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TIME EFFICIENCY MODEL FOR IDENTIFICATION OF DEVELOPMENT POTENTIALS IN URBAN LOGISTICS

ABSTRACT

The aim of this paper is to develop a model for estimating the urban logistics improvements potential based on success factors of intermodal urban transport. There were two aspects considered for building the urban logistics time efficiency model: achieving an improved transport capacity without purchasing new vehicles, and transferring responsibility of poor shipment planning to its owners by implementing the intermodal transport success factors. The model is to establish functional relationship among the shipment distribution requests (urbanization) and urban logistics inefficiencies management (market inconsistencies), and their impact on business operations. The applicability of the proposed model was tested on urban population growth data and time inefficiencies in urban distribution. The results provide both theoretical and practical confirmation of time efficiency importance of urban logistics and potential for introduction of new intermodal solutions in urban logistics. Different case scenarios for Sarajevo prove that reducing inefficiencies in urban logistics could reduce the number of delivery vehicles by less than a half. Since the delivery vehicles are sources of pollution, the subsequent conclusion is valid for externalities levels. The model, therefore, complements the existing knowledge and represents a practical tool for urban planners and logistics professionals for creating an efficient, innovative, and integrative approach to the development of urban logistics services.

KEYWORDS

urban logistics; intermodal loading unit; models; development potential; case study.

1. INTRODUCTION

Urban logistics represents an inevitable economic activity for urban areas and a significant source of negative effects for the environment and human life. Transport is still a key source of environmental pressure in Europe, in particular GHGs, air pollutants, and noise [1]. Urban freight is responsible for 25% of urban transport-related CO2 emissions and 30 to 50% of other transport-related pollutants [2]. Trade-off approach between distribution costs, externalities, and interest of stakeholders [3] is not sustainable. Urbanization process will keep pressure on urban logistics and global urban population in will rise by 60% by 2030 [4] and by over 80% in Europe by 2050 [5]. There is a correlation between the growth in transport demand and environmental pollution [6] with a negative impact on the population of cities [7]. Urban logistics is facing the challenges of the urbanization process with an inherited persistent process of environmental pollution.

Among other things, urban logistics also has an economic impact: road congestion, inefficiency, waste of resources [8]. The coexistence of inefficiency in urban logistics and waste of resources, due to the nature of business, is a sign of a market inconsistencies. There is lack of long term planning of sustainable urban freight transport [9] with the last 25 years of research in sustainable urban logistics being dominated by technical problems [10]. Urban logistics requires new sustainable solutions and models for existing, as well as for future challenges. In the past, the intermodal transport was successful in removing market barriers caused by the logistical inefficiencies. These market barriers were critical for expansion of industrial production and global growth in trade. Introduction of standardized transport/loading unit and reduction of dwell time (and other time losses) in logistics were the main principles for intermodal transport development and its success.

Therefore, the aim of this paper is to develop a new model for estimation of the potential for urban logistics improvements based on success factors of intermodal urban transport. Urban logistics sustainability requires focused and efficient improvements. These improvements should resolve the existing externalities and prepare urban logistics systems for new challenges of the urbanization process.

The paper identifies market inconsistencies as a cause of urban logistics inefficiencies and waste of resources. Urban logistics inefficiencies include, among other things, dwell time, empty running, partly loading, and other time losses. Market inconsistencies are substantial problems of urban logistics, since they directly endanger business operations and consequently urban logistics sustainability. As urban logistics services are business services, urban logistics inefficiencies can also be considered business inefficiencies. Inefficient urban logistics waste resources are a significant source of externalities. However, they are a great opportunity for improvement and reduction in pollution. The urban logistics time efficiency model evaluates how time inefficiencies in urban logistics and shipment demand influence the calculation of how many vehicles are required for distribution operations. The foundations of the model lie in the achievement of improved transport capacity without purchasing new vehicles and transfer of responsibility for poor shipment planning to its owners with the implementation of intermodal transport success factors. Based on literature review the following fundamental inconsistencies have been identified:

- Urban logistics is using the trade-off approach between distribution costs and externalities, despite of its strong negative impact on the environment and human life [1, 3].
- Coexistence of logistics/business services with unresolved inefficiency and waste of resources.
- Absence of urban logistics model that uses combined principles: reducing urban logistics inefficiencies in order to achieve cost and externalities reduction, resolving the effects of customer's poor planning, and using the intermodal transport success factors.
- Urban logistics/freight shipments do not have standard sizes and weight.

It can be concluded that the current management and economic possibilities of urban logistics resulting from the long term planning of urban freight transport in specific urban areas are flawed. The novelty of this approach is in the provision of a model that represents a functional relationship among shipment demands, urban logistics inefficiencies and vehicle frequency, and related externalities. It emphasizes value for business, services efficiency, and the related externalities. This article is to contribute to the science of the logistics in the following way:

- It identifies and elaborates on functional relationship among market inconsistencies, urban logistics inefficiencies, externalities, and business aspects of sustainable urban logistics.
- It identifies success factors of intermodal transport developed within the industrialization and globalization processes that are applicable to urban logistics, and provides basis for sustainable solution for the urbanization process and pollution.
- It elaborates on basic principles for the economic model of intermodal transport in urban area.
- It identifies shipment as the key factor of urban logistics and its necessity to evolve with product market approach.

Apart from its contribution in theory, it also has a contribution in practice aimed at the urban planners and carriers. It provides a model that can enable the urban logistics stakeholders to estimate, analyze, manage, control, and compare their urban logistics system efficiency and its externalities. Apart from the fact that it explains complex relationships in urban logistics, the model also offers results that are easy to interpret and apply.

2. LITERATURE REVIEW

Urban logistics is facing the challenges of the urbanization process with an inherited continued process of perpetuating externalities. Sustainable urban logistics requires solutions that offer substantial improvements in efficiency and reduction in externalities. The urban logistics services are business services with a purpose of "meeting customer's requirements" [11]. Contrary to its business nature, the inefficiencies of the urban logistics are related to low load and empty running, high number of deliveries to individual premises within a given period of time, long dwell times [12] having an impact on the economy: road congestion, inefficiency, and waste of resources [8]. Long term coexistence of providing logistics/business services and identified inefficiencies represent a significant inconsistency. These inefficiencies are sources of additional costs to urban logistics. Market demand, shipments, delivery time, destinations, and customer capability for loading and unloading are the exogenous factors for urban logistics or market conditions. These factors are subject to the decision of a third party and they change over time. The changes in the factors affecting the market (customers planning) that were mentioned here, along with the inability of the urban logistics to transfer related costs to their owners, represent the main market inconsistency important for sustainability in urban logistics.

The mentioned factors, urban logistics inefficiencies, and customer planning impact were the focus of the intermodal transport development. Among other things, intermodal transport has been successful in reducing dwell time. The average time ships spent in ports was reduced to 31.2 hours [13]. The introduction of intermodal loading units has reduced loading time, as well as unloading and handling processes, and defined standardized size and weights for shipments. It can be concluded that the solution for sustainable urban logistics has to be based on at least three principles: reducing inefficiencies in urban logistics in order to achieve a reduction in costs and externalities; resolving the effects of customer's poor planning, and using the intermodal transport success factors. Based on this conclusion, we have to ask what the additional value of the new solution based on the mentioned principles is.

Urban freight transport suffers from a significant modelling gap in comparison to passenger transport [14]. Some of these gaps have already been identified: new delivery models for new urban markets [15], appropriate models for evaluating policy measures and finding optimal solutions [16], innovation in last mile practices to reduce the use of large trucks in home delivery [17], etc. Those gaps that have already been identified are related to urban logistics and distribution.

Analyzing the literature, various approaches to resolving the issues with logistics can be identified. Among them are: comprehensive approach, cost management approach, spatial and urban planning approach, stakeholder approach, new services and new technologies, and organizational aspect approach, to mention just a few.

Comprehensive modelling of urban freight operations remains a challenge due to the diversity of commodities transported, shipment units, vehicle types used, stakeholders' objectives (e.g. suppliers, carriers, receivers), and limited availability of data [18]. Sternberg et al. [19] find that the fragmentation of transport planning and control activities lead to inefficient execution of road freight transport. However, the indicator approach to sustainable urban freight transport developed by Buldeo Rai et al. [20] has practical limitations of the comprehensive approach and did not succeed in implementing 42% out of 45 indicators. Taniguchi et al. [16] presented an overview of how city logistics modelling could use innovative technologies in autonomous vehicles for last mile delivery, multi-agent modelling, etc. ICT technologies have potential for city logistics improvements, but still new analysis, new optimization, and simulation models are required for parcel lockers, crowdshipping, and autonomous vehicles. These findings confirm that ICT technologies could support but not resolve the substantial issues in logistics.

Cost models are quite often used in the logistics. Gevaers et al. [21] have developed the B2C last mile costs model. They found that the main cost drivers are the level of consumer service, security and type of delivery, geographical area and market density/penetration, fleet and technology, and the environment. However, they concluded that more research had to be done and external costs had to be included in the model. Kordnejad [22] has developed the intermodal transport cost model based on the regional rail intermodal transport system. It examines the feasibility of daily consumables distribution in an urban area with related costs and emissions. The study concluded that a regional rail-based intermodal transport system is within the feasibility threshold in the region studied. Cepolina & Farina [23] have elaborated the Furbot system for urban centers. The model elaborates urban logistics inefficiencies but does not take them in its cost function. Furbot is focused on electric vehicles and loading boxes, which enables businesses to sell their products and services directly to consumers without establishing a physical point of sale. The 'loading boxes' in this case are expected to circulate only within this closed system. Muñoz-Villamizar et al. [24] developed the overall greenness performance tool (OGP and MILP model) that evaluates resource consumption and waste emissions of a company (i.e., externalities) with its production level using the value-added concept. However, they concluded that future work should extend the proposed methodology to other tools and techniques and different environmental metrics.

Dynamic assignment model of loading bays for urban last-mile deliveries, developed by Letnik et al. [25], aims to solve the problem of defining the most optimal number and location of loading bays, and their management for energy efficient urban freight deliveries. The model uses strategies of approximation of clusters to the loading bay and reducing vehicle waiting time before accessing loading bays. However, the model still needs to expand in relation to distance from a loading bay to the recipient. Calabrò et al. [26] have developed the agent-based model using a novel ant colony optimization algorithm. The model seeks an optimal set of routes for palletized fruit and vegetables from different farms to the main depot, while minimizing the total distance travelled by trucks. The model represents the basis for future analysis which will require more information and algorithm improvements. Qiu et al. [27] have developed the GLRPCCL multi-objective model that minimizes the total cost, greenhouse gas emissions, average waiting time, and total decline in quality. This model considers heterogeneous fleet, time windows, simultaneous pickup and delivery, and a feature of mixed transportation. The authors conclude that this comprehensive model needs further improvements due to the omitted variables.

Taniguchi et al. [28] elaborated on a number of available logistics models and recent trends in the modelling city logistics: the model with networking approach, fleet approach model, routing approach model, commodity-based models; trip based models; tour-based models, etc. However, none of those models take into consideration the possibility of using the intermodal transport success factors. The urban freight fleet composition model developed by Pinto & Lagorio [29] defines the optimal types and the number of vehicles for parcel delivery in an urban area. The model considers profit, fleet ownership costs, and penalties if the demand is not met. The authors conclude that a clear presentation of results of the computations to the decision makers and the stakeholders can improve their awareness of the issues and the potential impact of their decisions. The delivery tour model elaborated by Nuzzolo et al. [30] supports simulation of the freight transport demand and estimation of freight vehicle origin-destination. However, the paper identifies the need for further analysis in model calibrations, the influence of socio-economic attributes on tour definition, choice in departure time, etc.

Table 1 shows the comparison of the selected analyzed models with the identified principles for the development of a new urban logistics model:

Table 1 – Literature review on selected logistics models

Authors	1st principle	2nd principle			3rd principle
	Dwell times/loading & unloading (Other time losses)	High number of individual deliveries	Low load factors	Empty running	Intermodal transport
Our proposed model	x	x	x	x	x
(Gevaers et al., 2014) [21]	x				
(Taniguchi et al., 2014) [28]	x		x		
(Kordnejad, 2014) [22]	x	x			x
(Cepolina & Farina, 2015) [23]	x	x	x	x	
(Letnik et al., 2018) [25]	x	x			
(Calabrò et al., 2020) [26]	x		x		
(Muñoz-Villamizar et al., 2020) [24]	x				
(Pinto & Lagorio, 2020) [29]	x	x			
(Qiu et al., 2020) [27]	x	x	x	x	
(Nuzzolo et al., 2020) [30]	x	x		x	

1) Reducing urban logistics inefficiencies in order to achieve a reduction in costs and externalities (1st principle);
2) Resolving the effects of customer's poor planning (2nd principle), and
3) Using the intermodal transport success factors (3rd principle)

Based on the analysis of the scientific literature, a gap has been identified in the existence of an urban logistics model that uses a combination of the principles mentioned here. It can be concluded that there is a necessity for a model that promotes the business aspects of urban logistics and intermodal transport principles, as a future research in the urban freight system [9].

The following questions will support the experimental part of the paper in evaluating the mentioned three principles as a foundation for a new urban logistics model:

1) Does the model identify a functional relationship between market demand, market inconsistencies, urban logistics inefficiencies, and externalities?
2) Does the model provide a solution that identifies the impact of market inconsistencies on the sustainability of urban logistics?
3) Is the model applicable to the existing data on the growth of urban population and losses in time in urban logistics?

3. URBAN LOGISTICS TIME EFFICIENCY MODEL

The urban logistics time efficiency model is built on two considered aspects: achieving improved transport capacity without purchasing new vehicles and transferring the poor shipment planning responsibility to its owners for better time management.

The first aspect (1st principle) was built on resolving time inefficiencies of the existing urban logistics services. Time inefficiencies have been identified in various segments of the logistics services such as: dwell time, empty and half-empty trips, loss in time due to traffic congestion, etc. This aspect follows a simple principle: if loss in time is reduced or minimized, there is more room for effective work of the vehicles engaged. Applying this principle leads to a better use of the existing transport vehicles by achieving higher frequencies in shipment and more shipments delivered for the same period.

The second aspect is built on resolving the effects of customer's poor planning and poor unloading capabilities (2nd principle). Empty drive, low load, and a high number of individual deliveries are affecting time management of urban logistics as substantial market inconsistencies. Oscillations in the factors mentioned, as well as the growth in shipment demand caused by urbanization, represent additional challenges for urban logistics services and their sustainability. Providing services for all sorts of possible freight demands that could vary in weight, size, content, locations, delivery time (and other factors) without defining market conditions is not sustainable. Shipments have to have a specification that reflects the urban logistics capability and market demand specified with a focus on achieving the urban logistics sustainability. Standardizing shipment and introducing related urban intermodal loading units (UILU) fit under this approach (3rd principle). This principle is reflected in the model as a change domain of urban logistics services (*Figure 1*). He and Haasis [31] proposed the concept of sustainable inner-urban intermodal transport (SIUIT) for setting the research direction of future urban freight transport. UILU has a positive impact on time inefficiencies with introducing a "drop and go" principle at loading and unloading stations by reducing dwell time. It supports a reduction in traffic congestions, with less hold time during the unloading process. UILU enables better use of cargo space by promoting "units with given size and weight" and creating standard prices where half-loads occur. UILU is transferable to other transport vehicles and modes, which creates an opportunity for reduction in empty return drives. Therefore, the UILU can be viewed as a separate entity, the size of which is defined in accordance with standardization in urban shipment (size and weight) and market demands. It has to support the intermodal principle due to the need to use city metros, rail, or transfer to other cities. The savings it creates and the need for its long term use justify its purpose.

The urban freight demand represented as N_S (shipment distribution requests), urban logistics time efficiency UL_{TE} and Maximal theoretical number of shipments N_{MAX} represent market framework for calculation of necessary transport vehicles per day or daily requested frequency of vehicles f_V, *Formula 1*.

$$f_V = \frac{N_S\left(\frac{shipments}{day}\right)}{UL_{TE} \cdot N_{MAX}\left(\frac{shipments}{vehicle}\right)} \quad [vehicle/day] \tag{1}$$

Process	1st aspect	2st aspect		
Inputs	Dwell time/loading & unloading (Other time losses)	High number of individual deliveries	Low load factors	Empty running
Change domain	Introduction of UILU			
Effects	Faster loading/unloding, time loss reduced	Better shipments management	Better use of cargo space	Better use of cargo space
Outputs	Time efficiency	Cost efficiency	Cost efficiency	Cost efficiency
Results	Higher frequency and transport capacity increased	Transfer of responsibility for poor planning and better cost efficiency		
Benefits	Tansport capacity increased, less demand for additional transport vehicles, lower costs of vehicle non-transport time loss and inefficient handling and loading/unloading operations, less traffic congestion			
Long term benefits	Suppot to the urban logistic sustainbility and externalities reduction			

Figure 1 – Urban logistics time efficiency model

In *Formula 1*, it can be seen that the number of vehicles required per day (f_V) increases when: requests in shipment (N_S) rise, time efficiency decreases, the number of shipments per vehicle decrease, and vice versa.

Shipment distribution requests (N_S) represent an exogenous factor or market demand calculated in units, shipments per day. Civitas [8] has identified relations and created estimates of goods generated in an urban context deduced from studies and analyses conducted for several urban areas: 0.1 delivery/pick-up per person per day. This factor will rise in the future due to the process of urbanization. Variations in shipment (size, weight, etc.) and its oscillations represent 'hidden properties' of N_S. Those 'hidden properties' come out of market inconsistencies that are due to customer's poor planning and an unregulated urban freight market.

Urban logistics time efficiency (UL_{TE}) represents the relationship between time needed for transport activities and the sum of total time needed for one drive as shown in *Formula 2*.

$$UL_{TE} = \frac{T_E}{(T_E + T_T + T_L + T_O)} \tag{2}$$

UL_{TE} has a maximum value 1 for situation where time losses are zero. Urban logistics time efficiency is reduced as time losses increase. Time structure is defined as follows:

T_E – Time of exploitation of the vehicle (related to only transport operations)
T_T – Time loss in traffic congestion
T_L – Time loss for distribution inefficiencies
T_O – Other time losses

Time loss for inefficiencies in distribution is structured as follows: Low load factors – T_1; Empty running, mostly returning drive – T_2; Long dwell times at loading points - T_3; Long dwell times at unloading points - T_4. Total non-transport loss in time T_L is the sum of the above mentioned losses in time (T_1+T_2+T_3+T_4).

Maximal theoretical number of shipments (N_{MAX}) defines maximal number of shipments which one vehicle could carry out during its utilization timeframe (V_{TMAX}) within one day (for example 12 hours per day – t).

$$N_{MAX} = \frac{V_{TMAX}\left(\frac{t}{vehicle}\right)}{T_E\left(\frac{t}{shipment}\right)} \quad \left[\frac{shipment}{vehicle}\right] \tag{3}$$

A maximum number of shipments (N_{MAX}) is in theory a number of drives/shipments that one vehicle could carry out without loss in time within the vehicle utilization timeframe (*Formula 3*).

The indicator for comparison of two different urban logistics services is an average number of shipments (per day and vehicle) related to the level of UL_{TE} (N/UL_{TE}) achieved.

4. RESULTS

In order to estimate the number of shipments N_S, the model is applied to the data in *Tables 2, 3, and 4*. Data in *Table 2* represents a forecast of the global growth in urban population. In *Table 3* there are data of the selected cities around the world, which will have more than 5 million inhabitants and a high

Table 2 – Urban population by region, 2015 and 2030

	Urban population in 2015 (millions)	Urban population in 2030 (millions)
World	3,957.3	5,058.2
Africa	471.6	770.1
Asia	2,113.1	2,752.5
Europe	547.1	567.0
Latin America and the Caribbean	502.8	595.1
North America	294.8	339.8
Oceania	27.9	33.7

Source: United Nations, Department of Economic and Social Affairs [32]

Table 3 – Population size and ranking for cities with more than 5 million inhabitants

No	Urban agglomeration	Country	Population (thousands)	
			2018	2030
1	Delhi	India	28,514	38,939
2	Lagos	Nigeria	13,463	20,600
3	Chongqing	China	14,838	19,649
4	Atlanta	USA	5,572	6,602
5	Madrid	Spain	6,497	6,907
6	Baghdad	Iraq	6,812	9,365
7	Lima	Peru	10,391	12,266

Source: United Nations, Department of Economic and Social Affairs [33]

Table 4 – Population growth for Sarajevo, Bosnia and Herzegovina

Location	2015 (thousands)	2030 (thousands)
Sarajevo	342	358

Source: United Nations, Department of Economic and Social Affairs [33]

population growth by 2030. The third data set (*Table 4*) is for Sarajevo in Bosnia and Herzegovina, which will not have a significant growth in population and shipment demand but will have air pollution problems that are partly influenced by transport.

The number of shipments is estimated based on CIVITAS [8] identified relations deduced from studies and analyses conducted for several urban areas: 0.1 delivery/pick-up per person per day. *Tables 5, 6, and 7* present estimated N_S per day for the data in the tables above.

Daily requested frequency in vehicles f_V will be calculated for three different scenarios with a defined UL_{TE}, T_{MAX}, and N_{MAX} as presented in *Table 8*. T_{MAX} is estimated based on the data used by Firdausiyah et al. [34] for Yokohama case where it is assumed that the working time is from 8 AM to 8 PM, or 12 hours. Schoemaker et al. [11] assume that the average working day for urban areas of Bologna,

Table 5 – Global increase in shipment demand (2018 – 2030) – values per day

Area	N_S millions 2015	N_S millions 2030	N_S growth (millions)
World	395	505	110
Africa	47	77	30
Asia	211	275	64
Europe	54	56	2
Latin America and Caribbean	50	59	9
North America	29	33	4
Oceania	2.7	3.3	1

Table 6 – Selected Cities with high population and NS growth

Urban agglomeration	NS (thousands) per day		NS growth (thousands)
	2018	2030	
Delhi	2,851	3,893	1,042
Lagos	1,346	2,060	714
Chongqing	1,483	1,964	481
Atlanta	557	660	103
Madrid	649	690	41
Baghdad	681	936	255
Lima	1,039	1,226	187

Table 7 – Sarajevo has environment protection in focus, not population growth

Location	N_S (thousands) 2015	N_S (thousands) 2030
Sarajevo	34	35

Milan, and Genova is 7–20 hours which is a close estimate to the previous one. This is also confirmed by Cherrett et al. [35] where they conducted a study on delivery time arranged, with goods potentially arriving at any time during the working day.

T_E, time of vehicle utilization, is based on the data used by Firdausiyah et al. [34] for Yokohama case where it was assumed that the time window per customer for delivery is 30 minutes. Cherrett et al. [35] suggest that approximately 30 minutes should be allowed for an average articulated HGV delivery (heavy goods vehicle deliveries on a scheduled basis) for freight planning in urban centers. Therefore, for all case studies N_{MAX} is calculated as 24 shipments per vehicle per day.

UL_{TE} has three different scenarios with three values of T_L. T_L was calculated exclusively on values calculated for dwell time. Calculation of other losses in time reduces even more UL_{TE} values. Cherrett et al. [35] identified the average vehicle dwell time for deliveries: 31 minutes for articulated HGVs, 19 minutes for rigid HGVs, 10 minutes for vans, and 8 minutes for cars. Schoemaker et al. [11] identified the unloading times in Norway with an average of 17 minutes, mainly for cities Trondheim and Tønsberg. They concluded that earlier studies show similar average results in 4 cities, between 14 and 19 minutes for trucks with more than 11 tones in total maximum weight. The same study from 1994 also states that the average unloading time for vans is much longer – 40 minutes.

The values of dwell time were estimated in the Cherrett et al. study [35]. They calculated from the 2001 and 2008 Winchester surveys that the longest dwell times were associated with charity shops (26.3 minutes), food and drink retail (22.5 minutes), and 'other retail' (20.5 min). For rigid HGV, the average dwell in all studies was 19 minutes. It can be concluded that dwell times were considerably longer if they were over 20 minutes. Therefore, 20 minutes was selected as a 'middle value' for analysis of the three case scenarios. For the worst case scenario, the maximum recorded dwell time of 50 minutes was set (for articulated HGVs in the study). The best case scenario has a minimum dwell time value of 7 minutes recorded for rigid HGVs. The calculated UL_{TE} is presented in *Table 8*.

The calculations for the required frequency of vehicles for all three scenarios are shown in *Table 8*. *Figure 2* presents total vehicle frequency required for the demand influenced by a global increase in demand in shipment (2018–2030). The urban population will grow by an additional 1.1 billion, from 3.9 billion in 2018 to 5 billion in 2030. It is estimated that this growth in population will have an impact on an increase in shipment by the additional new 110 million shipments globally. *Figure 2* represents an estimation of the number of vehicles that would be required to provide services for the total demand in shipments globally for the three

Table 8 – Estimated f_V parameters and test cases

Scenario	UL_{TE}	T_{MAX}	N_{MAX} N_S per vehicle per day
First scenario f1, model mean values	0.6	12hrs	24
Second scenario f2, best case sc.	0.81	12hrs	24
Third scenario f3, worse case sc.	0.375	12hrs	24

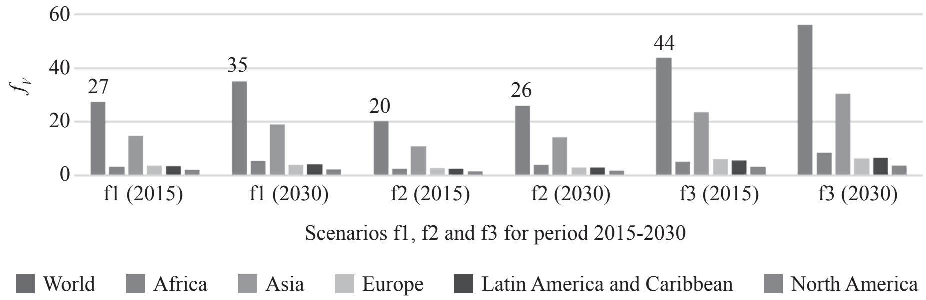

Figure 2 – Vehicles frequency – three scenarios (in million)

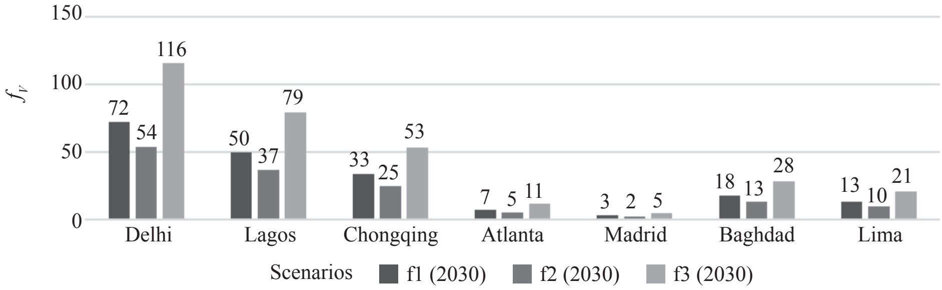

Figure 3 – Number of new vehicles necessary for shipment growth (in thousands)

different case scenarios. The rate of growth ranges from 27% to 30%, in observing each of the three scenarios separately (impact by shipment growth). The same graph shows that the change for the three scenarios caused by different UL_{TE} is bigger than the growth rate influenced by the growth in population. The number of shipments and urban logistics time efficiency are not correlated due to the absence of time lost in traffic congestion. That means that the parameters UL_{TE}, T_{MAX}, and N_{MAX} have their own impact domain on f_V, and the number of shipments has another domain of impact on f_V. However, both of the types jointly define f_V.

Figure 3 represents the number of new vehicles that will be needed for the growth in shipment in the cities of more than 5 million inhabitants by 2030, for all of the three case scenarios. This figure shows that the global growth in shipment demand will not be distributed evenly. The change will dominate in the big cities with the highest growth in their urban population. Applying different case scenarios poses an opportunity for significant savings in transport capacities and externalities as a response to exogenous changes.

Figure 4 represents a situation where there is no significant growth in urbanization. However, applying different scenarios to the data could help identify potential benefits to protecting the environment in the existing situation.

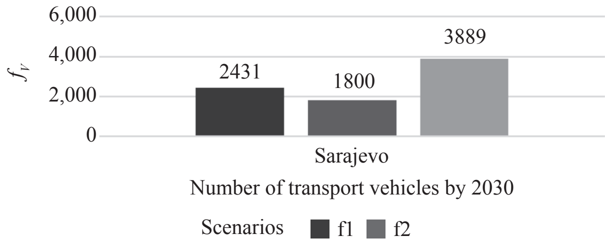

Figure 4 – Number of all vehicles in Sarajevo with applied different scenarios

Sensitivity analysis was performed in order to examine the parameters that may affect the management of the proposed model. Our purpose was to gain the knowledge on how the model is behaving, which would help decision makers in applying the model in practice. The urban logistics inefficiencies analysis and the impact of the related UL_{TE} values on f_V is shown in *Table 9*. A 'perfect case', where UL_{TE} has a value of 1, is added as a reference value. UL_{TE} has been subject to change +/- 10% value for the case scenarios already mentioned (baseline). The higher value of UL_{TE} means there is less loss in time. Additionally, the baseline values have been increased by 10 minutes loss in time spent in road congestions [36].

Sensitivity analysis was performed in order to examine whether a new additional loss in time affects the expected behavior of the model. The change in time efficiency by 10% represents a significant change in the number of vehicles

Table 9 – Sensitivity analysis of the model (values rounded)

	Perfect scenario	First case scenario	Second case scenario	Third case scenario
UL_{TE}/f_V (baseline)	1/21	0.6/35	0.81/26	0.375/56
UL_{TE}/f_V (+10%)	1/21	0.66/31.9	0,89/23.6	0.41/51.3
UL_{TE}/f_V (-10%)	1/21	0.54/38.9	0.73/28.8	0.33/62
		With congestion (baseline + 10 min)		
UL_{TE}/f_V	1/21	0.5/42	0.63/33	0.33/63

Note: fV (in million)

needed. Second case scenario results in an increase in f_V with 2.8 million additional vehicles or 2.4 million fewer, depending on how the UL_{TE} changes (+ or – 10%). When there was only 10 minutes of loss in time for the same scenario f_V, it resulted in a 7 million increase.

5. DISCUSSION

The first research question for the experimental part of the paper seeks to identify the existence of a functional relationship between the market demand, market inconsistencies, inefficiencies in urban logistics, and externalities. This relationship is important since the urban logistics has its market inconsistences and inefficiencies [8, 12]. There is an urban logistics modelling gap [14] and many existing models seek to resolve the issues of externalities [20, 24, 25, 27, 28] with some being more and some less successful. The proposed urban logistics time efficiency model creates a relationship between N_S that represents market demand for the number of shipments, and UL_{TE}, Urban logistics time efficiency. This relationship defines an impact of inefficiencies in urban logistics on vehicle shipment capacity during the utilization time. Lower number of vehicles for the same work means less externalities. *Formula 1* explains that relationship. The growth in the number of shipments N_S and the growth in urban logistics inefficiency affects the demand for more transport vehicles. As presented in the results section, the global daily need for vehicles (f_V) in the three scenarios varies from 20 to 27 and 44 million in 2015, and from 26 to 35 and 56 million in 2030. It can be concluded that, with UL_{TE} being fixed, f_V grows from 27 to 30% for the 2015–2030 period. That means that the market demand, including market inconsistencies, will have an impact on f_V growth in its own domain. On the other side, differences, for example between the second scenario in 2030 with f_V value 26 million, and 56 million of f_V in 2030, and the third scenario represent an additional change influenced by inefficiencies in urban logistics. Therefore, it can be said that the model identifies a functional relationship between the market demand, market inconsistencies, inefficiencies in urban logistics, and externalities. This model is an improvement to the problems identified in the literature review: comprehensive models that are difficult to develop and interpret [18] with the number of indicators that are missing data [20]. It offers a solution for substantial problems in urban logistics.

The second research question of the experimental part of the paper seeks to identify the impact of market inconsistencies on sustainability of urban logistics. Market inconsistencies by inefficiencies in urban logistics have an impact on the sustainability of urban logistics. Those impacts are calculated using UL_{TE}, T_{MAX}, and N_{MAX}, and their impact on vehicle frequencies f_V. As presented in the results section, N_S for daily need of vehicles f_V for the Sarajevo case for the period 2015–2030 is insignificant. However, the f_V for 2030 varies by 1800 for the second case scenario, 2431 for the first the first case scenario, and 3889 for the third case scenario. Therefore, one could conclude that the model could provide a solution that identifies the impact of market inconsistencies on the sustainability of urban logistics. Achieving an improved transport capacity without purchasing new vehicles, and transferring responsibility of poor planning on shipment to its owners, with implementing intermodal transport success factors significantly contributes to sustainability of urban logistics.

The third research question for the experimental part of the paper will explore if the model is applicable to the existing data for the growth in urban population and loss in time in urban logistics. An advantage of the proposed model is in its simplicity and realistic data framework. The model is useful for the existing data on the growth of urban population and loss in time in urban logistics, as it also shows specific results that point out to the following:

- Urban population will grow (by more than 5 billion by 2030) and the related demand in shipment will follow this trend.
- Loss in time is significant for urban inefficiencies. Among others, dwell time [11, 35] and loss in time loss spent in road congestions [36] are the subject of different studies and monitoring processes.
- The model establishes a functional relationship between the above mentioned data streams, and provides answers to the number of vehicles needed to meet the market demand.

This is also confirmed by the sensitivity analysis, which showed a high level of practicality and usability of the proposed model.

5.1 Theoretical and practical implications

Urban logistics time efficiency model identifies and elaborates the functional relationship between market inconsistencies, inefficiencies in urban logistics, externalities, and the business aspect of sustainable urban logistics. This model enables evaluation of urban logistics from the business perspective. The literature has identified a modelling gap [14], and there are various models focused on comprehensive analysis [18-20], cost management [22, 23], spatial and urban planning [25], stakeholders [26], new services and new technologies [16], and the organizational aspect approach. The proposed model considers the business function of urban logistics and its interaction with the environment. It attaches a great deal of attention to this interaction that affects inefficiencies in urban logistics and its sustainability. Market inconsistencies represent an urban logistics exogenous factor that is a source of urban logistics inefficiencies. Therefore, this model contributes to highlighting and proving the importance of the urban logistics business perspective, comparing it to other models that have a comprehensive approach or have focus on technical issues. The urban logistics services are business services, and substantial improvements in services efficiency shall start from this point, without neglecting contributions from other approaches.

The urban logistics time efficiency model identifies success factors of intermodal transport developed within the processes of industrialization and globalization that are applicable to urban logistics, and provides basis for a sustainable solution. The success of intermodal transport is observed by UNCTAD [13], who presented the data showing that an average time a ships spends in ports is reduced to 31.2 hours. The use of the containers in sea transport reduced unloading time and ship dwell time to the minimum of what today's technology is capable of doing. If one is to consider the time ships would spend in ports today with the use of old technologies (technologies that were in use prior to the intermodal transport means), we can say that today's global trade would almost never reach this current stage in its development. Also, if you consider the quantity of goods unloaded from the ships in 32 hours and loss in time for the same quantity of goods in urban distribution, we could conclude that the urban logistics is way behind in efficiency than the sea and intermodal transport is today. Therefore, applying the elements of success of intermodal transport from the process of industrialization and globalization to the urbanization contexts sounds only reasonable and logical. This model proves that it has potential too, with respect to costs and reduction in externalities. Urban logistics has another success factor from intermodal logistics to use and apply. Intermodal loading units have standardized shape, maximum weight defined, related technology, etc.. There are conditions for sending goods through intermodal channels. The shipment orders have to fit those conditions. The urban logistics time efficiency model identifies shipment as a key factor of urban logistics and its need to evolve with a product market approach. That is, the urban freight shipments have to be standardized, bearing in mind the capability of urban logistics, its sustainability, and structure of market demand.

The urban logistics time efficiency model elaborates basic principles for intermodal transport in the urban area. In the literature review, it was identified that new distributive models are necessary [15] [16, 17]. Moreover, the necessity for designing a feasible scheme of Inner-Urban Intermodal Transportation (SIUIT) from the viewpoint of management and economics [31] has also been identified. The model integrates urban logistics and intermodal transport in a way that enables identification of their synergy important for urban areas.

Apart from its theoretical contribution, it also contributes to the practice of urban planners and carriers. It provides a model which enables urban logistics stakeholder to estimate, analyze, manage, control, and compare their urban logistic system efficiency and its externalities. In addition to the fact that it explains a complex relationship in urban logistics, the model also provides results that are easy to understand and apply.

5.2 Limitations of the study and future directions

This paper does not investigate centralized logistics systems as a type of market monopoly and potential barriers to the implementation of urban intermodal transport as a market decentralization tool. It does not define the exact size and weight of urban intermodal loading unit and it does not specify the number of possible different types. The paper is focusing on specific issues and not on a comprehensive understanding or solutions. Additional benefits of UILU such as transport in the evenings or what will make significant time savings were not taken in consideration.

The future plans are to define the data framework, data model, and collection techniques for all time losses in urban logistics. This data framework shall be applicable on any urban logistics area. The definition of the framework will be tested by the use of data collected from several urban areas. There is also a need for the study and market analysis of standardization of urban shipments. This study shall provide insights in the structure of market demand within and a market demand of an urban area in relation to external shipments.

6. CONCLUSIONS

This paper presents an urban logistics model for an estimate of improvements in urban logistics, a potential based on success factors of intermodal urban transport. It is formulated on the modelling gap identified in urban freight transport for the model based on the principles of reduction of urban logistics inefficiencies for achieving a reduction in costs and externalities, resolving the effects of customer's poor planning, and using the intermodal transport success factors. The urban logistics time efficiency model identifies a functional relationship between the market demand, market inconsistencies, inefficiencies and externalities in urban logistics. It offers a solution for substantial urban logistics problems and contributes to the sustainability of urban logistics.

The model provides a calculation of vehicle frequency of the needed vehicles as a function of shipment demands and inefficiencies in urban logistics. The vehicle frequency for certain shipment demands will have more importance in the future, due to the process of urbanization and externalities related to vehicle operations. In the case of Sarajevo, even where the urbanization parameters are insignificant, time efficiency in urban logistics causes frequency to vary from 1800 to 3889 vehicles per day. Therefore, we can conclude that the economic and environmental impact of inefficiencies in urban logistics on urban logistics sustainability is significant.

However, the model does not take into account the complexities of urban freight market and the related resistance to change. It does not propose a specific size of the urban intermodal loading unit either. Therefore, future plans will be to develop a study and market analysis on standardization of urban shipments and to define a time inefficiencies data model.

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MODEL VREMENSKE UČINKOVITOSTI ZA IDENTIFIKACIJU RAZVOJNIH POTENCIJALA U URBANOJ LOGISTICI

SAŽETAK

Cilj ovog rada je razviti model za procjenu potencijala poboljšanja urbane logistike na temelju faktora uspjeha intermodalnog urbanog prijevoza. Dva su aspekta razmatrana za razvoj modela vremenske učinkovitosti urbane logistike: postizanje poboljšanih prijevoznih kapaciteta bez kupnje novih vozila i prenos odgovornosti na vlasnike slabog planiranja pošiljki primjenom faktora uspjeha intermodalnog prijevoza. Model uspostavlja funkcionalni odnos između zahtjeva za distribuciju pošiljki (urbanizacija), upravljanja neučinkovitošću urbane logistike (tržišne nedosljednosti) i njihovog utjecaja na poslovanje. Primjenjivost predloženog modela testirana je na podacima rasta urbanog stanovništva i vremenskoj neučinkovitosti u urbanoj distribuciji. Rezultati pružaju i teoretsku i praktičnu potvrdu važnosti vremenske učinkovitosti urbane logistike i potencijala za uvođenje novih intermodalnih rješenja u urbanu logistiku. Različiti scenariji slučajeva za Sarajevo dokazuju da bi se smanjenjem neučinkovitosti u urbanoj logistici mogao smanjiti broj dostavnih vozila za manje od polovine. Budući da su dostavna vozila izvori zagađenja, takav zaključak vrijedi i za negativne efekte. Model, dakle, nadopunjuje postojeće znanje i predstavlja praktični alat za urbaniste i planere logistike, za stvaranje učinkovitog, inovativnog i integrativnog pristupa razvoju urbanih logističkih usluga.

KLJUČNE RIJEČI

urbana logistika; intermodalna jedinica za utovar; modeli; razvojni potencijal; studija slučaja.

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