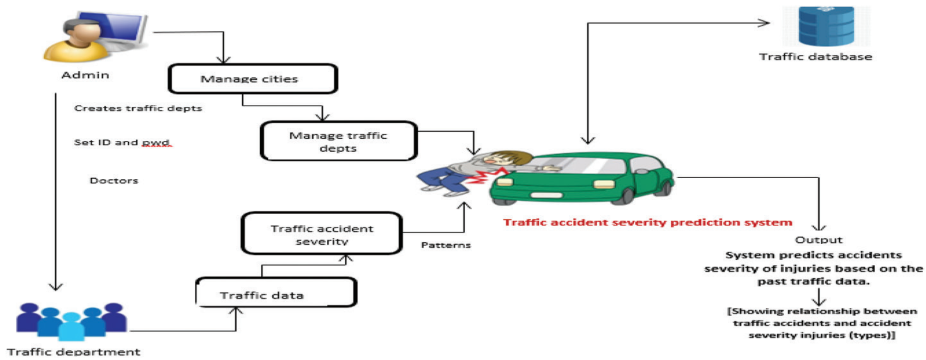


Figure 3: Architecture diagram of traffic accident severity.

Charger, Doctors) City In Charge is a service receiver and responsible for uploading the traffic accidents data into the server. Visitor (Public) Visitor is a user who visits the application. The visitor has limited accessibility.

3.1 Methodology

Unsupervised learning methods help to extract the relevant information and structure in unlabeled datasets. It takes less time to extract the patterns from the given datasets. Association rule discovers the patterns using support and confidence [19]. In this paper, we are using four types of algorithms i.e., Apriori [20], Apriori TID (transaction id) [21], SFIT (set operation for frequent itemset using transaction database) [22,29] and ECLAT (equivalence class clustering and bottom-up lattice traversal) [26] to discover the patterns of traffic accidents and its injury severities.

3.1.1 Apriori algorithm

Apriori algorithm is one of the association rule learning [20]. Defining association rule mining is as follows:

Let $I_{item} = \{i_1, i_2, i_3,\ldots\ldots,i_n\}$set of n attributes (items). Let $D_{transactions} = \{t_1, t_2, t_3,\ldots\ldots,t_n\}$ set of n transactions (database). Different attributes are used in the Apriori algorithm i.e., Itemset, K-itemset and null sets where the collection of more items including zero is called itemsets. Itemsets include k-items is called k-itemsets. Itemset that does not include any items called null (empty) set.

In each transaction *T* contains a subset of items taken from *I*. Transaction *T* includes an item set *A*. If *A* is a subset of *T* then the support count σ (*A*) can be written mathematically,

$$\sigma(A) = |\{t_i | A \subseteq t_i, t_i \in T\}| \quad (1)$$

Where | | indicated the number of items in a set. Transactions of items in an itemset with support [32] [33].

$$S(A) = \sigma(A) / N$$

Where S(A) is greater than or equal to some defined threshold.

An association rule for the Apriori algorithm with an expression form A->B where A and B are disjoint itemsets i.e., A ∩ B = ø. It can be measured by using support and confidence. The definition of support and confidence are:

$$\text{Support s(A -> B)} = \frac{\sigma(A \cup B)}{N} \tag{2}$$

$$\text{Confidence c(A -> B)} = \frac{\sigma(A \cup B)}{\sigma(A)} \tag{3}$$

In the above equation (i) and (ii) where support helps to measure the rule in a given itemset and confidence discovers frequently appearing items in a transaction T.

Figure 4 shows the processing of the Apriori algorithm. The data processing means extracting relevant data from the accident database or server. Now applying the Apriori algorithm for generating rules to predict the accident patterns and represents the results of generated patterns.

Algorithm 3.1 Apriori Algorithm for generating frequent itemsets

STEP 1: Examine old data sets then regulate the support (s) for each item.
STEP 2: Create L_1 (only one item set).
STEP 3: First use L_{k-1}, and then unite L_{k-1} to create candidate K sets.
STEP 4: Examine the generated candidate K item set and then create support for the candidate in each item set K.
STEP 5: Append item set frequently, till C = Null set (ø).
STEP 6: Create all non–empty subsets for frequent itemsets.
STEP 7: Examine the confidence for all non-empty subsets. If the examined confidence is higher or equal to the given confidence, then append to the association rule.

3.1.2 Apriori TID Algorithm

Apriori algorithm discovers all the patterns or relations in the given item set. It also discovers the number of candidate items [21].

Suppose $T_{transactions}$ $\{t_1, t_2, t_3, \ldots t_k\}$, (K ≥1) (transaction sets, T_{item} $(T_i) = (I_1, I_2, I_3, \ldots, I_m)$, (m ≥ 1) itemsets and K-itemsets $(I_n) = \{i_1, i_2, i_3, \ldots i_n\}$, (n ≥ 1) k-itemsets where $K_{itemsets} \subseteq I$.

Figure 5 shows the processing of an Apriori TID (transaction id) algorithm. Examine the old data items to regulate the support(s) for each item. Find C1, C2, C3,…..Ck and then

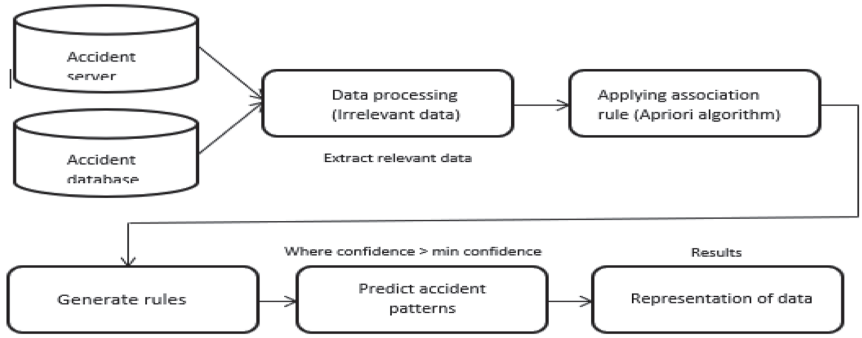


Figure 4: Processing of Apriori algorithm.

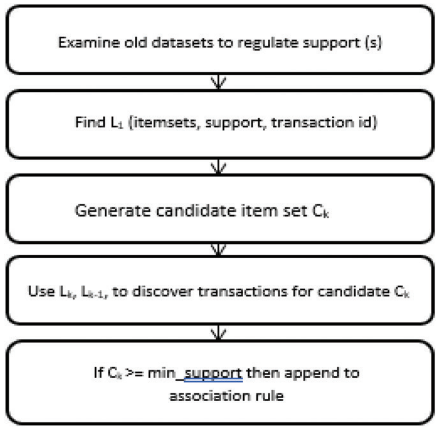


Figure 5: Processing of Apriori TID (transaction id) algorithm.

generate L_1, L_2, L_3,…..L_{k-1} for frequent item set. Generate candidate C_k set by using L_{k-1}. Append item set frequently till C = Null set (ø). If $C_k \geq$ min-support then append to the association rule and displays the results of generated patterns [30][31].

Algorithm 3.2 Apriori TID Algorithm for generating frequent itemsets

STEP 1: Examine old data sets then regulate the support (s) for each item.
STEP 2: Find C1'
STEP 3: Generate L1 (Frequent item set).
STEP 4: Find C2', C3' …..
STEP 5: First use L_{k-1}, and then unite L_{k-1} to create candidate K sets.
STEP 6: Examine the generated candidate K item set and then create support for the candidate in each item set K, by comparing with the previous step (but not with the original dataset as we did in the Apriori algorithm).
STEP 7: Append item set frequently, till C = Null set (ø).
STEP 8: Create all non–empty subsets for frequent itemsets.
STEP 9: Examine the confidence for all non-empty subsets. If the examined confidence is higher or equal to the given confidence, then append to the association rule.

3.1.3 SFIT (Set operation for frequent itemset using transaction database)

SFIT algorithm is a combination of apriori algorithm which is used for data mining and different set operations like union and intersection are used [22].

For constructing K-itemsets, we use frequent itemsets (K-1). Union is formed for K and (K-1) itemsets. Employing intersection operation for transaction identifiers (tids) of itemsets.

Itemsets {M} transactions with Tid 2, 4, 6, 8 and {N} transactions with Tid 1, 2, 3, 5, 6, 7, 8 i.e., T(M) = {2, 4, 6, 8} and T(N) = {1, 2, 3, 4, 5, 6, 7, 8}. The itemsets {M, N} is the union of MN itemsets. In order to find out the tids for {M, N} by using intersection principle as shown below:

$$T(MN) = T(M) \cap T(N)$$

$$= \{2, 4, 6, 8\} \cap \{1, 2, 3, 4, 5, 6, 7, 8\}$$

$$T(MN) = \{2, 4, 6, 8\}$$

If the obtained output is greater than the given minimum support, then it will be included in the frequent itemset otherwise it will be eliminated [29].

Algorithm 3.3 SFIT Algorithm for generating frequent itemsets

STEP 1: Examine old data sets then regulate the support (s) for each item.
STEP 2: Find C1 (candidate item).
STEP 3: Generate L1 (based on C1 finding L1 i.e., frequent one item set).
STEP 4: Find C2, C3…….., (based on C2……..Cn finding L2…..Ln).
STEP 5: Find C4, when C4 = ø (null set) then stop the iteration.
STEP 6: Find frequent itemset (L) and subsets showing the relationship between items.
STEP 7: Finally compare with minimum specified confidence, the rules where confidence is greater than or equal, add to the strong association rule.

3.1.4 ECLAT (Equivalence class clustering and bottom-up lattice traversal)
ECLAT algorithm is an acronym for equivalence class clustering and bottom-up lattice traversal [24][25]. In ECLAT algorithm, it will make use of vertical transactions id (tid) sets inside the database, clustering of equivalence classes and lattice traversal (bottom-up approach). This algorithm reduces storage and cost [26]. ECLAT algorithm metamorphose the parallel database into perpendicular database i.e., from item set format Apriori$<TID_x, X_1, X_2,\ldots,X_k>$ to transaction id(tid) set format ECLAT$<X_k, TID_1, TID_2,\ldots,TID_k>$. ECLAT algorithm uses a vertical approach tidset database includes a list of items: the set of all transaction identifiers called tidset of A, which is represented as tidset(A) = $\{T_i, T_{id} \mid T_i \in Di\ X \subseteq T_i\}$. Several elements in tidset (A) are called support of A i.e., represented as σ (A) = |tidset (A)|.

Figure 6 shows the processing of an ECLAT algorithm. From the accident database or server extracting the relevant information from the database is called data processing then applying the éclat algorithm for generating association rules that predict the accident patterns and represent the results of generated accident patterns.
Algorithm 3.4 ECLAT Algorithm for generating frequent itemsets

Step 1: Generate a tidlist for every item by scanning the database.
Step 2: Tidlist of {a} is precisely the item set of transactions {a}.
Step 3: Bisect the tidlist of {a} with the other items of tidlist, the resulting of dividing tidlist is {a,b}, {a,d}, {a,c}…..

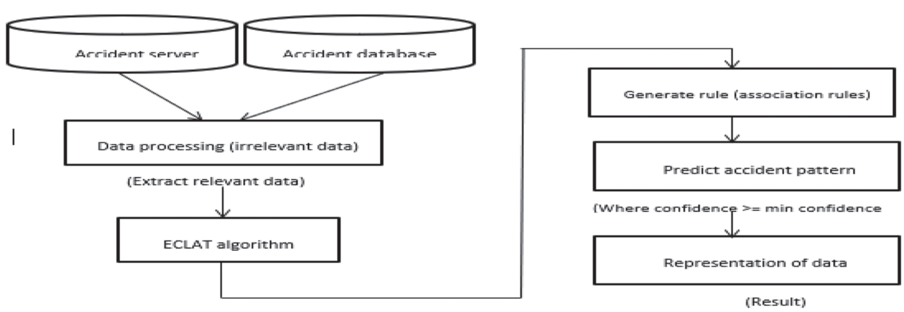


Figure 6: Processing of ECLAT algorithm.

Step 4: Recurrent 1 on {a} – given in the database.
Step 5: Replicate these steps for all other item sets.

4 COMPARATIVE ANALYSIS OF THE EXISTING METHODOLOGIES

In this section, Table 1 shows the performance of existing methodologies.

Table 1: Comparative analysis of other methodologies.

No.	Data sets used	Algorithms or techniques used	Accuracy	Limitations
[11]	>300 datasets of traffic accidents.	KNN, decision tree and association rule.	KNN – 80.26% Decision tree – 73.68%	Small Dataset, hence, less accurate results.
[12]	500 traffic accident data.	Raspberry pi, emission sensors, GPS and GSM modules.	70.1%	The cost of hardware components is very high.
[13]	5,000 datasets of traffic accidents	KNN, decision tree, RF, SVM.	Overall accuracy ranges from 44.7% to 80.5%	Used labeled/ trained datasets that lead to very low accuracy.
[14]	>6,000 datasets of Michigan traffic accidents.	RF, logistic regression, naïve bayes and ada boost.	Logistic regression – 74.5% Naïve Bayes – 73% Ada boost – 74.5% RF – 75%	This model is using only Michigan datasets and has less accuracy.
[15]	3,643 traffic accident data of china.	Bayesian network and information entropy.	Overall accuracy ranges from 50 to 90%	Using fewer china datasets leads to less accuracy.
[16]	1,130 traffic accident datasets.	Convolution neural network (CNN).	87%	Used fewer amounts of datasets which leads to low accuracy.
[17]	7,000 traffic crashes datasets of the UK	Feedforward neural network (FNN), SVM, fuzzy c means clustering-based feed-forward neural network (FNN-FCM) and fuzzy c means based support vector machine (SVM-FCM).	FNN – 69% FNN-FCM – 70.50% SVM – 73% SVM-FCM – 74%	They used both training and testing datasets but the accuracy is less compared to the proposed methodology.

Table 1: (*Continued*)

No.	Data sets used	Algorithms or techniques used	Accuracy	Limitations
[18]	150 traffic accident trained datasets.	Convolution neural network (CNN).	78.5%	Even though the datasets are small, this method gives less accuracy.
[19]	>10,000 traffic accident datasets of USA.	Naïve bayes, RF, MLP, Ada boost.	NB – 74% RF – 77% MLP – 77% AB – 75%	This framework predicts traffic accident severity in the USA but the accuracy is less.
[20]	> 4,000 traffic accident datasets.	Ordered a probit model, an artificial neural network (ANN) and an ensemble model.	OP – 80% ANN – 86.50% EM – 87%	Accuracy is less compared to the proposed methodology.

5 RESULTS ANALYSIS

In this paper, all the below figures represents the outcome of our proposed methodology. For predicting the injury patterns of traffic accidents, we are using unsupervised learning or association mining rules. The unsupervised learning method gives relevant information from the given datasets without training and testing those datasets. We took four algorithms to predict the traffic accident severities. All the four algorithms Apriori, Apriori TID, SFIT and ECLAT generate the patterns in three ways i.e., firstly, accident type with injuries for example collision may lead to spine fracture with 75% confidence means that 75% possibility of people frequently met with this accident severity. Second, discovering the relationship between the different categories of injuries for example brain injury may lead to spinal cord injury with 85% of confidence. The third category is to find out the relation between the accident types for example drunk and driving may lead to hit and run with 90% of confidence. Almost all the algorithms will generate the same kind of patterns but the difference is efficiency will vary. In this paper, we find out that the éclat algorithm is the best mining method to generate the patterns because it takes less storage capacity, cost and time.

Figure 7 shows the prediction of traffic accident severity patterns using ECLAT algorithm. This algorithm uses bottom up approach for mining frequent itemsets. ECLAT algorithm does not scan whole database to generate support values. The output of this ECLAT algorithm showed in three ways i.e., accident type with injuries (collision may leads to brain injuries and broken bones with confidence 100%), discovering the relation between different type of injuries (brain injury may leads to broken bones with confidence 100%) and also it helps to find out the accident types (drunk and drive may leads to hit and run with 100% confidence). It is best suitable for large and small datasets and discovers the pattern in 124 milliseconds as shown in above figure. This algorithm is best for mining when compare to Apriori, Apriori TID and SFIT algorithm because it takes less storage capacity, cost and less time.

As per the survey of the World health organization (WHO), Figs 8 and 9 shows the causes of traffic accidents. Different types of accidents due to collisions, violations of traffic rules and highways [28]. These are some of the old datasets which are taken from the government survey document to show how the traffic accidents took place and also shows the number of accidents, the person dies and the person injured from 2017 to 2018.

LHS	->	RHS	Confidence
Brain Injuries	->	Broken Bones	100.00%
Brain Injuries,Collision	->	Broken Bones	100.00%
Brain Injuries,Hit-Run	->	Broken Bones	100.00%
Broken Bones,Collision	->	Brain Injuries	100.00%
Broken Bones,Hit-Run	->	Brain Injuries	100.00%
Collision	->	Broken Bones	100.00%
Collision	->	Brain Injuries	100.00%
Collision	->	Brain Injuries,Broken Bones	100.00%
DrunknDrive	->	Broken Bones	100.00%
DrunknDrive,Skull & Maxillofacial	->	Broken Bones	100.00%
Hit-Run	->	Broken Bones	100.00%
Hit-Run	->	Brain Injuries	100.00%
Hit-Run	->	Brain Injuries,Broken Bones	100.00%
SportingAccident	->	Skull & Maxillofacial	100.00%

Execution Time: 124 milliseconds

Figure 7: Predicting severity patterns using the ECLAT algorithm.

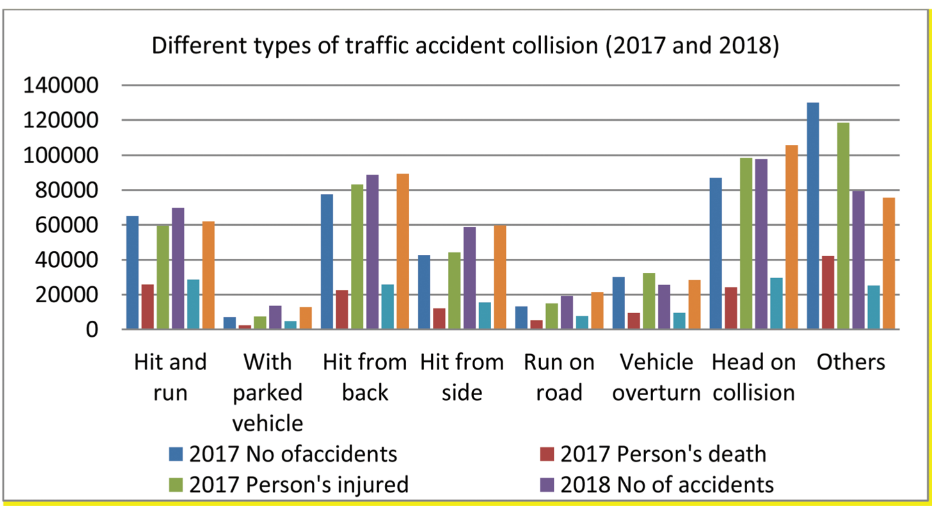


Figure 8: Different types of traffic accident collision of 2017 and 2018.

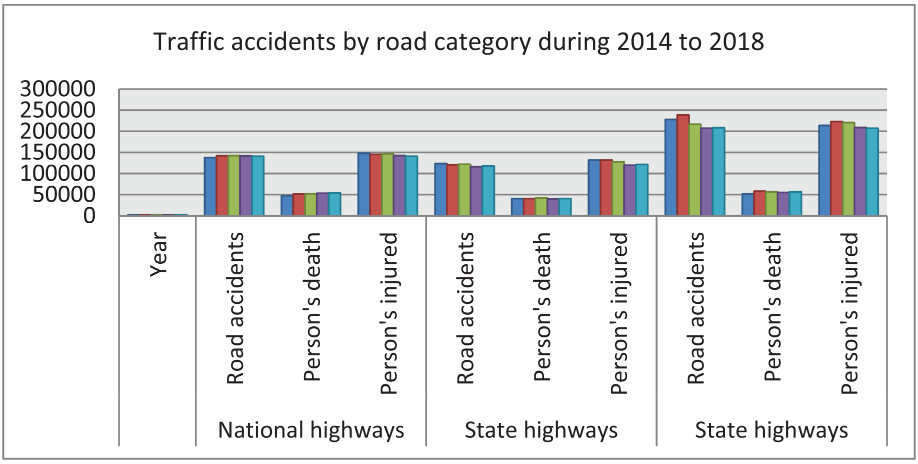


Figure 9: Traffic accidents due to traffic rules violations during 2017 and 2018.

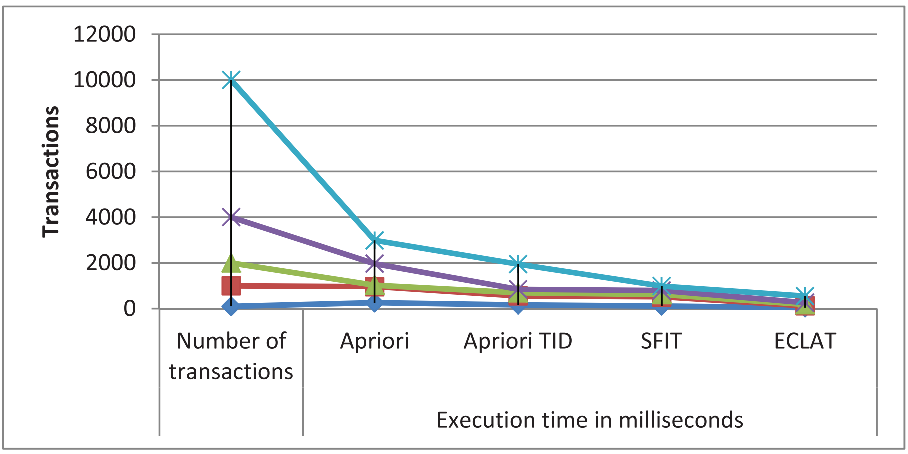


Figure 10: Time comparison between Apriori, Apriori TID, SFIT and ECLAT algorithm.

6 COMPARATIVE ANALYSIS OF PROPOSED METHOD

In this paper, we have done various experiments to scrutinize the performance of the proposed algorithms. The number of datasets 100, 1,000, 4,000 and 10,000 were taken to compare all the algorithms (Apriori, Apriori TID, SFIT and ECLAT) in terms of execution time represented in different colors.

Figure 10 shows the graphical representation of the execution time of all four algorithms. ECLAT algorithm is the best for finding out the frequent itemsets compared to other algorithms because the éclat algorithm took less time to discover the patterns of traffic accident severities from the given accident datasets.

7 CONCLUSION

Road safety represents a significant part of our lives, so it is necessary to reduce traffic accidents and their injury severities. The proposed work is a real-time application that is helpful for traffic departments as well as doctors to reduce traffic accidents and for providing proper treatments for injuries. In this paper, we used unsupervised learning methods to discover the patterns of traffic accidents and their injuries from the given datasets. The simulation results of the proposed methods for predicting traffic accident severities i.e., the Apriori algorithm predicts the patterns in 962 milliseconds, the Apriori TID algorithm predicts the pattern in 557 milliseconds, the SFIT algorithm predicts the pattern in 516 milliseconds and the ECLAT algorithm in predicts the pattern in 124 milliseconds. ÉCLAT algorithm is the best algorithm for discovering patterns of a traffic accident and its injury severities from the given traffic accident datasets, because it takes less time, cost and storage.

The proposed system in the future can be enhanced with a module like the Public notification module, Query Module and Predicting reasons for accidents. Public notification (SMS/Email): We can add a public notification that helps people who met with an accident and they can get help to reach the hospital and get treatment. Query module: We can add a query module for the interaction between administrator and member (Traffic in charger or Doctor) to maintain more traffic accident records and the public can get better treatment for a particular predicted injury. We can also predict reasons for accidents which helps traffic departments to take precautionary measures.

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PLANNING TRANSIT-ORIENTED DEVELOPMENT (TOD): A SYSTEMATIC LITERATURE REVIEW OF MEASURING THE TRANSIT-ORIENTED DEVELOPMENT LEVELS

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ABSTRACT

The recent decades have witnessed a growing trend towards transit-oriented development (TOD) to achieve sustainable development through maintaining the integration between land use and transport systems. It is believed that measuring the TOD level 'TOD-ness' is important for TOD planning. However, it has been found that the spatial studies and quantitative methods that comprehensively measure TOD-ness are still limited. Furthermore, some methods do not have standard frameworks, and they vary according to the research context and orientation. Accordingly, the major focus of this paper is related to the multi-criteria decision making (MCDM), quantitative measuring methods that prioritize potential areas for intervention. Based on a systematic review, this paper aims to evaluate the existing studies published between 2000 and 2020 in relation to TOD-ness measurement and its operationalization. This systematic review is an attempt to present the dominant methodologies used and analyse their pros and cons. Accordingly, the paper introduces a theoretical review of the TOD concept, its evolution and methods employed from the previous studies. Then, an analytical review is conducted for the eligible records, that are extracted from eight databases according to certain criteria. Finally, it is expected that the outcomes of the research will provide insight for further studies, in addition to presenting the best-adopted methods and assisting in developing MCDM models that measure TOD-ness quantitively.

Keywords: multi-criteria decision making (MCDM), TOD planning, TOD level, TOD measurement, transit-oriented development (TOD).

1 INTRODUCTION

Over the past few years, the population growth of cities has increased rapidly as a result of urbanization. The urbanization process impacts the spatial distribution of land use and the mobility demand created by the distribution of activities. Unfortunately, many urban areas across the world have become increasingly car-oriented, threatening the sustainability of the road structure as well as creating social, economic and environmental imbalances. Consequently, further road construction policies have failed to cope with the substantial increase in travel demands resulting from this rapid motorization, causing a transport vicious cycle. Meanwhile, transit-oriented development (TOD) has grown significantly, aiming to achieve sustainable development by maintaining the integration between land use and transport systems [1].

The concept of TOD has a variety of definitions, as given by many researchers, the researchers and stakeholders describe it differently in light of their different perspectives on the concept. Consequently, there is no general definition of TOD. Most commonly, TOD is

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considered a way to densify neighbourhoods, reduce congestion and increase accessibility and transportation options through land-use clustering and mixing. This could thus have a great impact on reducing the distance and time required for car trips; allowing a greater proportion of trips to be made via non-motorized transport; and reducing car ownership in some households. As a corollary, this reduces total transportation costs and helps to create a more liveable community [1], [2], [3].

The formulation of the TOD concept appeared in the USA during the late 1970s and early 1980s. However, it really gained prominence during the 1990s, through its strong association with the emerging planning movements in the USA at that time when Peter Calthorpe published 'The Next American Metropolis' in 1993. Therefore, studying TOD is crucial as it is considered as a specific component for smart growth, new urbanism sharing some common principles with the aforementioned movements.

More recently, a growing number of cities and regions have embraced the concept of tod, its planning policies and implementation at different scales for instance, Europe, in the Netherlands, Sweden and Austria. Asia, in Tokyo and Toyama in Japan. Australia, in Perth, in the USA such as California, Portland, the New Jersey transit village and many more. some cities have gained popularity through their tod qualities and successes, such as Curitiba (Brazil), Hong Kong (China), London (united kingdom) and Johannesburg (South Africa) [2]. In addition to that, the implementation of TOD varies, it can be utilized to develop around existing transit stations, or develop new transit stations [3]. Therefore, there is a crucial need to measure the outcomes of TODs, implementing more quantitative understanding of the existing situation when planning for TOD, and it is thus important to measure the overall TOD-ness (TOD level) of urban areas in order to carry out effective TOD planning [4].

It was found that the previous research concerned with TOD, are focused on two major orientations; first, the successful engagement of the private sectors in TOD implementation while the second, is the evaluation of TOD stations around transit corridors, such as bus rapid transit (BRT) or light rail transit (LRT). However, almost all of these studies have dealt with 'evaluating' completed TOD projects, with very little interest in 'measuring' TOD-ness. Further, most cases are mainly qualitative and with little quantitative analysis, simply discussing the success or failure of TOD plans at that location. Only limited research has been found that assesses TOD quantitively. In 2004, Schlossberg & Brown [5] carried out such study; assessing the TOD of 11 sites in Portland, Oregon using only the walkability indicator. This is considered to be an example of measuring TOD-ness quantitatively, utilizing ArcGIS as a spatial platform using one indicator. The literature shows that 'comprehensive' location-based TOD-ness measurements had not been attempted before that time. Over the past few years, some efforts have been made by researchers to fill this gap by proposing different spatial quantitative methods and models to measure TOD-ness comprehensively. Although the number of studies investigating this issue is growing, they are still limited and fragmented.

Accordingly, this research paper is an attempt to tackle this gap, as the spatial studies and quantitative methods that measure the TOD-ness of an area comprehensively are limited. Thus, the paper is an attempt to provide a useful synthesis of existing studies on TOD-ness measurement, through providing methodological and empirical systematic reviews. Moreover, it's major orientation relates to TOD-ness measuring methods that prioritize potential areas for intervention. The paper will focus on multi-criteria decision making (MCDM) methods and techniques that are employed for TOD-ness measurement in TOD planning, as a tool to support decision making process. Therefore, this paper seeks to examine the following research question:

Q: How did the studies measure levels of TOD quantitively using MCDM methods to prioritize the potential areas for an intervention?

As, MCDM process is one of the different methods that has proposed since the 1970s to select an optimal solution for a given situation from a set of alternatives and decision criteria [6], and has been used in many fields. In transportation planning, [7] was one of the first authors to propose an MCDM tool to be used for TOD planning purposes. This tool was aimed to 'assess the suitability of land use around proposed LRT stations of the Memphis metropolitan area' by applying the analytic hierarchic process (AHP) method in conjunction with geographic information systems (GIS). In 2005, Banai [8] added small improvements to convert it into a decision-support system through a 'land development concept plan'. Although the topic of measuring TOD employing MCDM methods has attracted considerable attention from researchers during the last decade, the number of studies is still limited, especially in developing countries.

2 METHODOLOGICAL FRAMEWORK

In this paper, a systematic review is adopted to synthesize the state of different research on measuring TOD-ness quantitatively and to build a strong theoretical basis. The systematic review is conducted using the selected studies from different electronic databases. Then, it provides literature analysis, which will be discussed with regard to the research gap. Finally, the paper presents the conclusion of this review by providing a summary of insightful findings, lessons drawn and directions for future research. This review follows the PRISMA method, as it is preferred in reporting items for systematic reviews and meta-analyses, which ensures a transparent, systematic review. In basic terms, the selection of publications follows the four stages of identification, screening, eligibility and inclusion.

2.1 Search strategy

The systematic search was conducted between since December 2018 and December 2020 and yielded more than 2,535 records. The different electronic databases were screened to continue the literature search. They sometimes use 'Boolean operators' – simple words such as AND, OR and NOT – to combine and/or exclude specific terms for a quick search. Initially, an explorative keyword search was employed to determine appropriate search terms for the study. The search used different combinations of the generic terms 'transit-oriented development' and 'TOD measurement'. Additionally, the search strategy did not restrict the search to the transportation planning domain but also considered related fields such as urban planning and geo-information science. The combination of search terms listed in (Table 1) was used (with some syntactic variants) and applied to the title, abstract, keywords and full text of the databases mentioned previously.

Based on the most frequent terms used to describe TOD-ness measurement, found in several studies, the researchers constructed some search strings – for example (Web of science):

TS (Topic) = ('transit-oriented development' OR 'TOD') AND TS= ('TOD-ness' OR 'TOD level' OR 'TOD Evaluation' OR 'TOD Measurement' OR 'Measuring TOD' OR 'MCDM' OR 'TOD planning' OR 'Potential locations for TOD' OR 'Planning Support System' OR 'Spatial Decision Support System' OR 'Spatial Models' OR 'Smart Growth').

2.2 Literature identification

Initially, the scholarly databases were searched to determine which ones provided relevant results, through an extensive search of international journals, articles, reports and other

Table 1: [Keywords used in guiding the systematic review and the literature search. *(Source: Authors.)*].

Keyword list		
Generic	Transit-Oriented Development (TOD) – TOD measurement	
Specific	TOD Measurement	MCDM methods
	Measuring TOD	Potential locations for TOD
	TOD Evaluation	Planning Support System (PSS)
	TOD Planning	Spatial Decision Support System (SDSS)
	TOD-ness	Spatial Models
	TOD level	Smart Growth

scientific web resources. In addition, a sample from grey literature resources was also included in the search, such as theses, dissertations and conference proceedings. The literature search was conducted across eight electronic scholarly databases: (1) Google Scholar, (2) ProQuest, (3) Science Direct, (4) Scopus, (5) EBSCOHost, (6) Springer, (7) SAGE and (8) Web of Science. In cases where publications appeared relevant but were not accessible, the researchers attempted to gain access via scientific communities (e.g. Egyptian Knowledge Bank (EKB), ResearchGate or Academia). After the initial database searches, preliminary criteria were established to narrow down the results, focusing on studies that were: (1) written in English and (2) published between 2000 and 2020.

This time-frame was chosen to limit the search based on the literature review conducted by [9]. Malczewski's review [9] revealed that the publishing of MCDM spatial methods such as SMCA-related (spatial multi-criteria analysis) articles has increased exponentially post-1995, with modest developments between 1990 and 1995. Finally, after narrowing down the results, the next inclusion/exclusion criteria were implemented, and the search was further refined.

2.3 Selection of eligible literature: Inclusion/exclusion criteria

In the first stage, the authors eliminated irrelevant papers through an initial screen. The foci of the eliminated papers were on TOD node typologies, TOD node models, TOD street design, TOD road network analysis, TOD real-estate prices, residential location, residential self-selection, or other irrelevant fields. Moreover, papers focusing on travel behaviour and/or environmental outcomes related to travel were also eliminated because they did not meet the scope of the current paper. During the second stage, titles and abstracts were screened to determine which ones are accepted for full paper screening. This was accomplished through selecting eligible literature resources based on a predefined criterion. The papers therefore had to meet the following inclusion criteria to be considered relevant for the research approach:

1. Papers must have a TOD measurement (quantitative) focus. Additionally, they must include planning aspects in line with TOD features and principles.
2. Papers must contain applied research that includes indicators or criteria identification.
3. Papers must have used an MCDM method or analytical technique (paper scope).

After removing the duplicated records, all titles and abstracts were screened based on the inclusion/exclusion criteria in order to select the relevant studies. Finally, 25 potentially relevant papers that matched the search criteria were identified for further analysis. Following each step in the previously mentioned databases, the final search results were exported into Mendeley.

3 SEARCH RESULTS AND SELECTION PROCEDURE

The four-level structure of the literature search and selection process is illustrated in PRISMA flow diagram (see Fig. 1). During the screening process of the full texts, 195 records were excluded due to the following reasons:

1. They evaluated suburban neighbourhoods or focused on measuring one indicator only which did not fall within the scope of the research.
2. They were less focused on TOD measurement or discussed several topics at once.
3. They contained a theoretical basis for measuring TOD-ness or TOD evaluation but did not carry out a case study implementation.
4. Although some studies aimed to bring out optimal TOD locations using one of the MCDM methods, they used it to classify the transit node typology needed for the areas under study.
5. They met the selection criteria, but they focused on a TOD behavioural study.
6. Although the American study by [10] was found to evaluate the potential locations for TOD, but it had a slightly different focus. It focused on developing an index model to identify the areas where changes in the TOD-related variables were consistent with a positive or negative relation to the surrounding urban environment.

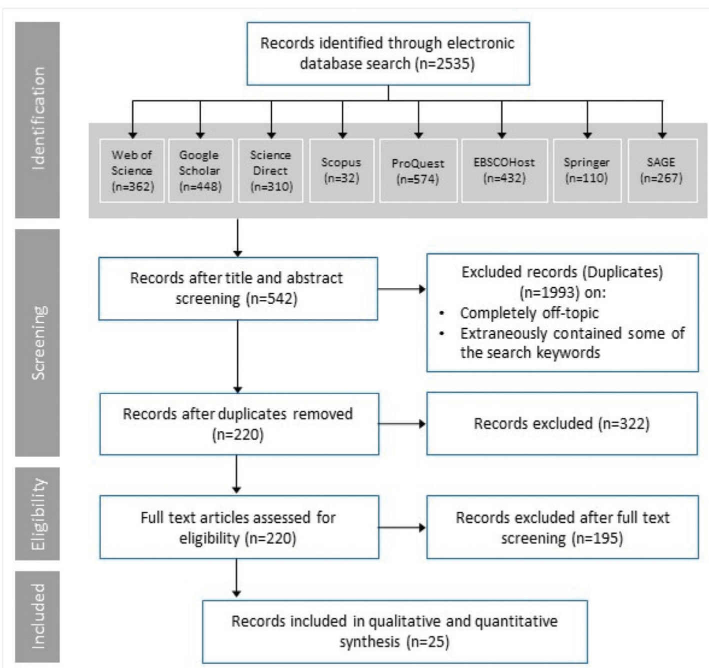

Figure 1: [The PRISMA flow diagram for the literature search. (*Source: Authors.*)]. The PRISMA diagram adopted from www.prisma-statement.org.

7. The review study by [11] was found to discuss only the necessary criteria and indicators that should be included in any study to establish an accurate TOD index which is used to measure TOD-ness. However, it did not discuss the methodology of measuring of TOD-ness via TOD index.

After the full-text screening, a total of 25 eligible records were included for data extraction and analysis and the review results are presented below through a narrative synthesis approach.

4 DESCRIPTIVE ANALYSIS OF LITERATURE RESULTS

The discussion of results was analysed according to the following: the origin of the studies, frequently analysed case studies and the transport modes included in the studies, the time of publication, the methods employed, the buffer size of the area of analysis and the main aims of the research.

The first observation was that the number of studies on TOD-ness evaluation or measurement has grown over the last decade, which has contributed to a better understanding of TOD indicators and criteria. However, no systematic reviews were found in the review results discussing this point. Moreover, the literature is dominated by studies from Northern Europe and South Asia, particularly the Netherlands (NL) and Indonesia.

As shown in (Table 2 and Fig. 2), it was found that 18 out of 25 selected studies were conducted in Northern Europe and South Asian countries, while four studies took place in Southern Europe and Western Asia, two studies were conducted in North America, particularly in the USA, and only one study in East Africa, particularly in Addis Ababa.

The second observation was that Arnhem-Nijmegen (SAN) was the most frequently analysed metropolitan area (*n* = eight, 32%) followed by Jakarta Metropolitan Region (JMR) (*n* = four, 16%). Most studies focused on more than three modes (11 studies), whereas fewer analysed only a single mode (nine studies) or two modes (two studies). Train stations were the most frequent focus of the studies (*n* = seven, 28%) and were included in multi-mode studies. Additionally, BRTs were included in eight studies (including one in which it was the exclusive focus), LRTs in ten studies (exclusively in two), MRTs in 11 studies (exclusively in two), rail-based stations in 20 studies (exclusively in three) and public transit stations in 21 studies (exclusively in five).

Another point observed was that a significant increase in the number of studies focusing on measuring TOD-ness had not been identified until very recently, after the TOD index appearance in 2007. One study was found in the years 2010, 2013, 2019 and 2020; two in 2012; four in 2014; three in 2015; and five and seven were published in 2017 and 2018, respectively. Concerning the publication year, although the review time-frame was from 2000 to 2020, some studies included earlier influential studies. These earlier studies were descriptive qualitative studies that discussed the indicators used to measure or evaluate TOD-ness.

Concerning the MCDM methods employed, the reviewed literature demonstrated a variety of methods being used, divided between analytical methods and simulation-based methods. A cumulative number of ten analytical techniques was obtained by grouping them into three main categories (suitability analysis, hierarchal decision process and statistical analysis). Among the most reliable methods, suitability analysis techniques (*n* = 19, 76%) were most common, especially multi-criteria decision-analysis (MCA) techniques, followed by spatial statistical analysis (*n* = 11, 44%) and then the hierarchal decision process (*n* = five, 20%). Much more common were those studies that used combined methods, which accounted for 52% (*n* = 13) of the total studies. Among the least reliable methods, the multivariate

Table 2: [Results of literature analysis sorted by year of publication ascendingly. *(Source: Authors.)*].

Reference	Case study	Type
[6]	Ahmedabad, India	Thesis
[12]	Gaza city, Palestine	Thesis
[13]	--	Book Chapter
[14]	SAN – NL	Thesis
[15]	SAN – NL	Thesis
[16]	Azambuja, Portugal	Research paper
[17]	SAN – NL	Conference paper
[18]	SAN – NL	Research paper
[19]	SAN – NL	Conference paper
[20]	SAN – NL	Dissertation
[21]	SAN – NL	Research paper
[22]	Rangsit Campus, Thailand	Research paper
[23]	Denver, Colorado, USA	Research paper
[24]	JMR, Indonesia	Research paper
[25]	SAN – NL	Research paper
[26]	Tehran, Iran	Research paper
[3]	Tehran, Iran	Research paper
[27]	JMR, Indonesia	Conference paper
[28]	Faridabad city, India	Research paper
[29]	JMR, Indonesia	Research paper
[30]	JMR, Indonesia	Conference paper
[1]	New Jersey, USA	Thesis
[31]	Depok City, Indonesia	Conference paper
[32]	Palembang city, Indonesia	Conference paper
[33]	Addis Ababa, Ethiopia	Research paper

regression method (n = one, 4%) was used in only one study by [16]. Moreover, the models were classified into four main categories (GIS-based, agent-based, AHP-based and statistical-based models).

The dominant models used were GIS-based models, which accounted for 92% (n = 23) of the total studies. Only the study by [23] used an AHP-based model without employing GIS, while the study by [3] was the only one that used an agent-based model, thus belonging to the category of simulation-based methods.

According to the studies that defined a specific radius for the area of analysis, the buffer size ranged from 300 to 1,200 m. Most of the researchers acknowledged that a 500 m boundary is a suitable distance for TOD development. However, the ‘pedestrian catchment area’ of built environment indicators found in ten studies (40%) measured the area within 800

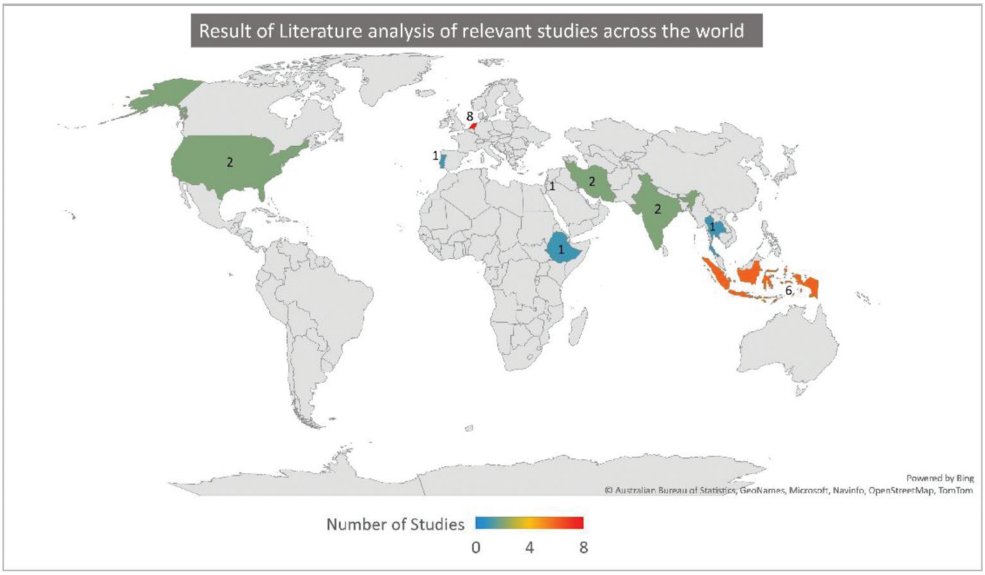

Figure 2: [The map depicts the results of literature analysis of relevant studies. (*Source: Authors.*)].

m around the stations, while seven studies (28%) measured within an area of 300 m and three studies (12%) within 500 m. The remaining four studies measured the area around the neighbourhoods or the stations within 400, 700 and 1,200 m each depending on the transport mode, corresponding station services and the context of the region. The reason for this disparity was highlighted by [15], who stated that a walkable boundary is not standard in all regions. For example, [34] defined a comfortable walking distance as a ten-minute walk within 609.6 m from the station in the context of American cities, while in the past 1,000 m (1 km) has been used as a comfortable walking distance for Australian urban settings. In conclusion, it is recommended for the study of TOD in different cities that the definition of an adequate distance for walking is based on the city context.

The main aims of the reviewed studies were grouped by the authors of this paper into eight different aims: (1) develop a TOD score for the study area, (2) measure the degree of TOD-ness of an area, (3) find station best allocation based on model/scenarios, (4) develop a framework to measure TOD-ness, (5) develop a GIS-based model to measure TOD-ness, (6) evaluate how the transit nodes function as TODs, (7) analyse the most feasible location for TOD planning or (8) develop DSS model used for choosing TOD site. Developing a TOD score, developing a GIS-based model for the study area and measuring the degree of TOD-ness of an area were the most extensively studied aims in the scientific work on this topic.

5 CONTENT ANALYSIS AND DISCUSSION

In this section, the discussion of the reviewed articles is grouped into seven topics: (1) the limited number of studies, (2) the indicators included in the studies, (3) the focus, TOD indices and scale of the studies, (4) the framework of analysis, (5) the methodological strengths and weaknesses of the studies, (6) stakeholder involvement and (7) study relevance for real-world practices.

5.1 The limited number of studies

It is quite surprising to find only two American studies in the review results, considering that TOD has received considerable attention in the USA and many American cities have undertaken TOD projects over the last decades. The notable thing about the literature review containing many USA studies that focused on the evaluation of existing TOD projects and discussed 'success/failure' factors at that location or the success of the project. In addition, only one study was found in African cities. Possible limitations to explain this are that selection bias might have occurred due to the exclusion of non-English records, some research papers were closed-access.

5.2 The indicators included in the studies

According to Calthorpe [34], TOD planning principles support the perspective of the 'physical-based TOD view', especially the walkable environment. Similarly, Cervero & Kockelman [35] focused on built environment principles and shed light on the '3Ds' (density, diversity and design), which are recognized as essential anchors in TOD planning. Dittmar & Ohland [36] also stressed the physical TOD aspects, while Ewing & Cervero [37] added 'two more Ds' as criteria of the built environment (destination accessibility and distance to transit), thus expanding it to the 5Ds. However, some researchers believe that it is not sufficient to analyse only physical TOD dimensions, despite their necessity. Hence, other researchers have tackled TOD from the perspective of the 'performance-based TOD view' and have moved beyond those variables to include others. For instance, Belzer & Autler [38] defined TOD from this perspective and Ewing & Cervero [39] added two more 'Ds', with demand management (including parking supply and cost) as the 'sixth D' and demographics as the 'seventh D'.

However, others have jettisoned the alliterative use of the letter D and employed their own formulations as shown in Fig. 3. Later, Evans et al. [40]'s report, identified the ten most frequently defined 'quantifiable' indicators to measure the existing TOD via an 'index'. Such an index allowed measuring all the indicators of TOD areas to identify which areas needed greater TOD-ness or better transit connectivity. As reported in a review study by Patel & Shah

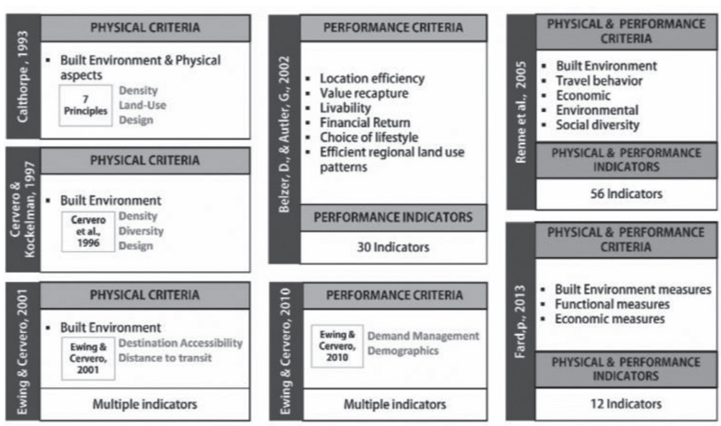

Figure 3: [Synthesizing the researchers' perspectives on TODs, their criteria and indicators. (*Source: Authors.*)].

[11], the necessary criteria to be included in any study in order to establish an accurate TOD index are: (1) density, (2) diversity, (3) walkable and cycle-able distance and 4) economic development. Regarding the indicators used in the studies, the number varied from four (in two studies) to 22 indicators (in one study). Furthermore, just over half of the studies (*n* = 22, 88%) used more than four indicators. The most frequently analysed indicators were density, diversity and design (*n* = 23, 92%).

Table 3 shows that five studies focused on physical TOD indicators only, while the majority of studies (*n* = 17, 68%) used physical and performance indicators. The literature acknowledged that since researchers' aims in regard to TOD vary, the indicators also differ. Further, the more the indicators included in any study, the more precise the results that the researchers will obtain. Several researchers, such as [3] tried to put this into practice by considering more comprehensive indicators in their study. They used public transit infrastructure indicators (i.e. route performance and service performance) and TOD-level indicators (i.e. density, diversity, design and economic development), which were evaluated at the neighbourhood scale. From the review, it was found that researchers such as [14], [15], [6], [18] excluded some indicators in their studies due to different limitations, including data availability (i.e. the meta-data for the dataset), time and energy resources.

For these reasons, some studies, such as that by [14], had to adjust some indicators, thus they became less precise. Further, the authors of six studies modelled the link between land use and transport by using Cervero's 1997 '3Ds' indicators. However, while these indicators can explain the relationship between land use and transport, they might not be comprehensive and efficient enough for the TOD-ness measurement of an area. As emphasized by many researchers, studies must include the '3Ds' and economic development indicators when measuring TOD-ness comprehensively. Further to this, some indicators change over time, such as accessibility, passenger load, etc., because these services differ across the duration of a day. Hence, it is highly recommended that a time-based dimension should be considered within TOD planning.

5.3 The focus, TOD indices and scale of the studies

It should be noted that TOD typically encompasses different types of development, as it sometimes refers to a development around new transit stations and sometimes refers to station re-development. The different foci of the studies revealed from the literature analysis are shown in Table 3. Some studies focused on a single TOD approach (*n* = 21, 84%) while others utilized both TOD approaches (*n* = two, 8%). From the review, it was noticed that Approach 1 (see Table 3) was the most adopted (*n* = 13, 52%) in the selected studies.

Many researchers, such as Singh, Fard, et al. [18], suggested that TOD planning for a region should address two approaches:

1. Approach 1: To identify the areas that surround high-quality transit but where TOD levels are low, and the transit orientation of these places needs improvement. Its objective: Plan for higher TOD levels in different areas where transit connectivity is available, but TOD levels are low.
2. Approach 2: To identify the areas that are characterized by urban development with high transit orientation but poor or absent access to high-quality transit. Its objective: Plan for transit connectivity at those locations or areas where high levels of TOD exist but transit connection is absent or poor.

Table 3: [Comparative analysis matrix between different studies on measuring TOD-ness. Note: ‘n.a.’ not applicable. *(Source: Authors.)*].

	Criteria & indicators			Focus of study			TOD index			Scale of analysis						Framework of analysis			
Study	Physical	Performance	Physical & Performance	Approach 1	Approach 2	Both approaches	TOD index score	Actual TOD index	Potential TOD index	TOD station / site	TOD station area	TOD neighbourhood	TOD corridor	TOD city region	TOD regional	Developed SMCA-based framework	Adopted Singh et al., [13] framework	Developed a framework based on Singh et al., [13]	Developed a new TOD (PSS)-based frameworks
[6]	●			●			●				●		●			●			
[12]	●			●			n.a.	n.a.	n.a.			●		●					●
[14]	●				●				●					●	●		●		
[15]			●	●				●			●						●		
[16]			●	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.				●						
[17]			●		●				●					●	●		●		
[18]			●		●				●					●	●		●		
[19]			●			●		●	●		●			●	●			●	
[20]			●			●		●	●		●			●	●			●	●
[21]			●	●					●					●	●		●		
[22]			●	●			●			●									●
[23]			●	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.		●			●					●
[24]			●	●				●			●		●			●			
[25]			●	●				●			●			●				●	

Table 3: *(Continued)*

Study	Criteria & indicators: Physical	Performance	Physical & Performance	Focus of study: Approach 1	Approach 2	Both approaches	TOD index: TOD index score	Actual TOD index	Potential TOD index	Scale of analysis: TOD station / site	TOD station area	TOD neighbourhood	TOD corridor	TOD city region	TOD regional	Framework of analysis: Developed SMCA-based framework	Adopted Singh et al., [13] framework	Developed a framework based on Singh et al., [13]	Developed a new TOD (PSS)-based frameworks
[26]			●		●		●					●							●
[3]			●	●			●					●							●
[27]	●			●			●				●		●			●			
[28]	●			●				●			●		●					●	
[29]			●		●				●					●	●	●			●
[30]			●		●		●		●					●	●	●			●
[1]	●				●		●							●	●	●			
[31]			●	●				●			●					●			
[32]			●	●			●				●					●			
[33]	●			●			●				●		●					●	
Total	7	0	17	13	7	2	9	7	7	1	13	3	6	12	9	9	5	5	8

Concerning TOD indices, Singh, He, et al., [17] claimed that the indicators proposed by [38] have not yet been used comprehensively. They also argued that a single TOD index is not sufficient, since the two approaches differ in terms of area, scale and measuring indicators. Hence, they proposed two TOD indices for each of the previously mentioned approaches, referred to as an ‘actual TOD index’ and a ‘potential TOD index’.

1. Actual TOD index: An index must measure TOD levels within walking distance of each transit node. It should also measure the characteristics not just of urban development’s surrounding the node but also of transit services in that area (eight criteria and 25 indicators).
2. Potential TOD index: An index must be able to measure urban development characteristics in all areas of the region. It cannot measure transit characteristics as it is found that those areas where transit connectivity is absent and is desired (four criteria and 11 indicators).

Noticeably, the approaches adopted by researchers are reflected in the scale of the studies in the review results. The station area and city scale were the most frequently analysed scales (*n* = 12, 48%), followed by the urban-regional scale (*n* = seven, 29.16%), then the transit corridor scale (along MRTs, BRTs and LRTs) (*n* = six, 24%) and lastly the neighbourhood-scale (*n* = three, 12%). From the review, it was recognized that TOD is a multi-scale concept that uses several scales. Many researchers have argued about this since Calthorpe [34] defined TOD as a conducive development that surrounds transit stops/stations and considered station level as the most critical scale of TOD planning. Some of the researchers adopted the local scale (i.e. station area and its neighbourhood level), believing that this scale is critical for developing transit-oriented activities as well as understanding the community. Nevertheless, others argued that the TOD should be applied to a region or a city, rather than around transit nodes. In their opinion, this scale helps to achieve a more efficient and comprehensive result for TOD planning and to ensure coordination between other existing regional plans.

It can be concluded that the two approaches towards measuring TOD-ness are essential to ensure the comprehensive elaboration of the studied area. However, research that used the two approaches for the same area was rare in the literature reviewed. Only three studies were found to be complementary to each other: [18], [20] and [21]. Working on both approaches for the same study areas is recommended as it can help to understand TOD-ness at a regional level and to establish significant strategies and scenarios that stand on the assessed indicators. This can also help the stakeholders and decision-makers to move towards a greater TOD-ness or better transit connectivity when choosing a TOD site for development.

5.4 The framework of analysis

To answer the question asked in the introduction of this paper, the review revealed the tools and methodological frameworks employed, but some caveats exist. The authors of 23 articles used computerized simulation tools and models that used spatial analysis to measure the degree of TOD-ness of an area. The authors of 24 articles employed different models in case studies to qualitatively measure the TOD-ness of an area, and one study developed a conceptual model only. As mentioned before, suitability analysis techniques (*n* =19, 76%) are the most reliable methods. Additionally, the majority of the reviewed studies did use a TOD index score to measure the TOD-ness of an area but with different methodological frameworks. To calculate the TOD index, it was found that many researchers employed an

SMCA analysis method. In general, MCA has been acknowledged as an effective method that aggregates multiple indicators into a single composite index. Moreover, 'GIS-based MCA' or 'SMCA' has been employed when dealing with spatial indicators. Singh et al. [13] took the TOD index to fruition within a proposed SMCA-methodological framework that calculated multiple 'spatial criteria' and combined them into this index. They described this framework as an extension of the work of [40].

Likewise, a number of studies (*n* = nine, 36%) developed the SMCA-based framework, while some researchers (*n* = five, 20%) operationalized the same framework as Singh et al. [13], which employed a GIS-based spatial model as an analytical measurement tool to measure the existing TOD-ness of an area. Moreover, four studies (20%) developed a framework based on that of Singh et al. [13] and eight studies (32%) developed a new TOD PSS-based framework (see Table 3). Additionally, [28] adopted Singh [19] framework while Semeraro c adopted that of Singh, Fard, et al. [18] and Sulistyaningrum & Sumabrata [31] adopted that of Singh et al., [25] . Moreover, the data obtained in the study by Fajri & Sumabrata [32] was analysed using Sulistyaningrum & Sumabrata [31] TOD measurement method and the TOD evaluation method by Galelo, et al. [16].

5.4.1 Interpretation of studies' results

It was found that visual analysis and statistical analysis were employed by researchers in TOD studies to aid in recommending alternative TOD locations for development or building. The methods found in the reviewed literature using visual analysis were spatial analytical and spatial statistical, which can facilitate in interpreting spatial indices. Many researchers admitted that the potential TOD index could only be used to make a comparison between locations in order to identify the potentially more transit-oriented location, but that the index may not clarify the magnitude of the differences. Moreover, Fard [14] added that computing the maps of SMCA analysis (i.e. in the form of either a suitability map or a TOD index map) provides us with different values without indicating the required actions in practice.

Likewise, almost all of the reviewed studies (96%) employed the spatial analysis using a GIS platform except Strong [23]'s study, which used statistical analysis. Seven studies (28%) employed spatial statistical analysis and six studies (24%) employed both spatial analysis and statistical tests. Almost all the studies that employed spatial statistical analysis studied the statistics of spatial association through 'spatial clustering' using global or local cluster statistics methods.

Arguably, the review revealed that the findings of the previous studies could not be compared in order to identify their degree of success in the future due to the diversity of the methods employed. Hence, without comparison or validation scores, it is difficult to know which method would produce the best results. The literature provided a few studies (*n* = 11, 44%) that suggested which policies were needed for improvements or suggested detailed TOD site decisions based on the results as in [33]. However, some researchers claimed that planners would still need more information on land use plans, planning policies or political motivations in order to make physical plans when the need arises. Finally, the review also revealed that the PSS-based framework in many studies could not predict or simulate how the increase in densities, jobs or economic development could affect the number of transit ridership.

5.5 The methodological strengths and weaknesses of the studies

After investigation, many researchers admitted that the methodological framework of Singh et al. [13] has obvious points of strength because:

1. It can quantitatively measure the TOD-ness of an area via the TOD index.
2. It is transparent and back-traceable.
3. It is simple, which makes it repeatable and easily applied in other countries as well.
4. The results can provide an input for an SDSS environment and can then be assessed by stakeholders in order to propose planning interventions in those areas.

Correspondingly, Singh, He, et al., [17] developed the framework and tool that had been proposed previously in the work by Singh et al. [13]. This development has strengths as follows: The researchers proposed two separate indices – an 'actual' and a 'potential' TOD index – where they differ in scale and indicators. They used spatial statistical analysis, which leads to higher accuracy in results. Moreover, the study is considered one of only a few studies across the entire study area that measured TOD-ness via a TOD index. In general, many researchers emphasized the advantages of measuring TOD-ness via a TOD index, as it can help in: assessing the existing TOD characteristics, maintaining effective TOD planning or evaluating TOD projects, justifying poor TOD performance such that proposed policies, programs or interventions can be created to improve TOD conditions and identifying whether an area is moving towards or away from performance threshold values.

Another argument was made by Lukman [15], who criticized Fard [14]'s study for applying the potential TOD index to the whole areas regardless of whether the areas had transit access or not. Therefore, the consideration of some transit system elements was missed in this study. However, [3,26] argued that Singh, He, et al., [17]'s study has some weak points: Ignoring accessibility or street connectivity, which are considered as efficient indicators in developing a TOD index. The indicators were computed in a 'raster format', which is considered inappropriate because data collection is usually represented in a 'vector format' in urban planning. Finally, they did not propose any scenarios for improving the TOD-ness of areas in the region, especially public transit service areas that had the potential for development.

Despite these weak points, Singh et al., [25]'s study employed the same methodology but discussed the first approach throughout an entire urban area. Finally, Motieyan & Mesgari [26] developed a four-stage methodology to calculate a TOD index score using an AHP analytical method. According to the results of the assessment, they described their method as robust and efficient for sustainable urban planning. stating that using this analytical method had many advantages for their modelling approach because: It produces the TOD index from the stakeholders' point of view. By calculating the indicators' weights using pairwise comparisons, it provides robust results where the inconsistency is computed. Additionally, by modelling uncertainties in stakeholders' views (sensitivity analysis), it gives more precise results.

Finally, the spatial data of the majority of studies used vector representation in GIS. Many researchers confirmed that the vector format has many advantages in producing reliable results, regarding either attributes or the spatial dimension. For instance, [26]'s study computed the indicators in the vector format at a neighbourhood scale, which they justified with the following reasons: Some errors may potentially result if data is converted into other levels because the majority of datasets are compiled at the neighbourhood level. The raster cell square area contains different urban environment areas with different characteristics, so using the vector format at a neighbourhood level is more efficient than the raster format. Density, diversity and land use mixedness indicators are usually employed at the neighbourhood level, thus utilizing them on other levels is inefficient.

5.6 Stakeholder involvement

It has been acknowledged that achieving efficient TOD requires cooperation between planners, policymakers, private investors, administrators, etc. Also, it is believed that stakeholder participation is a way to encourage the bottom-up approach in the planning process. Similarly, the researchers believed in the role of stakeholders' involvement in TOD planning studies. From the review, many researchers considered SMCA as the preferred analytical method for prioritizing potential locations for intervention, due to stakeholder participation twice during the process: first, their major role in assigning the weights to each indicator before calculating the TOD index, and second, when discussing the TOD indices. Further to this, the other advantage of SMCA or multi-criteria methods is that stakeholder bias can be eliminated after performing a sensitivity analysis to test the small change in the weights of the TOD scores.

From the review, a drawback was noticed regarding the weighting of the criteria that were determined through interviews or surveys. For instance, the ranks in the study by Shastry [6] were determined by a group of six people through interviews, which is a very small dataset. Moreover, not all of the interviewees were from the city of Ahmadabad and they were not representative of the entire list of stakeholders. Taki & Maatouk [29]-[30] overcame this drawback and obtained their AHP data (the primary data) from interviews and questionnaires answered by 12 experts in various scientific fields to obtain the weight value of each indicator. In Lukman's study [15], the weights were derived from a previously held stakeholder workshop by Singh [41], who worked on the same topic as Lukman's research. The weights were only derived from government representatives at the municipality level. In the study by Galelo et al. [16], the weights were derived from a national survey in the USA that used the opinions of 30 professionals, while in the study by Singh, He, et al., [17], a workshop was held with the municipal heads of all 20 municipalities, where they were asked to rank the indicators in order of their importance in the realization of TOD.

5.7 Study relevance to real-world practices

At a broader level, this review helps in identifying where the relevant research exists to help academics to be consistent with past and recent progress, as well as the considerations needed for future research. Moreover, the authors believe that exploring this kind of study can also help decision-makers to identify priorities and provide computerized models to be assembled and used. The review revealed that the direct impact and relevance of the studies are mostly on urban planning, TOD planning and decision-making processes. As mentioned before, only 11 studies had a direct impact on the policy-making process as well as TOD planning. The researchers admitted that measuring TOD-ness would help decision-makers to determine which areas had more potential for development. In addition, the results of the studies can provide an input for an SDSS environment (e.g. GIS) and can then be assessed by stakeholders again to propose planning interventions in those areas. Consequently, the selection of proper measurement frameworks needs more consideration, because without measuring the TOD-ness outcomes correctly, investment strategy mistakes will occur repetitively.

In some cases, such as that of Shastry [6], the secondary data (i.e. the number of jobs) has decimal values, which indicate that the data has been calculated using a mathematical operation and not been collected onsite. Hence, the authors believe that more empirical research on measuring TOD-ness is needed using real-world data, derived from interviews with stakeholders, reports, surveys and other sources, in greater detail. Although the PSS-based frameworks used by the reviewed studies are valuable in choosing potential TOD sites for development, they have not determined what is needed from the market demand perspective. Therefore, the use of more market studies should be another important topic that deserves further exploration by both academics and practitioners. Some researchers recommended that the results of ‘spatial clustering’ hotspots analysis could be further followed up with a detailed technical feasibility analysis or a financial/economic feasibility analysis.

6 CONCLUSION

Arguably, TOD has become the catchphrase of the planning world over three decades. It is widely recognized as one of the most comprehensive sustainable planning approaches. Moreover, it is believed that TOD has many aims that eventually achieve smart growth principles for enhancing local communities. It also attempts to orient land use and development towards the transport system. In line with this, this paper conducted a systematic literature review on the state of research on TOD-ness measurement and its operationalization. The systematic review method gathers search results from different resources and allows the effective analysis of relevant research studies. In the end, the paper has focused on some important considerations after reviewing 25 relevant studies published between 2000 and 2020. It should be noted that the total number of 25 eligible studies found for a systematic review is a rather small proportion.

This extensive review revealed some well-known facts about the TOD concept. First, the available literature on TOD is very vast and covers many aspects of the concept. Thus, the attempts to evaluate TODs have also been conducted differently by researchers and urban planners worldwide, as they perceive the concept differently. It is also very clear that TOD planning implementation is a multi-scale endeavour. At the same time, the review revealed that there is insufficient work in the literature that measures TOD-ness in certain areas quantitatively. Although the literature is rich with station-area studies attempting to measure levels of TOD, they did not quantify them until 2007. Furthermore, the review revealed that more published articles on this topic have been observed since 2010. With respect to the methods employed, combined methods using a suitability analysis SMCA and spatial statistical analysis techniques dominated the TOD measurement studies. At the same time, the authors of a few articles employed agent-based, AHP-based and statistical-based models in their work. In accordance with content analysis, the reviewed studies were classified according to seven topics.

In general, the review confirmed some results in the existing literature. For instance, many researchers have encouraged the development of a TOD index that can quantify TOD-ness to measure TOD comprehensively. This helps to identify what is lacking in the existing situation and what developmental interventions need to be carried out based on the location potentials. Moreover, review found that the literature is rich with studies that used a mix of ‘spatial’ and ‘non-spatial indicators’ to calculate such an index that is both measurable and quantifiable at the same time. Most commonly, the researchers excluded some indicators in their studies due to different limitations, including data availability or time constraints. However, some studies emphasized that certain indicators should be included to maintain effective TOD planning (e.g. the 3Ds and economic development). In addition, a temporal dimension should also be considered because some indicators differ across the duration of a day, such as accessibility, passenger load, etc. The review also revealed that these types of studies can have a valuable impact on real-world practices such as urban planning, TOD planning and decision-making processes. The results of the TOD scores can provide identification for decision-makers in order to focus their efforts on these locations.

To sum up, the review provided the following considerations needed for further research: First, this review has a 'methodological focus' and, to the best of the authors' knowledge, this is one of few attempts at a systematic review on this topic. Therefore, the authors believe that an additional review with an empirical focus is needed. If the same literature is used, the authors recommend a new angle to be investigated, resulting in different conclusions. Second, although there is a large amount of TOD research focusing on how users living in or moving to a TOD change their travel behaviour, this review did not consider travel behaviour and/or environmental outcomes related to travel. However, travel behaviour and mode shift should potentially be measured along with the TOD-ness measurement at some point, in order to strengthen the argument behind this paper.

Third, working on two approaches to measuring TOD-ness for the same study area is recommended, as it can help to understand the level of TOD at a regional level and to establish significant scenarios that stand on the assessed indicators. The researchers also suggest using the results of the studies on which to base the policies needed for improvements or a detailed TOD site decision in order to help policymakers to identify the priorities. Fourth, it is also recommended that studies that capture built environment indicators should define the adequate walking distance based on their local context. Moreover, the consideration of more stakeholder involvement as well as government policies would certainly have a major impact on the criteria weighting that may affect the value of each indicator. Therefore, the involvement of the local communities, the private sector and the public sector is considered an essential element to maintain a successful TOD.

Fifth, for further implementation of the methods, this review focuses on the methods and models used in Fard & Lukman studies [14,15], which measure the actual or potential implementation of the TOD concept in an area. It also suggests using combined methods to ensure a methodologically balanced approach. In addition, it is important to assess the model used in order to examine its efficiency by comparing and validating the resulting TOD scores. Further to this, future research should enlarge the TOD-ness measurement scope. For instance, people living in proximity to transit stations are affected by government policies and the demography of the area. Hence, there is a need for more agent-based models to consider other characteristics of the area. Further research should also include additional interviews to provide a vision of what the community wants, and whether they support or are against the proposed development. Finally, there is a need to conduct more studies that employ big and open data (BOD)-derived variables in the future, which allow planners to revalidate existing TOD planning principles, refine TOD analytics of measuring TOD-ness and evaluate different TOD plans and adapt them to local contexts.

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USER ACCEPTANCE OF PUBLIC TRANSPORT SYSTEMS BASED ON A PERCEPTION MODEL

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ABSTRACT
The purpose of this study was to evaluate the need for mass transportation in Makassar City, Indonesia and to analyze public perceptions of the relationships among transport management, service qualities, user capacity and acceptance through user satisfaction. This research was conducted in two stages. The first was a survey of public transport users and an estimate of the number of the bus fleet requirements. This was conducted by estimating the number of users, mapping the main public transportation routes and measuring the period based on the departure schedule and the headway. In the second stage, a survey of public perceptions of bus transportation, which covered transport management, service qualities, user capacity, user satisfaction and user acceptance, was conducted. A self-administrated questionnaire had been developed and distributed in 10 residential points representing a certain area in Makassar city, Indonesia. At each point, 40 questionnaires were distributed to respondents by non-probability samplings. The respondents were selected by certain criteria consisting of age, transport need and experience in receiving bus services. Out of 400 questionnaires that have been distributed, 315 were returned (78.0%). Of the 315, there were 15 regarded as invalid and 300 were considered valid responses. Therefore, further analyses were done by extracting those 300 valid responses. The results indicated that user acceptance was directly or indirectly influenced by transport management, service qualities, user capacity and user satisfaction. User satisfaction is an intervening variable between service qualities and user acceptance. Meanwhile, user capacity positively and directly affects user acceptance, but indirectly it has a negative relationship with user satisfaction. Therefore, the quality of the bus services in terms of security, comfort and orderliness significantly affects user satisfaction, which impacts acceptance.
Keywords: service qualities, transport management, user capacity, user acceptance.

1 INTRODUCTION

Transportation is a major component of the social system, which affects socio-economic conditions such as urban growth. It plays a pivotal role in promoting economic growth, especially in urban areas. Conversely, the socio-demographic conditions of an area may affect its transportation performance [1]. Population density has a significant influence on the ability of transportation to meet community needs. The complexity of public transportation is evident in big cities, which involves a combination of variables, such as population growth, the increase in the number of vehicles exceeding road capacity and user behavior related to ignoring traffic regulations on the highway [2,3].

Makassar, the largest city in eastern Indonesia, is located in South Sulawesi. This city serves as a service center for the educational and health sectors, industrial and government activities, and a node for the transportation of goods and passengers by land, sea, and air. The city has an area of 175.77 km^2 and a population density of 8,701 people/km^2. One of the chronic problems faced by residents is the severe level of traffic congestion caused by several factors, such as an increase in the number of private vehicles, insufficient public transportation, violation of parking orders, narrowing of roads in transitional sections, median openings by undisciplined road users, limited traffic signs and weak traffic law enforcement [4].

Insufficient public transportation occurs because the quantity and quality of mass transportation fall below the required standard. In Makassar city, the number of main bus lanes has reduced from five to one during the past 10 years. This situation prompted the government

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to restructure the public transportation system and improve the public transportation system. In 2020, the Indonesian Directorate General of Land Transportation launched a restructuring program based on the service purchase concept. This initiative has been implemented in nine cities: Medan, Palembang, Solo, Yogyakarta, Surabaya, Denpasar, Bandung, Makassar and Banjarmasin. The service purchase program is the program to purchase of public transportation services by the government to the private sector and public transport operators. Through this program, the government pays operators based on the value of the freight cost which is calculated per kilometer. As a result, the government subsidizes 100% of vehicle operating costs to transportation operators. With this program, the Ministry intends to eliminate the culture of reckless public transport traffic, unhealthy competition, erratic driving schedules and travel times. Therefore, a strategy that involves the public's perception is needed. Over the past ten years, buses have been distributed in this region. However, they lack adequate public transportation services because there is no pattern of guidance and supervision mandated in national regulations.

The strategy employed to improve the public transportation system must consider community needs, including the stipulated number of vehicles and the quality of services rendered. Several studies have indicated that safety, security, comfort and environmental friendliness are important factors [4–6]. Convenience and accessibility are the main factors impacting overall user satisfaction; these are followed by adequate facilities, namely, bus stops and public transportation services within the city [7]. However, the extent to which user perceptions of the relationships among service management, service qualities, user capacity and user acceptance affect user satisfaction has never been studied. Therefore, it is important to conduct a study to measure the level of community need for the number of vehicles and the perception of user acceptance of public transportation. This study aimed to analyze the need for mass transportation in Makassar City and evaluate public perceptions of the relationships among service management, service qualities, user capacity and user acceptance through user satisfaction. The hypotheses in this study are formulated as follows, (a) Transport management, service quality and user capacity have a significant effect on user satisfaction, (b) Transport management, service quality and user capacity have a direct significant effect on User Acceptance and (c) User satisfaction has a significant effect on user Acceptance.

2 MATERIALS AND METHODS

This research was conducted in two stages. First, a survey of public transport users and the estimated number of bus fleets. This stage is carried out by mapping the main bus routes. Estimated the number of bus fleets was conducted on four reopening routes. These routes consisted of the Route A (Terminal Mallengkeri – UNHAS, Via Metro Tanjung Bunga), the Route B (Mall Panakkukang – Bandara Internasional Sultan Hasanuddin), the Route C (Kampus 2 Politeknik Negeri Ujung Pandang – Kampus 2 Politeknik Ilmu Pelayaran) and the Route D (Pelabuhan Sukarno Hatta – UIN Alauddin Samata). Those routes previously existed, and this study project to reopen the services. The measurement of the number of fleets is determined based on the number of passengers, the number of circulation, change frequency and bus capacity.

Second, user perceptions of public transportation, covering transport management, service qualities, user capacity, user satisfaction and user acceptance were surveyed by distributing questionnaires. The total number of participants was determined based on Slovin's formula.

A self-administrated questionnaire had been developed and distributed in 10 residential points representing a certain area in Makassar city, Indonesia. At each point, 40 questionnaires were distributed to respondents by non-probability samplings. The respondents were selected by certain criteria consisting of age, transport need and experience in receiving bus services. Out of 400 questionnaires that have been distributed, 315 were returned (78.0%). Of the 315, there were 15 regarded as invalid and 300 were considered valid responses. Therefore, further analyses were done by extracting those 300 valid responses.

2.1 Estimated number of users

The number of users is estimated from the total number of captive groups and 30% of choice groups [8].

$$N = Ca + 30\%\ Ch \tag{1}$$

where
N = number of users
Ca = captive group
Ch = choice group

2.2. Estimated number of passengers in studied routes

The estimated number of passengers in studied routes was calculated by dividing the certain route length by the total length of routes, then multiply by the total number of users [9].

$$\sum P = \frac{LoR}{\sum LoR} \times \sum U \tag{2}$$

where
P = estimated number of passengers in the studied route
LoR = Length of route
∑LoR = Total length of all routes
∑ U = Total number of users

2.3. Circulation time (CT)

Circulation time was determined by summing up the time spent by the bus fleet from A terminal to B terminal and return to A terminal [9].

$$CT_{ABA} = (T_{AB} + T_{BA}) + (\sigma_{AB} + \sigma_{BA}) + (T_{TA} + T_{TB}) \tag{3}$$

where
CT_{ABA} = circulation time from A to B and back A
T_{AB} = average travel time from A to B
T_{BA} = average travel time from A to B
σ_{AB} = deviation time from A to B
σ_{BA} = deviation time from A to B
T_{TA} = bus fleet downtime in A
T_{TB} = bus fleet downtime in B

2.4 Estimated number of circulation at a route (Ci)

The estimated number of circulation in a certain route was determined by maximum daily service time divided by circulation time per hour [9].

$$\mathrm{Ci} = \frac{\mathrm{t\ max}}{\mathrm{CTABA} - 0.5} \times 60 \text{ minutes} \tag{4}$$

where

Ci = estimated number of circulation
t max = maximum daily service time (16 hours)
CT_{ABA} = circulation time from A to B and back A

2.5. Change frequency

Change frequency is the frequency of passenger change within a certain route. Change frequency is formulated based on the number of bus stops within a certain route divided by the average number of bus stops traveled [9]. The average number of bus stops traveled was determined by a survey of passengers.

$$\mathrm{CF} = \frac{\mathrm{BS}}{\mathrm{BST}} \tag{5}$$

where

CF = Change frequency
BS = bus stop
BST = average number of bus stop traveled

2.6. Estimated number of the bus fleet

The estimated number of bus fleet was calculated based on the number of passengers served, divided by the number of circulation, change frequency and bus capacity [9].

$$\mathrm{F} = \frac{\mathrm{P}}{\mathrm{Ci} \times \mathrm{CF} \times \mathrm{C}}$$

where

F = estimated number of the bus fleet
P = Number of passengers served
Ci = number of circulation
CF = Change frequency
C = bus capacity

2.4. Users' acceptance of public transportation

The conceptual framework of this research is constructed based on the theoretical foundation of various concepts and the results of previous studies as follows. First, transport management can increase user acceptance [10,11]. Second, service quality, customer satisfaction, and behavioral intentions in public transit transport management can increase customer satisfaction [13]. Third, personal outcome expectations and the perceived effectiveness of expenses (i.e. fares) is the pivotal factor in improving user acceptance [13]. Fourth, availability, safety and security positively influence to user satisfaction [14]. In general, previous studies did not distinguish between transport management and service quality by the provider. In this study, these two variables were separated because transport management is generally determined by the government, while service quality is provided by the operator.

User acceptance of public transportation was determined by constructing the behavioral model, which involved measuring some latent variables and indicator items. Subsequently, the data was obtained from the respondents' perceptions, while their responses to each question were subjected to five options as follows, 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree. The questions on the latent variables and indicator items are shown in Table 1. The qualification level was determined by the following ranges: Very low = 1.00 to 1.80, Low = 1.81 to 2.60, Moderate = 2.61 to 3.40, High = 3.41 to 4.20, Very high = 4.21 to 5.00.

This study applied Structural Equation Modeling analysis tools to analyze the correlation among the latent variables and indicators. Those analyses were done using the partial least square (PLS) method and processed with SmartPLS 3.0 software. Structural model analyses in PLS consisted of four stages as follows, formulating the structural model concept, analyzing the outer model validity and reliability, analyzing the inner model validity and testing the hypothesis. The conceptual model for the proposed framework was constructed based on the relevant theory and previous studies. Furthermore, the structural model was created based on conceptual relationships among the variables. The outer model test aims to evaluate the validity and reliability of a model. The result of the analysis was determined by Loading Factor value, Average variance extracted (AVE) and composite reliability. Loading factor analysis is the initial stage in testing the convergent validity of a model, with a cut-off value of 0.7. Furthermore, to find out the discriminant validity of the outer model of this study can be seen in the AVE value, with a cut-off value of 0.5. Discriminant validity was established to ensure the specificity of the constructs in the study. The correlation between the indicator and its latent variable must be greater than the correlation between the indicator and other latent variables (outside the block). Composite Reliability measures the true reliability value of a variable while Cronbach's Alpha measures the lowest value (lower bound) reliability. The value of composite reliability is analyzed to ensure real reliability measurement. The last step in evaluating the outer model is to test the unidimensionality of the model. This test was carried out using composite reliability and Cronbach's alpha. For both indicators, the cut-off value is 0.6.

The inner model test aims to ensure the accuracy of the structural model. The accuracy of the inner model was evaluated by several indicators, namely the value of RMSEA, chi-square, significance, d_ULS, d_G, normed fit index (NFI), standardized root means residual (SRMR) and adjusted goodness of fit index (AGFI). In the last step, testing the hypothesis is determined by the value of probability and t-statistics. The criteria for acceptance of the alternative hypothesis was decided when $p < 0.05$.

2.5. Recommendation for transportation development plan

Based on the results of the previous stage analysis, a recommendation for a transportation development plan was formulated. The phase was done through focused group discussions involving local government offices (including the Department of City Transportation) to compile a problem-solving scenario. This discussion focuses on strategy outlines and detailed scenarios to improve user acceptance. The scenario was selected based on the level of service.

3 RESULT

3.1 Estimated number of users

Based on the Statistics Central Bureau, the population of Makassar City is 1,423,877 individuals. The total of users aged between 17 and 60 years was 942,248 persons. [16] (Statistics Central Bureau, 2021). There are 1078 registered minibusses operated by private companies and 22 buses operated by the government company (Makassar City Transportation Department). Based on the calculation, the result showed that the captive group consisted of 122.492 individuals, the choice group consisted of 819,756 persons, and the total of users was estimated as 368,419 individuals. Of the total users, 129,360 persons are served by existing secondary transportation (as feeders), while the remaining 239.059 individuals would be distributed into five routes. There is an existing bus route serving approximately one-fifth of the remaining users (47,812 persons), while this study estimated the rest of the four routes users (191,247 persons). A total of 191,247 individuals were distributed proportionally into four routes based on the length of the route (Table 1). The result showed that the number of passengers ranged from 42.258 to 53,963 persons (Table 1).

Table 1: Estimated number of passengers (persons) in each route.

Route	Length of circulated route (km)	Estimated number of the user (persons)
Route A	53.25	53,963
Route B	42.65	43,221
Route C	51.12	51,805
Route D	41.70	42,258
	188.72	191,247

3.2. Estimated number of the fleet (circulation/day), number of bus stop, the average number of bus stop traveled and change frequency

Results demonstrated that total traveling time ranged from 166.8 minutes to 213 minutes when the average bus speed was 15 km/hour. The number of circulation ranged from 4 to 5 circulations/day. The number of bus stops ranged from 35 to 55. The number of change frequencies ranged from 13 to 16.3 (Table 2).

Based on the data presented in Table 2, the estimated number of the bus was calculated based on three scenarios. First, all buses have a capacity of 40 persons. Second, all buses have a capacity of 20 people. Third, combined passenger capacity of both 40 and 20 persons (big and medium bus). The first scenario demonstrated that the number of the bus was 16 or 21 units per route and headway ranged from 10 to 11 minutes (Table 3). The second scenario demonstrated that the number of the bus was 33 or 41 units per route and headway was 5 minutes (Table 4). The third scenario demonstrated that the number of the bus was 25 or 30 units per route and headway was 7 minutes (Table 5).

Table 2: Estimated number of the fleet (circulation/day), number of the bus stop, the average number of bus stops traveled and change frequency.

Route	Length of circulated route (km)	Bus speed (km/hour)	Traveling time (minutes)	Maximum number of circulation per day	Number of bus stops	The average number of bus stop traveled	Passenger change frequency
Route A	53.25	15	213	4.2	44	2.7	16.3
Route B	42.65	15	170.6	5.3	35	2.7	13.0
Route C	51.12	15	204.48	4.4	43	2.7	15.9
Route D	41.7	15	166.8	5.4	35	2.7	13

Table 3: Estimate the number of the bus (units) and headway (minutes) when applying the passenger capacity of 40 persons (big bus).

Route	User (persons)	Fleet (number/day)	Passenger change frequency	Bus capacity	Number of the bus (units)	Headway (minutes)
Route A	53,963	4	16	40	21	10
Route B	43,221	5	13	40	16	11
Route C	51,805	4	16	40	21	10
Route D	42,258	5	13	40	16	11

Table 4: Estimate the number of buses (units) and headway (minutes) when applying the passenger capacity of 20 persons (medium bus).

Route	User (persons)	Fleet (number/day)	Change /circulation	Bus capacity	Number of the bus (units)	Headway (minutes)
Route A	53,963	4	16	20	41	5
Route B	43,221	5	13	20	33	5
Route C	51,805	4	16	20	41	5
Route D	42,258	5	13	20	33	5

3.3 User acceptance of the public transportation

3.3.1 Description of Respondents' Answers

The responses for each indicator or item on the questionnaire were analyzed descriptively. An overview of the respondent's answers indicated good results represented by its high category, except travel intensity. The travel intensity falls in the moderate category (Table 6).

Table 5: Estimate the number of the bus (units) and headway (minutes) when applying a combined passenger capacity of both 40 and 20 persons (big and medium buses).

Route	User (persons)	Fleet (number/day)	Change/ circulation	Number of combined buses (capacity)	Headway (minutes)
Route A	53,963	4	16	B (40) = 11 and M (20) = 19	7
Route B	43,221	5	13	B (40) = 8 and M (20) = 17	7
Route C	51,805	4	16	B (40) = 11 and M (20) = 19	7
Route D	42,258	5	13	B (40) = 8 and M (20) = 17	7

Table 6: Description of Respondents' perceptions toward the variables and indicators.

Variables	Indicators	Respondent score	Categories
Transport management	X1.1. accessibility	4.17	High
	X1.2. connectivity	3.93	High
	X1.3. fare/ticket price	3.78	High
Service quality	X2.1. security	4.02	High
	X2.2. comfortability	4.17	High
	X2.3. orderliness	3.95	High
User capacity	X3.1. the family income per month	3.49	High
	X3.2. allocation of transportation costs	3.49	High
	X3.3. travel intensity	3.36	Moderate
	X3.4. number of family members	3.44	High
User satisfaction	Z1. service suitability	4.04	High
	Z2. Ticket price	4.03	High
	Z3. Accuracy	4.05	High
	Z4. Willingness to recommend.	4.09	High
User acceptance	Y1. Productivity	4.07	High
	Y2. utility	4.00	High
	Y3. acceptability.	3.92	High

The results of the convergent validity analysis for each variable in this study are presented in Tables 7 to 11, while the discriminant validity analysis, Composite Reliability and Cronbach's Alpha measures are shown in Table 12. It showed that transport management (X1) was developed by the following indicators, namely accessibility (X1.1), connectivity (X1.2) and fare rate (X1.3). Moreover, all the outer loading values were greater than 0.70, indicating that the research instrument met the requirements of convergent validity. The other number displayed shows the extent to which the indicator reflects each latent variable. Therefore, the instrument consisting of indicator items was valid for analyzing transport management. All transport management indicators showed significant results of $p < 0.001$, indicating this variable was formed by the causative factor, accessibility, connectivity and fare rate (Table 7).

Security (X2.1), comfortability (X2.2) and orderliness (X2.3) developed sustainable service qualities (X2). The outer loading value of all indicators was greater than 0.70, depicting that the research instrument met the convergent validity requirements. Therefore, the instrument consisting of indicator items is reliable for analyzing service qualities. Furthermore, all service quality indicators showed a *p*-value less than 0.001, implying that the service qualities were formed by security, comfortability and orderliness, as shown in Table 8.

The sustainable user capacity (X3) was developed by indicators such as family income per month (X3.1), transportation costs allocation (X3.2), travel intensity (X3.3) and the number of family members (X3.4). The outer loading values of all indicators were greater than 0.50, depicting that the research instrument met the convergent validity requirements. The number displayed outside the loading value shows the extent to which the indicator reflects each latent variable. Therefore, the instrument consisting of indicator items is reliable for analyzing user capacity. Furthermore, the *p*-value is less than 0.001, indicating that the user capacity was shaped by family income per month, transportation costs allocation, travel intensity and the number of family members (Table 9).

According to the result, user satisfaction (Z) was developed by service suitability (Z1), fare compliance (Z2), accuracy (Z3) and willingness to recommend (Z4). The outer loading value of all indicators was greater than 0.50, depicting that the research instrument met the

Table 7: Value of convergent validity (outer loading) transport management.

Indicator	Outer loading	Standard deviation (STDEV)	T Statistics (|O/STDEV|)	*p*-value
X1.1	0.816	0.034	23.67	0.000
X1.2	0.905	0.014	64.76	0.000
X1.3	0.803	0.031	25.86	0.000

Table 8: Value of convergent validity (outer loading) of service qualities indicators.

Indicator	Outer loading	Standard deviation (STDEV)	T Statistics (|O/STDEV|)	*p*-value
X2.1	0.803	0.0305	26.278	0.000
X2.2	0.856	0.023	37.584	0.000
X2.3	0.777	0.042	18.408	0.000

Table 9: Value of convergent validity (outer loading) of user capacity indicators.

Indicator	Outer loading	Standard deviation (STDEV)	T Statistics (|O/STDEV|)	*p*-value
X3.1	0.896	0.020	45.86	0.000
X3.2	0.927	0.011	81.92	0.000
X3.3	0.907	0.017	52.8	0.000
X3.4	0.843	0.027	31.8	0.000

convergent validity requirements. The number displayed outside the loading value shows the extent to which the indicator reflects each latent variable. Therefore, the instrument consisting of indicator items is reliable for analyzing the users' satisfaction. Furthermore, all indicators of user satisfaction demonstrated a *p*-value of less than 0.001, illustrating that the user satisfaction variable reflected service suitability, fare compliance, accuracy and willingness to recommend (Table 10).

User acceptance (Y) reflected the user perception of productivity (Y1), utility (Y2) and acceptability (Y3). The outer loading value of all indicators was greater than 0.70, indicating that the research instrument met the convergent validity requirements. The number displayed outside the loading value shows the extent to which the indicator reflects each latent variable. Therefore, the instrument consisting of indicator items is reliable for analyzing the users' acceptance. Furthermore, the *p*-value is less than 0.001, indicating that the user acceptance supported the user perception of productivity, utility and acceptability (Table 6).

The result of the outer model analysis indicated that all latent variables have AVE scores of more than 0.5. Both Composite Reliability and Cronbach's Alpha values were also more than 0.6, indicating that all variables were valid and reliable (Table 12).

The modeling results indicated that transport management had a positive correlation with user satisfaction ($p < 0.01$) and user acceptance ($p < 0.001$). Service qualities had a significant

Table 10: Value of convergent validity (outer loading) of the user satisfaction indicators.

Indicator	Outer loading	Standard deviation (STDEV)	T Statistics (|O/STDEV|)	*p*-value
Z1	0.860	0.02	44.07	0.000
Z2	0.685	0.047	14.46	0.000
Z3	0.813	0.029	28.48	0.000
Z4	0.891	0.013	69.82	0.000

Table 11: Value of convergent validity (outer loading) of the user acceptance indicators.

Indicator	Outer loading	Standard deviation (STDEV)	T Statistics (|O/STDEV|)	*p*-value
Y1	0.857	0.023	37.055	0.000
Y2	0.873	0.019	46.119	0.000
Y3	0.807	0.034	23.897	0.000

Table 12: Result of outer model analysis of all variables.

Latent variables	Average variance extracted (AVE)	Composite reliability	Cronbach's alpha
Transport management	0.710	0.880	0.795
Service quality	0.660	0.853	0.743
User capacity	0.799	0.941	0.916
User satisfaction	0.666	0.888	0.829
User acceptance	0.716	0.883	0.801

and positive relationship to user satisfaction ($p < 0.001$) but it had a negative correlation to user acceptance ($p > 0.05$). Meanwhile, user capacity had a significant and negative relationship with user satisfaction ($p < 0.001$). This variable also had a significant and positive correlation with user acceptance ($p = 0.001$). User satisfaction had a significant and positive correlation with user acceptance ($p <0.001$) (Table 13 and Fig. 1).

Based on indirect testing, Transport management had a positive relationship with user acceptance through user satisfaction. Service qualities had a positive relationship with user acceptance through user satisfaction ($p < 0.001$). User capacity had a negative relationship with user acceptance through user satisfaction ($p < 0.05$) (Table 14).

Table 13: Total direct effect among variables.

Variables	Loading factor	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	*p*-values
Transport management → user satisfaction	0.213	0.075	2.844	0.005
Transport management → user acceptance	0.387	0.069	5.574	0.000
Service qualities → user satisfaction	0.535	0.082	6.540	0.000
Service qualities → user acceptance	–0.011	0.089	0.124	0.902
User capacity → user satisfaction	–0.174	0.039	4.475	0.000
User capacity → user acceptance	0.119	0.047	2.499	0.001
User satisfaction → user acceptance	0.282	0.07	4.056	0.000

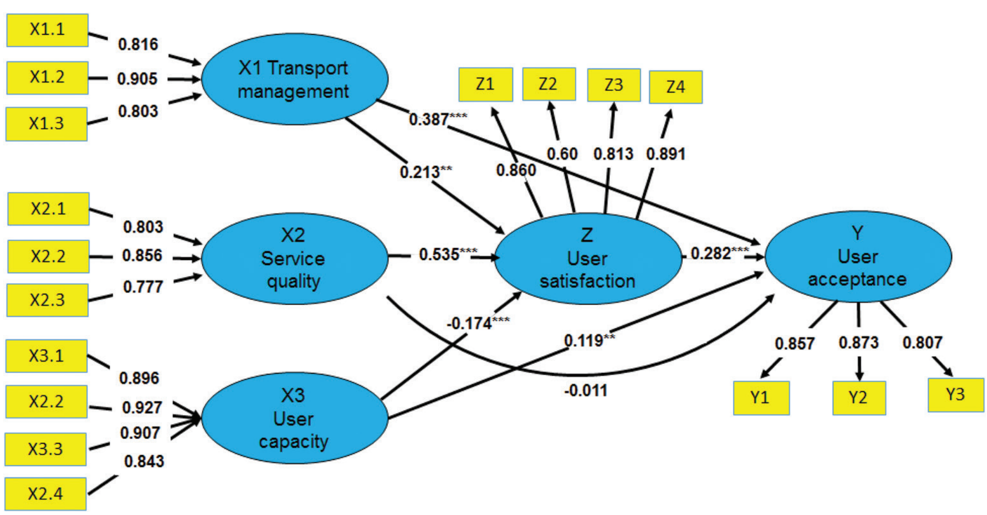

Figure 1: Structural model of user perception on the effect of transport management, service qualities and user capacity on user satisfaction with public transportation. Note: asterisk symbols represent significant correlation at ** ($p < 0.01$), *** ($p < 0.001$).

The validity of the formative indicator model was determined using the significance criteria of each external weight indicator. This criterion was accomplished when the test statistic value-t is $t < 1.96$ or $t > 1.96$. In addition, the path diagram was used to classify all latent variables as formative, implying that significant and valid criteria were adopted. The Fit Model Test results according to several criteria indicated that the overall framework was fit and acceptable. The AGFI had an output of 0.909, demonstrating that it had a better fit because its value was greater than 0.90 (Hair et al., 2010). The SRMR value of 0.011 also demonstrated an acceptable fit model because it has a lesser value, indicating a better match. The NFI had an output value of 0.910, demonstrating this model had a better fit because it is approximately 1, as shown in Table 15.

3.3.2 Recommendation for transportation development plan

The results of the focus group discussions indicate the need for a short, medium and long-term solution. These short-term recommendations for transport management include setting a particular type of vehicle on the route and monitoring its intensity or schedule. It includes safety and comfort improvements for better service quality. Meanwhile, medium and long-term solutions comprise integrated connectivity between primary and secondary transport (feeder) systems, repair of bus stops and stations, handling roadblocks, improvement of service qualities and facilities, increased number of buses, and its ratio to minibusses (Table 16).

4 DISCUSSION

This study revealed that user acceptance is directly and indirectly influenced by transport management, service qualities, user capacity and user satisfaction. Users tend to be more concerned about transport management and service quality. Interestingly, user capacity has

Table 14: Total indirect effect among variables.

Variables	Loading factor	Standard deviation (STDEV)	T Statistics (|O/STDEV|)	p-values
Transport management → user acceptance	0.06	0.027	2.187	0.029
User capacity → user acceptance	−0.049	0.015	3.217	0.001
Service qualities → user acceptance	0.151	0.042	3.552	0.000

Table 15: Indicators of the goodness of fit of the model.

Indicators	p-value	Cut off-value	Acceptable fit
AGFI	0.909	≥0.90	Acceptable fit
SRMR	0.044	≤0.08	Acceptable fit
NFI	0.910	≥0.90	Acceptable fit
RMSEA	0.015	≤0.08	Acceptable fit
Chi-Square	6.515 ($p > 0.05$)	≤32.67	Acceptable fit
Significance	$p > 0.05$	$p \geq 0.05$	Acceptable fit

Table 16: Short, medium and long terms solutions.

Variables	Solution		
	Short-term	Mid-term	Long-term
Transport management	Manage the type of vehicle in one route Manage vehicle intensity/schedule settings	Integrate/ connectivity between primary transport and secondary transport (feeder) Integrate/ connectivity between primary transport and secondary transport (feeder)	Bus stop and station repairs Handling roadblocks Bus stop and station developments Reducing congestion
Service qualities	Improve safety and comfort	Improve service qualities and facilities Increased the number of buses	Improve bus ratio; minibus

a positive direct effect on user acceptance, although indirectly, it has a negative relationship with user satisfaction. This implies that the higher the user's ability to pay, the more difficult it is to feel satisfied with the service management and service qualities. Additionally, user satisfaction is an intervening variable between both transport management and service qualities with user acceptance. Those indirect effects are positive for user acceptance. In contrast, the effect of user satisfaction as an intervening variable between user capacity to user acceptance is negative. The higher the user's ability to pay, the higher their demands on service management and service quality. Therefore, it is necessary to improve transportation management and service quality in terms of accessibility, connectivity, acceptability of fares/ticket prices, security, comfortability and orderliness which greatly affect user satisfaction.

Several studies have shown that public transportation services in Indonesia are very poor [7, 17, 18]. This situation led the users to switch to private vehicles. With a high number of private cars and motorcycles, congestion has gradually worsened the environment [19]. To retract people to use bus service substitutes for personal vehicles, the service providers must struggle to improve quality to increase passenger satisfaction. Various studies have shown that quality of service has a positive impact on user satisfaction and consequently leads to customer loyalty [13,17,20]. Therefore, improving the overall service quality would be the best strategy to increase bus ridership [12, 21]. A study in Yogyakarta showed that several indicators were related to transportation services as follows: availability, timeliness, security, and comfort both at the bus stop and on the bus [7,18]. Meanwhile, customer satisfaction with the Transjakarta Public Bus in Jakarta was influenced by service quality, price and brand image [22]. Therefore, it is necessary to pay attention to improving the quality of the bus transportation system in several cities in Indonesia, including Makassar city.

A previous study evaluated the perceptions of users of paratransit services in Thailand. The results indicated that reliability, in-vehicle environment, comfort, convenience and environmental impact were useful indicators for customers [23]. In another study, it was reported that service quality, perceived value, engagement and satisfaction positively affected the behavioral intentions of public transport passengers in Kuala Lumpur. It has also been reported that a direct negative relationship exists between perceived value and passenger satisfaction, which determines behavioral intentions. Additionally, this variable, however, depends on improving the service quality provided by the public transport system, which, in turn, affects passengers' perception. Service attributes, namely, vehicle safety, cleanliness and complaint management, have a major influence on the perceptions of public transport passengers [24]. Based on these analyses, ticket prices significantly affected consumer satisfaction. This was perceived as an intervening variable between service quality and consumer loyalty [25]. Other studies reported that passengers expect higher levels of safety and environmental friendliness from minibuses [5,17]. In the future, users will expect more qualified and automated public transportation. This is because the results reveal a high level of familiarity with the topic and an overall intention to use fully automated public transport in the future [26,27].

The results of this study can be used to recommend short-, medium- and long-term strategies. The short-term strategy focuses on managing the type and schedule of vehicles. Meanwhile, medium- and long-term strategies focus on improving facilities and increasing transit connectivity between primary and secondary transportation systems. A study in Taiwan demonstrated the importance of the perceptions of urban travelers of the interactions among availability, mobility and seamed connectivity of the public transportation system [28]. Therefore, a strategy to increase user satisfaction can be implemented by improving user-friendly public transportation services in terms of availability, accessibility, comfortability, mobility and connectivity of the bus transportation system.

CONCLUSION

This study estimates that efforts to reopen four bus lines with a total length of 188.72 km, can serve a total of 191,247 users. To meet the needs of those people, this study offers three scenarios. First, all buses have a capacity of 40 persons. Second, all buses have a capacity of 20 people. Third, combined passenger capacity of both 40 and 20 persons (big and medium bus). The first scenario demonstrated that the number of buses ranged from 16 to 21 units per route, while the headway ranged from 10 to 11 minutes. The second scenario demonstrated that the number of buses ranged from 33 to 41 units per route, while the headway was 5 minutes. The third scenario demonstrated that the number of buses ranged from 25 to 30 units per route, while the headway was 7 minutes.

The structural model of passenger perception demonstrated that user acceptance is directly and indirectly influenced by transport management, service qualities, user capacity and user satisfaction. Both transport management and service quality have a positive correlation to user satisfaction. User capacity has a negative effect on user satisfaction. User satisfaction is an intervening variable between both transport management and service qualities with user acceptance. Those indirect effects are positive for user acceptance. In contrast, the effect of user satisfaction as an intervening variable between user capacity to user acceptance is negative. This implies that the higher the user's ability to pay, the more burdensome it is to feel satisfied with the service management and service qualities. Therefore, the service qualities in terms of security, comfort and orderliness greatly affect user satisfaction. The results of this study can be used to recommend short-, medium- and long-term strategies. The short-term strategy focuses on managing the type and schedule of vehicles. Meanwhile, medium- and long-term strategies focus on improving facilities and increasing transit connectivity between primary and secondary transportation systems.

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CONTAINER PORTS IN COUNTRY SYSTEMS: CALIBRATION OF THE AGGREGATE FUNCTION FOR THE TIME OF THE SHIP IN PORT

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ABSTRACT
The maritime transport of goods has always been the crucial element of international trade. The two pillars of maritime transport are: the sea routes and the port systems. The main characteristic that represents the performance of the ports, in sea side, is the time of the ship in port from the arrival and entrance in the port, to the departure from the port, after having completed the loading/unloading operations. The time of the ship in port, by considering the largest ports of a country, is therefore a synthetic indicator of the ability of each country-system to compete in international trade challenges. It is useful to investigate what are the significant characteristics, aggregated at the country level, that determine the average ship time in port at the country level. This analysis is important for planners operating at national level and for technicians and planners who operate within the individual port systems, because it allows to define general policies aimed at improving the performance of the country-system in the global competition, and of the generic port in the competitiveness.
Keywords: aggregated calibration, country systems, port time function, third-generation port, transport system models.

1 INTRODUCTION

The maritime transport of goods was the crucial element of international trade allowing the integration of countries and continents, which took place in the second part of the 20th century and in the first two decades of the twenty-first one. The globalization of national economies has determined a shift to export-oriented policies based on maritime transport. The two pillars of maritime transport are sea routes and port systems. The development of the routes is linked, on the one hand, to the types of ships available and, on the other, to the organization of services on a global scale that can be differently developed in relation to the available ports' supply. As an example, the hub-and-spoke service model can be implemented only if large ports capable of hosting the 24,000 TEU container ships, operating along transoceanic routes, are available. Ports are therefore one of the two pillars and are also the core of new route structures. Their role becomes crucial and the trade capacity on a global scale of the countries depends on performance of country port systems.

In the literature, several attempts have been made to introduce classifications of ports. The difficulty in identifying commonly accepted classifications depends on the complexity and heterogeneity of port systems.

In 1994 UNCTAD [1] introduced the concept of 'generation' and defined the characteristics of three generations of ports. In the literature there is a wide debate about the definition of UNCTAD [2-5] generation. The three generations are briefly recalled, on which there is a general acceptance in the international literature.

First generation ports are ports in proximity of cities, that are part of them. Cities develop where the port is located, that is, the port is born first and then the city, which grows in

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symbiosis with the port [6,7]. Cities are fed by ports and urban productions are sent to other cities through ports [8,9]. The ships that arrive in this port, were initially promiscuous, both freight and passengers, while today they are dedicated according to the two types of demand.

Second generation ports are ports that develop with the great industrial systems during the 20th century. The steel, petrochemical and energy industries determine the birth of second-generation ports. The technical characteristics differ from the first-generation ports, due to the different requirements: large yards near the docks, oil terminals with sophisticated security and safety systems, starting points for pipelines and power lines [10,11]. The territorial model is overturned: first the industrial plant is established and then the port is built to serve it. The ships that arrive are specialized; they are today mainly oil and gas tankers.

Third-generation ports are born with the container transport. In the second part of the 20th century, maritime container transport became the most advantageous freight transport service [12]. Container ships allow to simplifying the loading/unloading operations in ports. The increase of ships' size allows the reduction of transport costs. Container ports are born. They have well-defined technical and functional characteristics: long docks, high draft, large equipped squares, gigantic cranes.

Third-generation ports are not only the basis for the container transport; but they are also able to generate added value. This characteristic differentiates them from the ports belonging to the previous generations that are a center of costs, even if optimized. Ports have gained strategic importance as they became crucial nodes in the global supply chain. UNCTAD proposed in 1999 the definition of fourth generation port [13-15], and later formulations of fifth-generation port were proposed in the literature [16-18]. The scientific debate is still open on these last two generations [19-22].

Third-generation ports are object of interest of scientific researchers, as far as concerns two main territorial elements: the port areas, which are important for handling and transportation operations; the port hinterland where activities could establish, increasing the added value of goods in transit through ports.

As far as concerns the two above territorial elements of third-generation ports, a specific study was conducted on a large European hub port. The limits and weaknesses of port areas and the general actions to be implemented to reduce the costs of a third-generation port were identified in [23-24]. The external and internal components of the examined port that can support its growth were analyzed. The external components, both those generated by the relationship with the territory and those generated by the relationship with the research centers, have been studied respectively in [25] and [26]. The internal components, concerning the three industrial sectors connected with the third-generation ports (logistics, mechanics and agri-food) were analyzed in [27-29]. It emerged that in many countries, especially in less-developed areas, it is necessary to implement specific national, or local, policies that allow ports to become a value-added generator. One policy, largely implemented with success, is the Special Economic Zone (SEZ) near port areas. A recent study identified the activities that SEZ can activate in order to make port areas more attractive in line with a sustainable development. The study has examined the territorial attractiveness [30], modeling the aggregate economic impact [31] and the disaggregated one [32], verifying therefore the impact that the system of higher education and research can have for the SEZ development [33]. An interesting study compares some aggregate characteristics of the different country systems, from which it emerges that higher times are necessary to export goods to many developed countries [34]. The study presented in [35] showed relevant differences on times connected to the export/import of goods for countries having similar technical-administrative structure and belonging to the same economic-political area. It is emblematic the case of Europe where the time connected to the export of goods has high variance among countries respect to the average value of 10 days.

On the basis of [35], the Italian Presidency Council on Ministers presented an analysis of times connected to export issues, disaggregating them into documentation times, customs times, handling and transport times [36]. A summary is proposed in Table 1, where it emerges that customs times are similar for all countries, while documentation and handling times considerably differ. It is particularly useful to investigate these times because they constitute one of the main elements for the definition of the export capacities of each country. Specifically, it is necessary to deepen the ship times in port because they are an important element for the port choices of shipping companies and directly affect transport costs of containers. It is worth noting that the documentation and customs times depend on the administrative organization of the country and not on the ports' organization.

The main characteristic that affect port on the sea side, is the time of ships in the port, from their arrival and entrance in the port, to their departure from the port, after having completed the loading/unloading operations. Ship port time, by considering the largest ports of a country, is therefore a synthetic indicator of the performance of each country-system to compete in international trade challenges.

The first research question that arises is: which are the main country attributes that affect the average ship port times at country-level? The reply to this question implies a careful analysis of the different databases available at international scale.

The second research question is: is it possible to calibrate a function that relates the average port times of container ships at country-level to country attributes?

Two different approaches are present in the literature to model the above relationship: aggregated and disaggregated [37]. The most common models for the estimation of generalized cost functions, in this case ship time, are statistical-descriptive; which estimate demand

Table 1: Times connected to export operations in different EU and Mediterranean countries (source: [35]).

	Time [days]				
	Documentations	Customs and checks	Handling and transport	Total 2014	Total 2012
Netherlands	4	1	2	7	6
Cyprus	3	1	3	7	7
Germany	4	1	4	9	7
Belgium	3	1	5	9	8
Spain	5	1	4	10	9
France	4	1	5	10	9
Morocco	6	1	4	11	11
Egypt	7	1	4	12	12
Greece	11	1	4	16	20
Italy	11	2	6	19	20

levels through functional relationships with service level and economic-territorial attributes [38,39].

The objective of the paper concerns the analysis and evaluation of ports' performances, according to quantitative indicators that link some country characteristics with the average port ship times at country-level. According to the general objective and to the above research questions, the paper is structured as follows. Section 2 presents synthetically the method used to calibrate the port ship time function, and the attributes that can be used for the model specification, accessible in large international databases. Section 3 presents the results of the model calibration, by discussing the meaning of the calibrated parameters. Finally, some conclusive elements are highlighted and development prospects for work are discussed. The study of the main characteristics that affect ports ship times at country-level is useful for planners operating at national level, because it allows to identify and eliminate the critical issues in order to improve country's competitiveness in global trade. The study is equally useful for technicians and designers who work within individual port systems, because it allows to compare the characteristics of a single port with the average country values.

2 MODEL SPECIFICATION

The model considered put in relation the average port ship times, dependent variable, with different attributes, independent variables, at country-level. The link is supposed to be one-way cause-and-effect, that is, explanatory variables affect the dependent variable. The model is estimated using the least squares method. The next paragraphs present the basic formulation of the method and, then, the attributes used for the specification.

2.1 Method

The general functional form of the model is the following:

$$y = f(\mathbf{x}; \boldsymbol{\beta}) + e \qquad \text{Equation (1)}$$

where

$\mathbf{x}$, is the vector of independent variables (or attributes)
y, is the dependent variable
$\boldsymbol{\beta}$, is a vector of unknown parameters
f (), is a function
e, is the error.

Given model (1), it is assumed that *f ()* is linear,

$$y = \beta_0 + \Sigma_{j=1,k}\, \beta_j x_j + e \qquad \text{Equation (2)}$$

where β_0 and β_j are parameters of vector $\boldsymbol{\beta}$.

Model (2) is called multiple linear model. The vector of parameters, $\boldsymbol{\beta}$, is estimated by means of the least squares (LS) method. LS operates by choosing, among the infinite possible lines, the one that minimizes the sum of the squares of the deviations between the values observed and the values estimated by model (2) the vector $\boldsymbol{\beta}$, that is, the one for which it results:

$$\boldsymbol{\beta}_{LS} = \operatorname{argmin} \Sigma_{i=1,n} e^2_i = \Sigma_{i=1,.n} (y_i - (\beta_0 + \Sigma_{j=1,k} \beta_j x_{j,i}))^2 \qquad \text{Equation (3)}$$

with

$\boldsymbol{\beta}_{LS}$, vector of parameters that minimizes eqn (3)
e_i, observed deviations for each country *i*
y_i,average ship port time observed for the country *i*
$x_{j,i}$, attribute j observed for country *i.*

It is useful to calculate a multiple correlation index, denoted by R^2, which measures the intensity of the linear link between the dependent variable y and the vector of explanatory variables, **x**. The R^2 index is equal to:

$$R^2 = 1 - RSS/TSS \qquad \text{Equation (4)}$$

where

$RSS = \Sigma_{i=1,n} (y_i - (\beta_0 + \Sigma_{j=1,k} \beta_j x_{j,i}))^2$, is the residual deviance*;*
$TSS = \Sigma_{i=1,n} (y_i - \underline{y})^2$, is the total deviance;
$\underline{y}$ is the average value of the dependent variable.

To consider the number of parameters used in each estimated model, it is useful to calculate the adjusted multiple correlation coefficient, denoted by $\underline{R}^2$:

$$\underline{R}^2 = 1 - (n-1)/(n-k-1)\ RSS/TSS \qquad \text{Equation (5)}$$

where:

n is the number of observations;
k is the number of attributes.

2.2 Attributes

The model aims to estimate the role of different attributes, aggregated at country-level, in the determination of the average Port Ship Time, PST, aggregated at country-level, which represents the average port time between all ports and between all ships of a 'Country-System'. This term embraces the role of several characteristics of a country. It is evident that every country has high performance port, compared to the average value, in terms of ship times and less performing ports. The attention is focused on the overall performances of a country considered as a homogeneous system.

The model specification considers two macro-classes of attributes for estimating the value of the average PST:

- transport;
- economic and technological.

The transport attributes can be aggregated into three classes:

- Ships, attributes of container ships related to the country;
- Infrastructures: infrastructural equipment of the ports of the country;
- Services: maritime transport services of the country.

The attributes belonging to class Ships are the following.

- *Average Gross Tonnage of container ships [AGT],* measured in Gross Tonnage: which indicates the average gross tonnage of container ships using country's ports during the period considered (year).
- *Maximum Gross Tonnage of container ships [MGT],* measured in Gross Tonnage: which indicates the maximum gross tonnage of the container ship that used at least one time one of the ports of the country during the period considered (year).
- *Average Capacity of container Ships [ACS],* measured in TEU/10^3, which indicates the average capacity of container ships using country's ports during the period considered (year).
- *Maximum Capacity of container Ships [MCS],* measured in TEU/10^3, which represents the maximum number of TEUs carried by a container ship using country's ports during the period considered (year).

The attributes belonging to class Infrastructures are the following.

- *Linear Shipping Connectivity Index [LSCI]*, with extremes of variability [0–100], which indicates the level of integration of a country inside the global maritime transport network.
- *Logistics Performance Index [LPI],* with extremes of variability [1-5], which evaluates countries based on their efficiency of handling goods both inside and outside the country.
- *Ports Infrastructure Index [PII]* with extremes of variability [1-7], which assesses the quality of the country's port infrastructure over a reference period (year).

The attributes belonging to class Services are reported in the following.

- *Number of Ship Calls [NSC],* which indicates the number of port calls during the examined period by all ships in all ports of the country.
- *Throughput [THR],* measured in TEUs/10^6, which indicates the number of handled containers in a country during the period considered (year).

The attributes related to country are aggregated into two classes Technology and Economy.

The attributes belonging to class Technology are the following.

- *Technology-Overall Index [TOI],* with extremes of variability [0-1], which estimates technological capabilities of a country in relation to physical investment, human capital and technological effort and represents national capacities to use, adopt and adapt new-generation technologies.
- *ICT Technology Index [ITI]* with extremes of variability [0-1]: estimates technological capabilities in a similar way to TOI but only with respect to ICT technologies.

The attributes belonging to class Economy are the following.

- *Gross Domestic Product [GDP]*, which indicates the average annual growth of total GDP as a percentage of the country under consideration.
- *Gross Domestic Product per Capita [GDC],* which indicates the average annual growth of GDP (Gross Domestic Product) per capita as a percentage.

Table 2 shows the attributes considered with the bibliographic references to the database from which they were extracted with the reference year, and the countries that have the maximum and minimum values of the attribute.

3 MODEL CALIBRATION

The model was calibrated using the LS method, as reported in section 2.1. A preliminary, internal, correlation analysis between the variable PST, and the attributes presented in section 2.2, and between the above attributes was carried out. The correlation analysis showed that the attribute maximum capacity of container ships, MCS, is highly correlated with the examined variable average port ship time, PST. Moreover, it is of particular interest to study the impact of ICT dotation of the country, through the attribute ICT-Technological index, ITI, on the variable PST. For the above reasons, the two attributes were considered as the basis for all the specified models. Different models were then calibrated by considering the attributes MCS and ITI as a reference basis, and adding each time one more attribute defined in section 2.2.

Table 3 shows the values of the calibrated parameters, $\boldsymbol{\beta}$, estimated in each model and the values of R^2 and $\underline{R}^2$.

It is recalled that a positive value of the generic parameter β_j indicates a positive linear dependency between the variable port ship time, PST and the attribute x_j, while a negative value indicates a negative linear dependency, that is, as the value of the attribute increases, the value of PST decreases.

The first notation to be made is of a general order and concerns the sign of the parameters, which is almost always, in line with what is expected.

The basic considerations concern model 1 which can be considered the reference model. The value of β_0=2.56 [days] defines the reference threshold of PST for all countries. The value of MCS parameter (β_{MSC}=-0,10) indicates that PST reduces when the country offers ports able to host large capacity ships, that is, countries with larger and more performing ports. Similarly, PST reduces as the country's technological dotation in terms of ICT increases (β_{ITI}=−0,52). It is worth noting that the ratio between the two parameters is 1 to 5, therefore, investments in physical port infrastructures that allow to potentially increase MSC of 5,000 TEUs causes the same impacts on PST generated by an increase of 20% of ITI, indicating the considerable potentialities reduction of PST by increasing the level of ICT in the country.

In models 2 and 3, both the attributes average and maximum gross tonnage of container ships, AGT and MGT, are introduced, while model 4 considers the attribute average capacity of container ships, ACS. According to the calibrated parameters, as the values of above three attributes grow, the value of PST reduces with a weight of at least an order of magnitude lower generated by a reduction of MCS. It is worth noting that the presence of MGT, given the high correlation with MCS, induces a modification of the sign of MCS parameter.

Models 5 and 6 introduce the attributes LSCI and LPI, which both have a positive sign, thus they may be considered as proxies of ports' saturation. In other words, they may indicate that countries with more connections and more logistics services actually induce container ships to spend more time in ports than average.

Models 9, 10 and 11 introduce attributes that, again, indicate that ports are congested: both directly with the attribute throughput, THR, and indirectly with the economic variables GDP, and GDC. Due to the positive signs of parameters, the attributes may be considered as proxies of ports' saturation due to the considerable amount of trade, as in models 5 and 6.

Table 2: Characteristics of the attributes.

	Transport attributes									Economic and technological attributes			
Classes	Ships			Infrastructures				Services		Technological		Economics	
Attributes	AGT	MGT	ACS	MCS	LSCI	LPI	PPI	NSC	THR	ITO	ITI	GDP	GDC
Unit of M	GT	GT	TEUs/10^3	TEUs/10^3	----	----	----	----	TEUs/10^6	----	----	----	----
Database	*	*	*	*	*	**	***	*	*	*	*	*	*
Min	9.36	19.131	0.876	1.740	6.8	2.0	2.1	0.118	0.18	0.0	0.1	0.0018	523
Country	Tunisia	Tunisia	Tunisia	Tunisia	Gambia	Angola	Venezuela	Libya	Venezuela	Gambia	Gambia	Gambia	Libya
Max	85.8	232	8	24	152.9	4.2	6.5	72.6	0.242	1.0	1.0	21.48	64,671
Country	Saudi Arabia	Belgium, …	Saudi Arabia	Saudi Arabia	China	Germany	SING.	China	China	USA	Sweden	USA	USA

(*) UNCTADSTAT (www.unctadstat.unctad.org); (**) The World Bank (www.worldbank.org); (***) The Global Economy (www.theglobaleconomy.com)

Table 3: Calibrated models.

	UoM	1	2	3	4	5	6	7	8	9	10	11	12
β0	----	2.56	2.47	2.63	2.47	2.44	2.38	2.45	2.55	2.44	2.44	2.60	2.4
AGT	GT		−0.001										
MGT	GT			−0.02									
ACS	TEUs/10^3				−0.011								
MCS	TEUs/10^3	−0.10	−0.08	0.11	−0.08	−0.11	−0.07	−0.082	−0.07	−0.08	−0.08	−0.07	−0.07
LSCI	----					0.01							
LPI	----						0.09						
PII	----							−0.003					−0.04
NSC	----								−0.0015				1.02
THR	TEUs/10^6									0.04			
ITO	----												
ITI	----	−0,52	−0,08	−0,002	−0,0002	−0,012	−0,67	−0,00008	−0,53	−0,01	0,00	−0,7	−0,001
GDP	----										0.01		
GDC	----											0.0027	
R^2		0,60	0,58	0,63	0,58	0,60	0,60	0,58	0,6	0,59	0,58	0,60	0,63
$\bar{R}^2$		0,58	0,56	0,60	0,56	0,57	0,57	0,56	0,57	0,57	0,56	0,58	0,57

Model 7 is interesting because the presence of the attribute port infrastructure index, PII, causes the reduction of the value of parameter associated to ITI attribute and that, even if in modest amount, of the MSC attribute.

Finally, model 12 presents four attributes, in which the attributes PII, and NSC are considered. It emerges that the parameter associated to attribute NSC is positive, if compared to model 8, in accordance with the attributes of models 9, 10, 11, as NSC may be considered as another and different indicator of ports' congestion.

4 CONCLUSIONS

In this work, the study of the representative function of the time of container ships in the ports of a generic country was presented. The average value of times between all ports in a country was considered. Attributes that can be considered as independent variables were analyzed.

Two basic attributes have been identified that determine the value of ship time with a negative linear dependency. The first is the maximum capacity, in TEU, of the ships that can be hosted in the ports a country. The second is the country's ICT technology index.

From the different specifications and calibrations three classes of quite homogeneous attributes may be identified.

A first class that refers to the ships' size that can use the ports of a country, these attributes weigh heavily in determining the average time per country, and reduce it as they grow. The result is interesting because it identifies a better organization of the ports as their infrastructural capacities grow. The result is confirmed by the role of the infrastructure indicator which also has a negative linear relationship.

A second class refers to the aggregate economic characteristics of the country. The attributes of this class have a positive linear relationship, that is, as they grow, the average time increases. This result is also interesting because it indicates that an high utilization of the ports induces on average an increase in ship time.

A third class is composed by attributes that may be associated to the country's performance in terms of logistics services and maritime connections with other countries. These attributes, like those of the second class, have also a positive linear relationship, confirming that their growth indicates a better organization of services, but aggravates port systems that fail to meet this demand well.

Finally, the parameter associated to the infrastructure index has a negative linear dependency with port time that confirms the importance of investments in the port sector.

This work provides an important contribution to the knowledge of the ability of each country system to deal with maritime transport through its access points which are the ports. In the literature, ports are studied as individual systems, while there is no transversal knowledge to all ports of each country, although the overall supply policies and the knowledge of the potential of each country by demand must be based precisely on these overall assessments.

The results obtained allow to planners and technicians of the decision-making departments at national and regional level to implement adequate policies for the improvement of the overall values of the country or region in the performance of the ports that insist in that territory. The results are useful for the technicians of the various port authorities because they allow to build an (average) bench marking with respect to the country and allow to identify in which position the individual port is located. Further developments need to be carried out by analyzing the disaggregated characteristics of individual ports.

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THE STRUCTURAL BARRIERS TO UNIVERSALLY ACCESSIBLE TRANSPORT: THE TSHWANE (ZAF) METROPOLITAN AREA STUDY CASE

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ABSTRACT
People with disabilities face many obstacles in accessing public transport and their needs are often overlooked. The transport systems in many countries including South Africa do not meet the basic requirements of universal design, despite the awareness, support from different organisations and inclusion in policy. The purpose of the study was to investigate the structural barriers experienced by people with disabilities in accessing transport. A structured questionnaire was used to collect data from people with disabilities. The findings of the study reveal that infrastructure is generally poorly designed and there is a lack of accessible infrastructure, which consequently compromises the safety of people with disabilities. Most people with disabilities find it difficult to cross roads or intersections. The results also reveal that public transport vehicles do not comply with universal access principles. The study recommends regular accessibility audits of infrastructure which involve the participation of people with disabilities. This study contributes to literature on transport barriers experienced by people with disabilities not only in Tshwane but in other African cities. The barriers experienced by people with disabilities established in this study could inform decision makers and thereby help to improve policies and legislation regarding the provision of universally accessible transport infrastructure and services.
Keywords: developing country, people with disabilities, public transport, structural barriers, universally accessible transport.

1 INTRODUCTION

Worldwide, cities struggle with the complex nature of transport [1]. Urban transport management is complicated as it deals with other transport sectors, coordination and integration of different transport systems and co-produces transport services jointly with urban land use development [2]. Transport is not equally distributed; 'some people have more transport possibilities than others and some can travel much faster than others and, in more directions' [3]. A group of transport users severely affected by transport inequalities is people with disabilities. In many countries, especially developing countries, the public transport that is available to the general public is not always accessible to people with disabilities [4], yet accessible public transport can significantly improve the quality of life of people with disabilities and their families [5,6]. Because of the low presence levels of people with disabilities on public transport, there is a misconception that there is little demand for public transport amongst people with disabilities [7].

The Convention on the Rights of Persons with Disabilities (CRPD), Article 9, requires '*all signatories to provide equitable access to the physical environment, transportation and information, communication and other services, as well as to public areas, urban and rural*' [8]. To address the issue of accessibility in transportation, the concept of universal access can be adopted by governments. Universal design (also known as inclusive design, universal access or accessible design) refers to equal access enabled through designing products and spaces in a way that is accessible to everyone including people with disabilities, elderly and many

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other groups usually left out of traditional design [9]. It is well documented that universally accessible transport has a positive impact on people with disabilities and other vulnerable groups of transport users [5,6,10].

Universally accessible transport 'creates a system that maximises the possibility to meet, via mobility, the needs of all sorts of people and is basically about the power of joint experiences, dialogue and creating community via transport and transport services' [10]. Universally accessible transport is regarded as the key to social inclusion of people with disabilities in society, and lack of it can increase the risk of poverty, exclusion, inequality or poor quality of life among people with disabilities [11-13]. According to Coxon et al. [7], provision of universal accessibility to mobility is an indication of a progressive society.

People with disabilities face many obstacles in accessing public transport [7] and their needs are often overlooked [11,13]. Research shows that transport systems in many countries do not meet the basic requirements of universal design, despite the awareness and support from different organisations [14]. South Africa is one the countries in which people with disabilities experience significant problems in accessing public transport [15-17]. The City of Tshwane, a metropolitan municipality in South Africa, shows an increase in the number of people with disabilities [18], yet there is little research focused on transport problems experienced by people with disabilities. It is inevitable that they will experience transportation problems, given the lack of inclusivity in transport provision in South Africa [17,19]. Therefore, the transport needs of people with disabilities should be understood, so that they can be addressed and integrated into city policies.

Transport barriers for people with disabilities are typically classified as structural, psychosocial, socio-demographic, service quality and institutional barriers [4,11,13,20-23]. Structural barriers are widely documented as critical barriers that affect people with disabilities in developing countries [4,15,24]. This study only focusses on people with mobility, vision and hearing disabilities because they are among the groups that face severe transport problems compared to other groups with disabilities [25]. Although people with mental disabilities are also among people who face significant transport barriers [5,20,26], the researchers do not have the requisite skills to interact with people with mental disabilities. It is not recommended to conduct research in such circumstances [27,28]; as such, people with mental disabilities were excluded from the study.

According to literature, structural barriers are obstacles that prevent transport users from accessing the service because of the condition of the built environment, transport infrastructure and vehicle design [13,22]. The barriers created by the built environment are interlinked with architecture and design [29]. The barriers that are created by vehicle design include vehicle space, steps in vehicles and seating, while barriers related to transport facilities include bus and train stations which are not universally designed [20]. To summarise barriers which are related to structural barriers, Table 1 shows a list of the barriers established from literature.

Structural factors established from the literature include the pedestrian environment, ramps, stairs, elevators, vehicles design, platforms and toilets. Literature indicates that people with mobility and visual disabilities experience severe structural barriers compared to people with hearing disabilities [15,29].

2 RESEARCH METHOD

The study site is the metropolitan area of the City of Tshwane, which is located in the Gauteng province of South Africa. The City of Tshwane has a coverage area of about 6 298 km^2 and a population of approximately three million people [38]. In the metropolitan area of the City of Tshwane, there are approximately 184,434 people living with some form of disability

Table 1: Summary of barriers that affect accessibility.

Disability	Barriers
Mobility	Stairs and steps [7,30]
	Insufficient space for wheelchairs [31]
	Inaccessible toilets [6,13]
	Vehicle design [32,33]
	Building entrance and exits [6]
	Pedestrian environment (uneven surfaces, kerbs, street furniture, open manhole, street vendors) [34]
Visual	Tactile surfaces [6]
	Stairs and steps [6]
	Pedestrian environment (uneven surfaces, kerbs, open manhole, street vendors) [13,15]
	Navigating unfamiliar environment [20]
	Stops [5]
	Voice announcements [9,35]
Hearing	Display information [36)
	Traffic lights [37]

[18]. This population includes people with disabilities over the age of five, and includes all the types of disabilities. The study was focused on three types of disabilities: mobility disability, hearing disability and vision disability and participants were adults between the age of 18 and 65 years.

A quantitative method was adopted in this study using a survey-research design. Similar studies have also used the quantitative research method [12,39,40,41,42]. Using Raosoft [43], the sample size was estimated to be 384 to achieve 95% confidence level with margin of error of 5%. Snowball and purposive sampling were used to select people with disabilities participating in the study. Purposive sampling can be described as non-probability sampling in which a researcher intentionally selects participants in the study [44]. Snowball sampling can be described as a non-probability sampling method in which research participants recruit other participants in a study [45]. Data from people with disabilities was collected through a self-administered questionnaire. A sample size of 384 could not be achieved because there is no database of people with disabilities in the City of Tshwane. It was difficult to access people with disabilities as data was collected during the time of COVID-19. However, the responses were sufficient. For the purpose of this study, the sampling size of the people with disabilities was N = 214. A sample size of about between 30 and100 is considered to be sufficient to perform basic statistical procedures [46]. ‘Statistical techniques have minimum threshold of data cases for each cell’ [47]. For the purposes of this study, the sample size was therefore considered to be sufficiently large to provide meaningful results.

The two types of statistical methods used to analyse data are descriptive statistics and inferential statistics. SPSS statistical software package version 26 was used to perform inferential statistics. The results of the study are presented in section 3.

3 STRUCTURAL BARRIERS

Using a five-point Likert scale, respondents were asked to rate the extent to which they agree or disagree with the effect of structural barriers of public transport in terms of their disabilities. Table 2 presents item mean and standard deviation of structural barriers.

The items in Table 2 are arranged from highest to lowest score to give a perspective on the main concerns. The results show that the highest score (M = 4.43, Mdn = 5) was on Item D1.14 'It is difficult for me to cross busy intersections' while the lowest score was Item D1.3 'With my disability, I cannot use a minibus taxi' (M = 2.23, Mdn = 2).

Exploratory factor analysis (EFA) was conducted to uncover the underlying structure of the variables and to interpret the results [48]. The Kaiser-Meyer-Olkin (KMO) measure of sampling [49] and Bartlett's test of sphericity [50] were conducted first to evaluate the strength of the linear association between the 15 items in the correlation matrix. The results for KMO showed a value above 0.6 and Bartlett's test of sphericity was statistically significant ($p < 0.001$) thereby confirming viability to conduct factor analysis.

An inspection of the scree plot suggested that the first four factors as 'strong factors'. The second stage was to determine the number of factors from the individual statements. The results showed that the four factors in the solution had eigenvalues greater than 1 and accounted for 69.6% of variability in the original variables.

Table 2: Structural barriers.

	Items	Mean (M)	Std. Dev
D1.14	It is difficult for me to cross busy intersections	4.43	0.837
D1.8	Crossing busy streets is difficult for me	4.42	0.824
D1.9	There is no space for wheelchairs in public transport I use	4.27	0.896
D1.15	There are no bus shelters (bus sheds) in my community	4.16	0.798
D1.6	There are poor or no sidewalks/pavements where I live	3.99	1.015
D1.5	Bus stops in my community are not located within walking distance/short distance	3.87	1.026
D1.10	Toilets at stations are inaccessible for people in wheelchairs	3.83	0.994
D1.12	There are no lifts/elevators to platforms at train stations	3.81	0.965
D1.11	Train platforms are inaccessible e.g. no ramps	3.76	0.997
D1.13	Steps or stairs make it difficult or impossible for me to move	3.66	1.697
D1.7	Pavements/sidewalks which are in my community make it difficult for me to walk or move	3.65	1.420
D1.1	In my community, public transport is not accessible to people with my disabilities	3.36	1.223
D1.4	Boarding or exiting a transport vehicle is difficult for me	3.05	1.546
D1.2	With my disability, I do need specialised vehicles	2.67	1.537
D1.3	With my disability, I cannot use a minibus taxi	2.23	1.350

The highest communality value in Table 3 was 0.945. Item D1.1 was included although the communality value was slightly below 0.3 because the measure of sampling adequacy (MSA) value (0.807) was above 0.6. Using these criteria, three items were found loading on the first, second, third and fourth factor, which were subsequently labelled: (1) Station accessibility, (2) Vehicle accessibility, (3) Mobility barriers and (4) Transport facilities respectively. Items D1.6. D1.8 and D1.14 were omitted since the values for MSA were below 0.6 and no further

Table 3: Rotated factor pattern and final communality.

Items	**Rotated component matrix**				**Communalities Extraction**
	Component				
	1	**2**	**3**	**4**	
D1.11 Train platforms are inaccessible	**0.945**	0.177	0.137	0.132	0.960
D1.12 There are no lifts/elevators to platforms at train stations	**0.835**	0.245	0.137	0.247	0.838
D1.10 Toilets at stations are inaccessible for people in wheelchairs	**0.588**	−0.155	0.135	0.440	0.582
D1.2 With my disability, I do need specialised vehicles	0.295	**0.717**	0.162	−0.084	0.635
D1.3 With my disability, I cannot use a minibus taxi	0.078	**0.555**	0.234	0.038	0.371
D1.1 In my community, public transport is not accessible to people with my disabilities	−0.011	**0.433**	0.122	0.268	0.275
D1.13 Steps or stairs make it difficult or impossible for me to move	0.184	0.143	**0.819**	0.077	0.731
D1.4 Boarding or exiting a transport vehicle is difficult for me	−0.098	0.468	**0.601**	0.079	0.596
D1.7 Pavements which are in my community make it difficult for me to walk or move	0.221	0.208	**0.553**	0.156	0.422
D1.15 There are no bus shelters in my community	0.138	−0.050	0.040	**0.579**	0.358
D1.5 Bus stops in my community are not located within walking distance/short distance	0.164	0.355	0.151	**0.502**	0.428
D1.9 There is no space for wheelchairs in public transport I use	0.368	0.286	0.136	**0.501**	0.487

Extraction Method: Principal Axis Factoring. Rotation Method: Varimax with Kaiser Normalization[a].
a. Rotation converged in eight iterations

items were excluded thereafter. The communality values of the structural barrier items were all above 0.2; therefore, items were considered to belong to the respective factor structures.

The reliability of the constructs was established through Cronbach's alpha coefficient. Constructs 1 to 3 had a coefficient of above 0.8 while Construct 4 had a coefficient of 0.592 which indicated uncertain reliability. As recommended by Pallant [48], the level of consistency was reported through the mean inter-item correlation. The inter-item correlation mean value was 0.326, indicating that construct 4 had an acceptable level of consistency. The four constructs for structural barriers were therefore found to be reliable.

To check for similarities and differences in the structural barriers experienced by the three groups of people with disabilities, a one-way analysis of variance test (ANOVA) was conducted. An ANOVA test is a type of statistical test used to determine if there is a statistically significant difference between different groups by testing for differences of means using variance [48]. However, to assess whether specific differences exist between the groups of people with disabilities in terms of the barriers related to the four factors, a multiple comparison test (Scheffe) was performed, and the results are shown in Tables 4 to 7. Scheffe test is post-hoc test used to make comparisons in an ANOVA test; it explores the differences between each of the groups in the study [48].

Table 4 shows that there is a statistically significant difference in barriers related to station accessibility between people with mobility and hearing disabilities ($p = 0.001$), as well as between people with mobility and vision disabilities ($p = 0.003$). However, there were no significant differences between the people with vision and hearing disabilities ($p = 0.978$).

The results for 'Vehicle accessibility' are presented in Table 5. Scheffe's post hoc test shows that there is a statistically significant difference in barriers related to vehicle accessibility experienced between groups with mobility and hearing disabilities ($p < 0.001$), groups with mobility and vision disabilities ($p < 0.001$), as well as groups with vision and hearing disabilities ($p < 0.001$).

Table 6 summarises the results for multiple group comparison concerning 'Mobility barriers'

The results in Table 6 show that there is a statistically significant difference in mobility barriers experienced between groups with mobility and hearing disabilities ($p < 0.001$), mobility

Table 4: Station accessibility.

Dependent variable:	SecD1_F1					
Scheffe						
(I) B3		Mean Difference (I-J)	Std. Error	Sig.	Lower 98,33%	Upper
Mobility	Hearing	.589*	0.154	**0.001***	0.14	1.04
	Vision	.552*	0.158	**0.003***	0.10	1.01
Hearing	Mobility	−.589*	0.154	**0.001***	−1.04	−0.14
	Vision	−0.036	0.173	0.978	−0.54	0.46
Vision	Mobility	−.552*	0.158	**0.003***	−1.01	−0.10
	Hearing	0.036	0.173	0.978	−0.46	0.54

*The values in bold are (p-value is smaller than 0.05).

Table 5: Vehicle accessibility.

Dependent variable:	SecD1_F2					
Scheffe						
(I) B3		Mean Difference (I-J)	Std. Error	Sig.	Lower 98,33%	Upper
Mobility	Hearing	2.087*	0.130	**0.000***	1.71	2.46
	Vision	1.488*	0.133	**0.000***	1.10	1.87
Hearing	Mobility	−2.087*	0.130	**0.000***	−2.46	−1.71
	Vision	−.599*	0.146	**0.000***	−1.02	−0.18
Vision	Mobility	−1.488*	0.133	**0.000***	−1.87	−1.10
	Hearing	.599*	0.146	**0.000***	0.18	1.02

*The values in bold are (p-value is smaller than 0.05).

Table 6: Mobility barriers.

Dependent variable:	SecD1_F3					
Scheffe						
(I) B3		Mean Difference (I-J)	Std. Error	Sig.	Lower 98,33%	Upper
Mobility	Hearing	2.918*	0.114	**0.000***	2.59	3.25
	Vision	.579*	0.117	**0.000***	0.24	0.92
Hearing	Mobility	−2.918*	0.114	**0.000***	−3.25	−2.59
	Vision	−2.339*	0.128	**0.000***	−2.71	−1.97
Vision	Mobility	−.579*	0.117	**0.000***	−0.92	−0.24
	Hearing	2.339*	0.128	**0.000***	1.97	2.71

*The values in bold are (p-value is smaller than 0.05).

and vision ($p < 0.001$), as well as groups with vision and hearing disabilities ($p < 0.001$). Table 6 presents results for multiple group comparison concerning ‘Transport facilities’.

The results in Table 7 show that there is a statistically significant difference in barriers related to transport facilities between groups with mobility and hearing disabilities ($p < 0.001$), as well as groups with mobility and vision disabilities (0.006). However, there were no significant differences between groups with vision and hearing disabilities ($p = 0.200$).

4 DISCUSSION

The results revealed that the highest score was found on Item D1.14 ‘It is difficult for me to cross busy intersections or roads or streets’. This result is consistent with the Gauteng Household Travel Survey which reported that the design of transport infrastructure and

Table 7: Transport facilities.

Dependent variable:	SecD1_F4					
Scheffe						
(I) B3		Mean Difference (I-J)	Std. Error	Sig.	Lower 98,33%	Upper
Mobility	Hearing	.615*	0.115	**0.000***	0.28	0.95
	Vision	.383*	0.118	**0.006***	0.04	0.72
Hearing	Mobility	−.615*	0.115	**0.000***	−0.95	−0.28
	Vision	−0.232	0.129	0.200	−0.61	0.14
Vision	Mobility	−.383*	0.118	**0.006***	−0.72	−0.04
	Hearing	0.232	0.129	0.200	−0.14	0.61

*The values in bold are (*p*-value is smaller than 0.05).

services remains critical in the Gauteng Province [51]. The mean score could be high because in the City of Tshwane there is not much infrastructure or assistive devices for people with disabilities at intersections. According to Arrive Alive [52], intersections in South Africa are dangerous because the constant flow of vehicle traffic is intensified by human error, road engineering and lack of design measures to ensure safe intersections. Arrive Alive [52] maintains that the first measure of safety at intersections is driver etiquette and compliance with road rules. A study done in Nigeria reveals that there is a high risk for people with disabilities to collide with fast-moving vehicles as there are many drivers who do not observe traffic rules [53]. The same is true in South Africa, where some drivers are not very law abiding on the road [52].

The lowest score was found on Item D1.3 ‘With my disability, I cannot use a minibus taxi’ (M = 2.23, Mdn = 2). The low score could be because this barrier is primarily experienced by people with mobility disabilities. In South Africa, minibus taxis are designed with a step at the entrance, thereby making it difficult for people with mobility disabilities to enter the vehicle. People with hearing and visual disabilities are marginally affected by the design of a vehicle.

4.1 Station accessibility

The items which loaded to Factor 1 ‘Station accessibility’ were D1.11 Train platforms are inaccessible; D1.12 There are no lifts/elevators to platforms at train stations; and D1.10 Toilets at stations are inaccessible for people in wheelchairs. It was found that people with mobility disabilities are significantly affected by these barriers. There was a statistically significant difference in barriers experienced between people with mobility disabilities and the other two groups. Previous research indicate that the platform-to-vehicle gap is a critical issue among people with mobility disabilities and to some extent to people with visual disabilities [6,20]. Inaccessibility of the platform is attributed by the height and width of platforms which are not compatible with train heights, as well as stairs and steps with no alternative of lifts or ramps [9]. Lack of maintenance of lifts can also affect mobility of people with mobility disabilities. In Stockholm, some lifts at the stations can be out of order for two or three months, thereby making it impossible for people using wheelchairs and others with mobility disabilities to reach platforms [54]. Whilst lifts have occasionally been reported as being out of order for several months in developed counties [54], these issues are more pronounced in developing countries where lifts often do not exist or are permanently out of order [55,56]. In Cape Town, six key Metrorail stations have lifts which are either permanently out of order or have no lifts or ramps [56].

Although ramps, elevators or lifts may not be absolutely necessary to people with visual disabilities, these elements can aid smooth mobility and reduce the risk of falling. Another barrier which only confronts people with mobility disabilities is the design of toilets. In South Africa, the National Building Regulations and Building Standards Act (103 of 1977) prescribes the design standards for accessible toilets for people with disabilities but the problem of inaccessible toilets persists. The standard requirements for these toilets are wide with easily opened doors, sufficient space to manoeuvre, sufficient space for the assistant, support handrails and washing basins and dryers within reach. In summary, inaccessibility of stations is constituted by platforms which are not compatible with train heights, lack of ramps, lifts or elevators; inadequate or inaccessible toilets and with a too steep gradient.

4.2 Vehicle accessibility

Factor 2, ‘Vehicle accessibility’, consists of three items: – D1.2 With my disability, I do need specialised vehicles; D1.3 With my disability, I cannot use a minibus taxi; and D1.1 Public transport in my community is not accessible to people with my disability. These barriers mostly affect people with mobility disabilities, especially those using wheelchairs. People with visual and hearing disabilities generally do not encounter many difficulties in physical accessing of vehicles. People with mobility disabilities typically require physical help in boarding and alighting vehicles, which may require features which enable accessibility. Vehicle physical accessibility is mostly impacted by vehicle design, vehicle, steps at the entrance and seating set-up [20]. Research done by Pyer and Tucker [30] reveals that British teenage wheelchair users found it difficult to use buses with steps at the entrance. Some may fold the wheelchairs to gain access to the bus and the folding of wheelchairs is cumbersome for parents or companions [30]. Ahmad [2015] found that the boarding and alighting of people with mobility disabilities is a challenge and there is also no space to manoeuvre for wheelchairs. Although in South Africa, mini-bus taxis are the most available form of public transport, the vehicle design does not accommodate the needs of people with mobility disabilities [57,58]. The step into the entrance of the taxi makes it difficult or impossible for people with mobility disabilities to use minibus taxis and is a common problem across many cities in developing countries such Thailand, Nigeria and Ghana [34,41,59]. Overall, accessibility to public transport among people with mobility disabilities is significantly affected by ‘vehicle accessibility’.

4.3 Mobility barriers

The items which loaded to Factor 3 were D1.13 Steps or stairs make it difficult or impossible for me to move; D1.4 Boarding or exiting transport vehicle is difficult for me; and D1.7 Pavements which are in my community make it difficult for me to walk or move. These barriers are related to mobility. The two groups of people with disabilities that are affected by these barriers are people with mobility and vision disabilities. People with mobility disabilities need physical assistance in boarding and exiting vehicles while people with visual disabilities may only require guidance to board and exit. Mobility of people who use wheelchairs may be completely blocked in cases where lifts or ramps are not provided. Steps and stairs pose a high risk of falling among people with visual disabilities. Steps are found in both vehicles and built environment. The results indicate that 'steps or stairs make mobility difficult' (M = 3.66). According to the World Bank [60] 'where steps are prevalent, there should be adequate grab rails and colour contrasting of steps'.

The results show that existing pavements make walking difficult (M = 3.65). The study did not establish the reasons why pavements make mobility difficult. Similar studies reveal that some of the barriers created by pavements are insufficient width, lack of pavements, unevenness of surfaces, uncovered manholes, obstructs such as bins or street lights or street vendors, broken pavement [24,34,41,61-63]. The state of pavements not only hinder accessibility of people with disabilities, but endanger everyone [34]. Walking along busy streets can be stressful for people with visual disabilities as they constantly need to negotiate pavements and try to avoid collisions [64]. In Chengdu, China, Wu et al. [23] found that there are many sidewalks for blind people but some spaces were partially blocked by parked vehicles, were poorly designed or lacked maintenance. The results also indicate that boarding or exiting transport vehicles is difficult for people with disabilities (M = 3.05), which is a significant problem. The results are in line with previous research revealing that mini-bus taxis in South Africa are not universally designed; hence they do not accommodate the needs of people with disabilities, especially people with mobility disabilities [57]. Overall, mobility barriers severely affect people with visual and mobility disabilities.

4.4 Transport facilities

Factor 4, 'Transport facilities', consists of three items – D1.15 There are no bus shelters (bus sheds) in my community; D1.5 Bus stops in my community are not located within walking distance/short distance; and D1.9 There is no space for wheelchairs in public transport I use. The results show a high score (M = 4.16) for item D1.15 'There are no bus shelters (bus sheds) in my community'. These results are consistent with study done by Ahmad [2015] revealing that terminal facilities do not have adequate shelter to protect transport users from harsh weather conditions.

When using public transport, walking is inevitable: for example, a walk to the bus stop or train station, a walk between transfers, a walk to the destination from the bus stop or train station [65]. Respondents in this study reported that bus stops are not located within walking distance (M = 3.87). According to the City of Tshwane [2015], most residents in the city are within a walking distance to a taxi service, however, some residents do not have access to bus services.

The results indicate that public transport vehicles that carry respondents do not have space for wheelchairs (M = 4.27), which can be difficult for people who use wheelchairs. Research done by Velho [2019] reveals a constant battle for space between wheelchair users and other passengers. Some passengers can get angry at wheelchair users because they occupy more space in a vehicle [33]. Mini-bus taxis, used by many, are not designed with space for wheelchairs [57]. Previous research shows that, in African countries such as Nigeria, Kenya, South Africa and Ghana, wheelchair users incur high transport costs, which include charges for space for wheelchairs [16,34,53, 67], thereby frequently disadvantaging or totally excluding users with disabilities, particularly those with low incomes. In summary, a lack/shortage of bus shelters, and bus stops which are not located within a reasonable distance, affect all the groups, while lack of/limited wheelchair space in public transport affect mainly people with mobility disabilities who use wheelchairs.

5 RECOMMENDATIONS AND CONCLUSIONS

The study aimed at presenting an analysis of the transport arrangements and difficulties for people with disabilities in the City of Tshwane metropolitan area. EFA was conducted to uncover the underlying structure of the variables and to interpret the results [48], 2007). The four factors retained for rotation were renamed as (1) Station accessibility; (2) Vehicle accessibility; (3) Mobility barriers; and (4) Transport facilities. From this study, it was found that, to a large extent, the existing transport infrastructure in the City of Tshwane is not widely accessible to people with disabilities. The results indicated that the extent of the structural barriers depends on the type of disability. Compared to people with mobility and visual disabilities, people with hearing disabilities do not appear to be as severely affected, which may result in their needs being overlooked.

Based on the findings on structural barriers experienced by people with disabilities in the City of Tshwane, it is recommended that the city prioritise the upgrading of infrastructure to comply with universal access principles. According to the National Building Regulations and Building Standards Act (103 of 1977) of South Africa, all commercial buildings should adhere to principles of universal access. However, design of most stations and other transport facilities do not comply with universal access principles. Regular accessibility audits of transport facilities such as stations and taxi ranks need to be conducted and people with disabilities should be actively involved in the audits. Development of new infrastructure such as stations and taxi ranks should ensure full compliance with universal access principles.

To improve physical vehicle accessibility among people with disabilities, the city should encourage private transport providers to acquire universally accessible vehicles which accommodate the needs of different groups of transport users. In Taiwan, both the public and private sectors provide low-floor buses to improve transport accessibility of people with disabilities [68], which is not true in South Africa; only the public sector provides low-floor buses (for example, A Re Yeng buses and the Tshwane Bus Service).

According to Vanderschuren & Nnene [15], transport barriers experienced by people with disabilities in general are underrepresented in the literature; therefore, this study contributes to literature on transport barriers experienced by people with disabilities not only in Tshwane but in other cities. The structural barriers experienced by people with disabilities established in this study could help the City of Tshwane to carry out condition assessment reports on existing public infrastructure to ensure compliance with universal access principles.

The government could provide incentives to transport companies, especially those contracted to provide subsidised public transport services, to acquire universally designed fleets of vehicles that accommodate the needs of different groups of transport users. Based on the results indicating that people with mobility and vision disabilities find it difficult to cross intersections and streets, the city is recommended to implement safety features at intersections, for example, traffic lights with countdown signals. In addition, future intersection design should incorporate needs of different groups of users.

Future studies could use behavioural theories in mobility behaviour research on people with disabilities to determine whether disability is a key characteristic that informs travel behaviour. This study was only focused on three groups of disabilities, future studies could investigate challenges encountered by other groups of people with disabilities.

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SUSTAINABLE DEVELOPMENT AND PLANNING 2022

OVERVIEW

With the main objective to preserve our delegates' wellbeing, but also with the belief that the international contacts among the scientific community should not be stopped, WIT decided that this conference should not take place as scheduled in Madrid, Spain, but take place as an online event instead.

The conference was organised by the Wessex Institute, UK, represented by Professor Juan Casares, a member of WIT Board of Directors.

The 12th International Conference on Sustainable Development and Planning built upon a series that started in 2003 in Skiathos, Greece. Planners, environmentalists, architects, engineers, policymakers and economists have to work together to ensure that planning and development can meet our present needs without compromising the ability of future generations. Problems related to development and planning, which affect rural and urban areas, are present in all regions of the world. Sustainable Development and Planning 2022 brought together academics, policymakers, practitioners and other stakeholders from across the globe to discuss the latest advances in the field. The conference discussed new academic findings and their application in planning and development strategies, assessment tools, and decision-making processes.

OPENING OF THE CONFERENCE

The conference was opened by Professor Santiago Hernández, Chief Academic Officer of WIT, who welcomed the delegates to the event.

INVITED SPEAKERS

There were a series of invited lectures on advanced topics of research and applications, as follows:

"Proximity as design strategy for sustainable and inclusive urban public spaces" **D. Longo, S. Orlandi, A. Boeri & B. Turillazzi**, University of Bologna, Italy

"Adaptive places: achieving resilience, by facing risks" **M. Sepe**, DiARC University of Naples Federico II, Italy

"Carrying capacity indicators in relation to a tourist destination. The case of the island of Paros, Greece" **D. Prokopiou & B. Tselentis**, University of Piraeus, Greece and Paros Municipality, Greece

CONFERENCE SESSIONS

The papers presented during the conference were classified under the following headings:

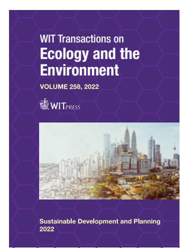
- Community and social planning
- Climate change
- Eco-architecture
- Sustainable mobility
- Regional planning
- Sustainable development goals
- Sustainability and the built environment
- Sustainable solutions in emerging countries
- Sustainable development indicators
- Heritage conservation

Q&A LIVE ZOOM SESSIONS

Conference delegates were invited to participate in three Q&A live zoom sessions which took place on 8th, 9th and 10th June 2022. These friendly sessions were a great opportunity for participants to interact with each other and put questions to authors about their papers.

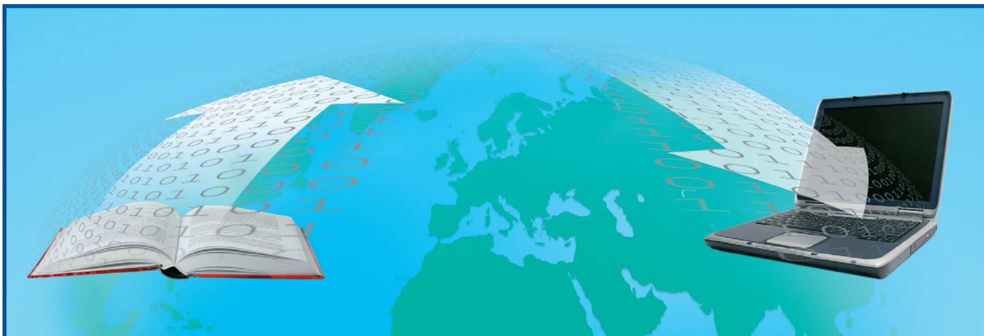
CONFERENCE PUBLICATION

Papers presented at this conference are published in Volume 258 of the WIT Transactions on Ecology and the Environment (Electronic ISSN: 1743-3541). Papers presented at the meeting are available Open Access in the eLibrary of the Wessex Institute (https://www.witpress.com/elibrary) from where they can be freely downloaded by any interested parties.



CLOSING OF THE CONFERENCE

We are very sorry that we were not able to meet our delegates in person this time, but hope that we will be able to do so at a future event.



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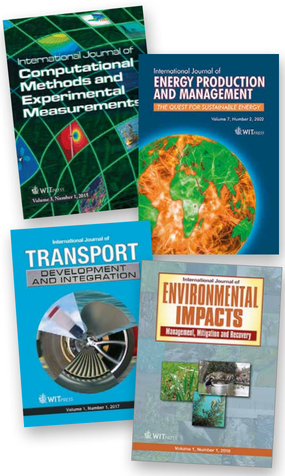

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