IMPACT OF INCLUSIVE SERVICES OF URBAN BUS TRANSPORTATION ON USERS AND OPERATOR

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People with physical disabilities (PPD) are part of the category of disability people who can more easily benefit from social inclusion programs by improving their accessibility of various public services. This paper examines: (i) – the adaptation of bus fleet in urban public transportation by introducing the electrohydraulic actuating to the manual existing ramp for the PPD access; (ii) - widening the mooring space for PPD wheelchairs to part of the bus fleet; (iii) - selection of several transportation services (on a bus line) and adjustment of their timetables to facilitate the access of the PPDs to the selected bus services and stops. Together, these improvements impact on operator - by the costs involved in adapting the buses dedicated to inclusive services, on one side, and on the regular users of the bus transportation - by longer total trip of the selected bus services, on the other side. For the selected bus services, the shadow cost of additional stop time for regular users is estimated through the average value of travel time.

Keywords: inclusive bus services; people with physical disabilities; electric access ramp; value of time

1. Introduction

"Passenger with limited mobility" means any person who has difficulty in using public transport, such as people with disabilities (e.g. people with sensory, intellectual disabilities or wheelchair users), people with limb disabilities, people of small stature, even persons with heavy luggage, the elderly, pregnant women, persons with shopping carts and persons accompanied by children (including children in prams), according to the definitions identified in the specific regulations [1]In this article, we address people with physical disabilities (PPD), who use wheelchair traveling alone or with a companion.

The term of inclusive service refers the regular service ability to cope with all type of users, simultaneously, with and without disabilities of any kind. The devoted research, regulations, developments to the inclusive public services and in particular to public transportation and inclusive mobility is impressive [2-17].

In Romania the number of the registered PPD has an increasing tendency, according to the Romanian statistics (Fig.1) [18].

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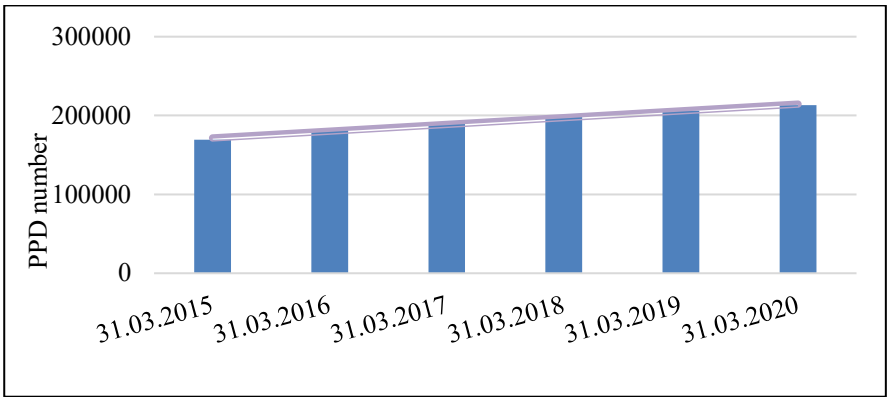

Fig.1. Evolution of the number of people with physical disabilities in Romania, [18]

Ensuring access for people with disabilities to a quality and accessible public transport service is an integral part of ensuring access to public space, public services and space mobility. The right to unrestricted/ free mobility is provided by Convention on the Rights of Persons with Disabilities (art. 9 -Accessibility, and art.20 -Mobility) [19]. European Union Member States also take steps to achieve the highest possible degree of mobility, encouraging the autonomy of choice of mobility and ensuring an affordable cost. [20]

However, the Romanian legal frame for the establishment of model conventions on the transport of persons with disabilities contains several articles that jeopardize the transport and mobility rights of people with disabilities [21]. We mention hereafter some examples of shortcomings that make the inclusive urban public transportation difficult to implement, as follows:

- journeys must be round-trip between the same stations;
- the procedures for reimbursing the cost of travel by carriers/ operators are laborious, which contributes, in combination with the lack of adaptations of transport vehicles, to the refusal of many private transport operators to provide inclusive services;
- there are no mechanisms for sanctioning transport operators that do not conclude contracts for free tickets to people with disabilities;
- there is a lack of systematic data both on the supply of inclusive urban transport services and, on the demand for inclusive transport services, which makes it difficult to plan mobility/ movements for disability people, that ultimately leads to a low demand for such services;
- lack of data provision by the municipality on the volume of demand from disability people, or even missing data.

In any case, several municipalities in Romania have improved their fleet (by aquiring low-floor buses and/or trolleys with manual ramps and one spot for the PPD with wheelchair), during last years (Table 1).

Table 1

The size of low-floor public transport fleets in the main cities in Romania

No.	Public transport operator	Bus fleet available
1	Public Transportation Company, Arad	135 buses
2	Public Transportation Company, Craiova	180 buses
3	Public Transportation Company, Cluj-Napoca	252 buses, 87 trolleys
4	Public Transportation Company, Iași	140 buses
5	Public Transportation Company, Bucuresti	1100 buses și 181 trolleys
6	Public Transportation Company, Pitești	86 buses

In this paper we propose several solutions to improve the degree of inclusiveness of the public bus services for the PPD, and we assess their impact on operator and general users.

In the next section, the method of investigation is described. The third section is devoted to the actual adaptation description of the typical bus of the Bucharest public operator fleet and also to the description of bus service adjustment on a selected bus line. The impact assessment through the involved costs for the operator (in fact, for the municipality) and, of the additional shadow cost for the ordinary bus users is provided in fourth section. Besides the main conclusions, the last section contains also several further necessary research.

2. Method

The used method consists in: (i) – checking the regulatory frame related to the vehicle design for PPD, including the ramp access design; (ii) – selection of a bus line, and for this, selection of several bus services during an operational day, and the bus stops, especially for the PPD inclusive trip.

(i) Regulation No 107 [22] contains the provisions which apply to a vehicle designed for easy access for passengers with reduced mobility and wheelchair users. The main requirements with relevance for this paper approach are related to the following:

- low-floor buses: floor height must not exceed 250 mm;
- seats should be located as close as possible to the access door and allow easy placement of wheelchairs either front or rear.
- *Communication devices* must be located near the special place intended for PPD, in order to facilitate the signaling of the intention to get off the bus;
- The standard dimensions for a wheelchair are provided, as well as the dimensions of the space intended for PPD, necessary for an easy handling: l: 1200 mm, b: 700 mm, h: 1090 mm (Fig.2)

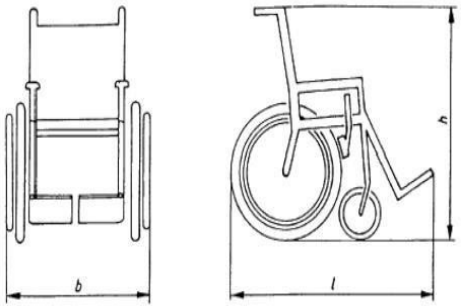

Fig.2.Reference wheelchair dimensions

- The main dimensions of the total space required for a reference wheelchair are defined, too, by adding minimum 50 mm to the reference wheealchair dimensions, which means 1300x750x1150 mm, respectivelly.
- For the stability of wheelchairs, in the space specially arranged for the transport of PPD, it is mandatory to have mechanisms to secure the seat, in order to ensure a high level of safety. The values of the forces acting on the PPD during transport are defined and framed in certain limit intervals, as well as the effects produced by all the elements mounted in the specially arranged space for diminishing these values.
- For the boarding devices- access ramp, there are certain recommendations and conditions for both automatically and manually operated ramps (loading capacity, dimensions, safety elements, tehnical requirements)

(ii) In order to observe the impact of the implementation of the proposed solutions for inclusive services on the regular users, a relativelly long bus line was selected in Bucharest. It provide access to many important functional areas (it has 30 bus stations) such as parks, markets, medical centers, mall, railway station. This bus line crosses also many residential areas with high densities. It is bus line no 105 (Fig.3). The dedicated stations for the PPD disembarking and and then boarding were selected according to the main space functionality is presented in Table 2.

Table 2

Selected stations for inclusive service bus line 105

Selected station	The main interest for PPD					
	Market	Hospital/ clinic	Railway station	Park	Mall	Supermarket/ Shopping gallery
Lainici(S_{15})		X				
Garade Nord(S_{31})			X			
Garade Nord(S_{33})			X			
GaraBasarab(S_{35})			X			
Bd.Timișoara(S_{45})					X	
Favorit(S_{49})		X				
PiațaDrumulTaberei(S_{53})	X					X

PoianaMuntelui(S_{54})				X		
ȘoseauaOrhideelor(S_{38})						X
SpitalulCFR 2(S_{0*})		X				

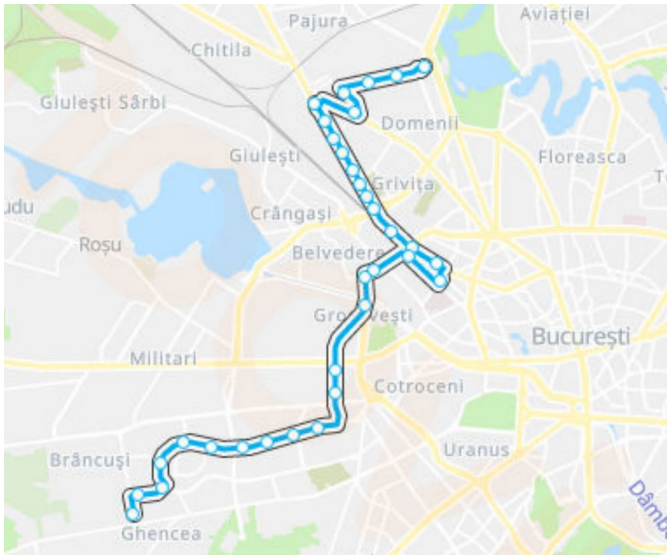

Fig.4. The bus line 105 and the bus stops
(source: [23])

In the next section the proposed adaptation of the inclusive buses and inclusive bus service are descriebed.

3. Improving the inclusive urban bus services

3.1. Adjusting manual ramp to electrohydraulic actuating ramp

The manual ramp is formed between the main structural components and the secondary elements for the movement of the three structural elements. These three components namely the metal frame, the second plate and the first plate. The first plate and the second plate are the movable components of the ramp where both can move linearly in the metal frame. Under the ramp will be mounted a bi-derectional hydraulic pump with electric actuation. In Figure 5 we give an example for this device and its main components. This will allow the manual ramp transformation to an electrohydraulic actuation ramp (Fig. 6), which is called as automatic ramp for an easier distinction from manual ramp.

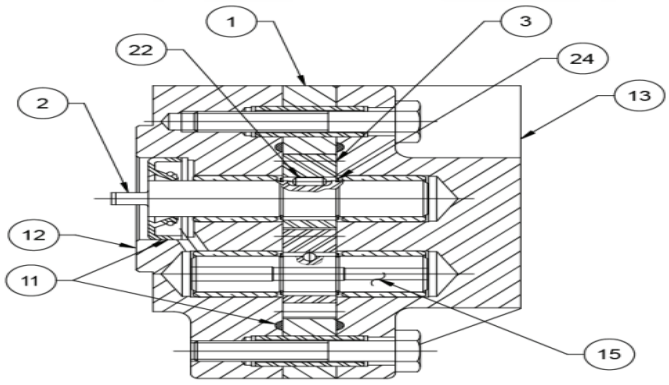

Fig.5 . Bi-directional hydraulic pump section [24]
Legend: 1-gear case; 2-drive shaft; 3-gear; 11-seal kit; 12-drive plate; 13-end plate; 15-idler shaft; 22-gear pin; 22-retaining ring

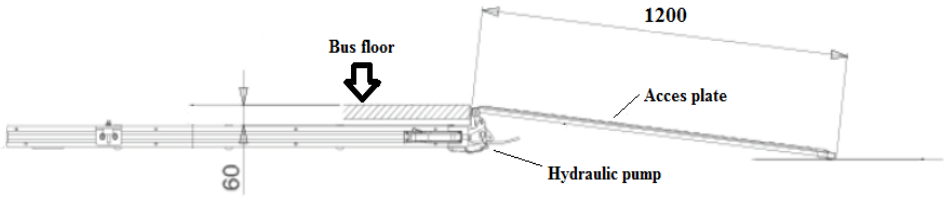

Fig.6. Side view of the automatic ramp

The hydraulic pump is controlled by two relays, which activate the hydraulic pump in opposite directions for deploy and stow functions (powering dual-acting hydraulic cylinders). No sensitive electronic controls or sensors are required for operation.

3.2. Adapting bus space to additional wheelchairs installing

Figure 7a) shows is a simplified sketch of the main arrangements in a reference regular bus of the Bucharest public transportation fleet. The bus has three regular access doors (in the front, back and in the middle part, respectivelly). The loading sitting capacity is of 27 seats and one wheelchair. In the next sketch, 7b, the main adaptations are highlited. The adapted bus will provide 21 seats and three reference wheelchairs.

By removing six seats for regular passengers the additional two spaces for wheelchairs, respecting the requirements and recommendations of the European

Regulation.The exist and then, the entrance out/in bus is made through the midlle part of the bus.

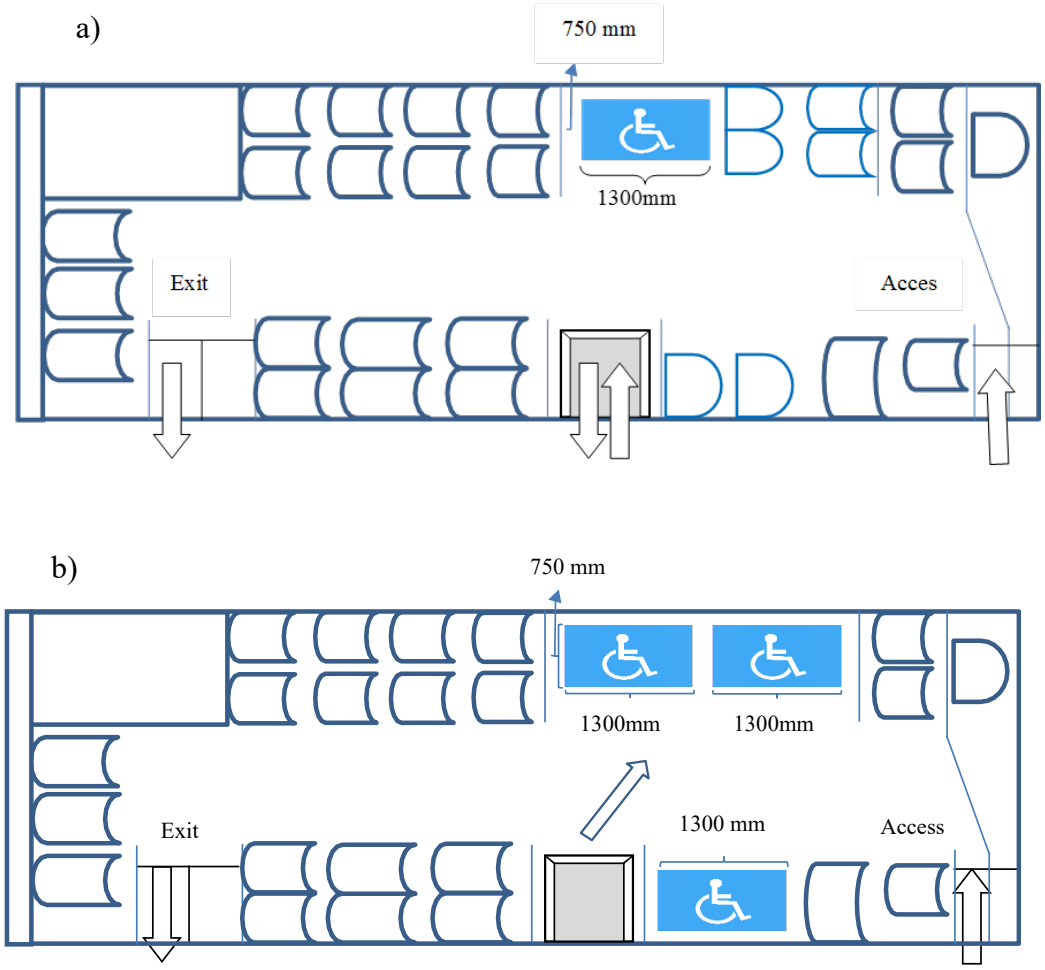

Fig. 7. a) Regular urban bus (27 seats and one wheelchair, and b) adapted bus for a more inclusive bus service (21 seats and three wheelchairs)

3.3 Bus service adaptation

The automatic ramp have an estimated opening/closing time of 8 seconds, so a complete cycle of its operation is about 16s. The other estimated times are mentioned in the Figure 8 bellow, where the exit of three PPD wheelchairs is firstly considered and then other three succesive enterings are depicted. The is no need for bus waiting time in station alloted for the wheelchair locking (anchoring).

Total time for access in buses equipped with a electro-hydraulic actuation ramp:

$$T_{EHAR} = T_{ro} + T_{ba1,2,3} + T_{e1,2,3} = 66 \text{ s}$$

where: T_{ro} - time for the manual ramp to be opened by the bus driver,

$T_{ba1,2,3}$ - time for succesive bus access of all three PPDs,

$T_{e1,2,3}$ - time for succesive bus exit of all 3 PPD.

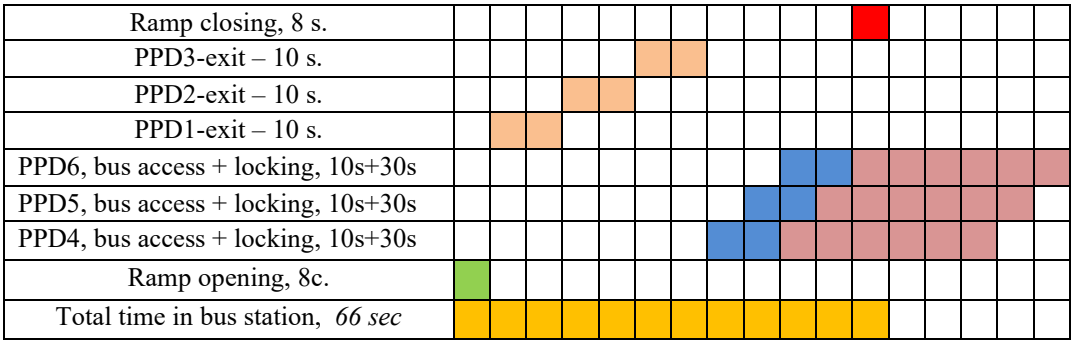

Fig.8.Time required for PPD access using an automatic ramp

The selection of three bus services of 105 bus line, per direction, considers only non-rush hours. In Table 3 below an example of the three bus services selection for one-way direction is given, including the addapted timetable in selected bus stations (in italic letters). The modified schedule reffers to the additional time in several selected bus stations.

Those three bus services do not affect the transport capacity nor the traffic capacity, because the non-rush hour selected intervals.

For the oposit direction, the services are in-pairs and the selection procedure is even easier.

The operation job for round services requestes two addapted buses.

Table 3

Impact of additional transport time for PDM on the bus timetable 105

Direction 1: Piata Presei- Valea Oltului	Bus service 1		Bu service 2		Bus service 3	
	Original schedule	Modified schedule	Original schedule	Modified schedule	Original schedule	Modified schedule
Piața Presei(S_1)	10:01	10:01	14:09	14:09	20:05	20:05
Univ. Româno-Americană (S_3)	10:03	10:03	14:11	14:11	20:07	20:07
Traian Vasile(S_5)	10:04	10:04	14:12	14:12	20:08	20:08
Bd. Expoziției(S_7)	10:05	10:05	14:14	14:14	20:09	20:09
Aviator Popișteanu(S_9)	10:07	10:07	14:16	14:16	20:11	20:11

Clăbucet(S_{11})	10:10	10:10	14:19	14:19	20:13	20:13
R.A.R(S_{13})	10:11	10:11	14:21	14:21	20:14	20:14
Lainici (S_{15})	*10:12*	*10:13*	*14:22*	*14:23*	*20:15*	*20:16*
Feroviarilor(S_{17})	10:13	10:14	14:23	14:24	20:16	20:17
Griro (S_{19})	10:14	10:15	14:24	14:25	20:17	20:18
Caraiman(S_{21})	10:15	10:16	14:25	14:26	20:18	20:19
Cimitirul Sfânta Vineri(S_{23})	10:16	10:17	14:26	14:27	20:18	20:19
Pasaj Grant(S_{25})	10:17	10:18	14:27	14:28	20:18	20:19
Stoica Ludescu(S_{27})	10:18	10:19	14:28	14:29	20:19	20:20
Șoseaua Nicolae Titulescu(S_{29})	10:19	10:20	14:29	14:30	20:20	20:21
Gara de Nord(S_{31})	*10:20*	*10:22*	*14:30*	*14:32*	*20:21*	*20:23*
Gara de Nord(S_{33})	*10:22*	*10:25*	*14:32*	*14:35*	*20:22*	*20:25*
Gara Basarab(S_{35})	*10:24*	*10:28*	*14:34*	*14:38*	*20:23*	*20:27*
Calea Giulești(S_{37})	10:27	10:31	14:37	14:41	20:26	20:30
Bd. Regiei(S_{39})	10:28	10:32	14:38	14:42	20:27	20:31
Podul Grozăvești(S_{41})	10:30	10:34	14:40	14:44	20:29	20:33
Bd. Iuliu Maniu(S_{43})	10:33	10:37	14:44	14:48	20:32	20:36
Bd. Timisoara (S_{45})	*10:34*	*10:39*	*14:45*	*14:50*	*20:33*	*20:38*
Orizont(S_{47})	10:38	10:43	14:49	14:54	20:37	20:42
Favorit(S_{49})	*10:40*	*10:46*	*14:51*	*14:57*	*20:38*	*20:44*
Drumul Taberei 34(S_{51})	10:42	10:48	14:53	14:59	20:40	20:46
Piata Drumul Taberei (S_{53})	*10:43*	*10:50*	*14:55*	*15:02*	*20:41*	*20:48*
Poiana Muntelui(S_{55})	10:47	10:54	14:59	15:06	20:45	20:52
Romancierilor(S_{57})	10:49	10:56	15:00	15:07	20:46	20:53
Piața Valea Ialomiței(S_{59})	10:50	10:57	15:02	15:09	20:47	20:54
Poșta(S_{61})	10:51	10:58	15:04	15:11	20:48	20:55
Valea Argeșului(S_{63})	10:52	10:59	15:05	15:12	20:49	20:56
Valea Oltului(S_{65})	10:54	11:01	15:07	15:14	20:51	20:58

4. Impact assesment of inclusive bus services

4.1. Impact of inclusive buses adaptation on operator and regular users

The total costs for the adaptation of the two buses per line includes:

- Cost of electrohydraulic actuating ramp: 1500 $ for a full kit,
- Cost of assembly labor (about 10 hour of work): 10 hours x 40 $/hour = 400 $/monted and connected electrohydraulic actuating device,
- Cost of adapting the bus interior space for wheelchairs anchoring (about 5 hours of work and additional parts/elements for anchoring): 5 hours x 40 $/hour + 200 $ parts = 400 $/addapted bus.

Hence, total cost for addapting two buses for a more inclusive bus services: 2X 2300 $/bus = 4600 $.

The new capacity of the addapted buses is estimated considering that out of the 27 seats, 6 seats are switched with the two additional special seats/spots for PDMs, that have the dimension accordin to the European regulations. The remained seats for regular users is 21.

The space for standing passengers is reduced by approximately 10%, (considering that a standing passenger occupies about 0.5 sqm).

Therefore, the total capacity of a bus adapted for more inclusive bus services for PDM is reduced by 22.2% + 10% = 32.2% of a maximum of 107 seats (maximum capacity of an ordinary bus, 12 m). However, the adapted buses are not excluded from the regular services (when no PDM is inside the bus) for regular users. Moreover, the selected bus services are out of rush-hour when the loading of regular users is usually low, during large majority of cases.

4.2. Impact on regular users because of a longer inclusive service

For one-way inclusive service, on a first direction, there are seven selected bus stations, where the additional time required for thee succesive PDM exit and then another three acces take 1 minute for each station.

For the paired one-way bus service, on the second direction, there are nine selected stations where again the additional time required for thee succesive PDM exit and then another three access, take 1 minute for each station.

The maximum estimated time is nine minutes for one-way service. In case that all regular users in the inclusive bus (about 100 of users) travels from one bus end station to the other bus end station we estimate their total value of time which is wasted during that trip.

For this estimation we use a simplified methodology [25],[26] for value of time estimation (VoT), which is based on the average income/wage of passengers in the study area. Thus, the average net wage in Bucharest was in 2020 about 3217 RON- Romanian currency, that is about 740 USD per month (considering an average exchange rate USED/RON of about 0.23)[18].

The value of time for traveling is considered of about 25% of the average net wage per unit time, that is VoT=0.25x740USD/month: 22 working days/month: 8 hours/day: 60 min/per hour= 0.017 USD/minute.

Thus, we may conclude that for the worst case when the inclusive bus carries all about 100 regular passengers on one-way trip, their total shadow cost of traveling in an inclusive bus along with PPD, when additional time is about 9 minutes, is about: 9 min x 100 pass.x 0.017 USD/min.= 15.3 USD per one-way trip.

However, the shadow cost per each passengers is only 0.15 USD per trip in an inclusive bus, that is in fact the price of each cititzen for living in an inclusive environment.

5. Conclusions

- The estimation of the impact of several improvments to the bus and to the bus service (for a more inclusive public transportation) on transport operator and regular users reveals several aspects, as follows:

- The acces ramp automatisation is posible and the total cost of two buses adaptation for operation of a bus line with about 30 bus stations is less than 5000 USD; the monetary effort for the public operator, and ultimatelly, for the municipality can be gradually implemented.

- The transport capacity for the regular passengers standing travelling is not significant reduced, but only for the sitting passengers, and this aspect should be further investigated to find the regular passenger' perception in this matter.

- The shadow cost of time loss because of extendet total time of a full trip from one end station to the other end station, for one passenger is only about 0.15 USD per trip.

- For a larger spatial coverage of a trustfull inclusive public transportation network, further researches are needed in order to establish the bus and trolley lines and the addapted fleet part for special needs of PPD.

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