PASSENGER HANDLING FUNCTIONS IN AUTONOMOUS PUBLIC TRANSPORTATION

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Abstract: Emerging infocommunication and vehicle technologies (e.g. autonomous vehicle) facilitate evolvement of autonomous public transportation in urban areas. It involves launching new service concepts (e.g. telematics-based shared demand responsive transportation), transformation of existing modes and automatization of passenger handling functions. However, there are debates about which processes how to be automatized. The aim is to replace human personnel by machines so as to improve service quality and decrease expenditures. The research questions were, how the functions are to be automatized and what the consequences are on both the machine and the human side. All the passenger handling functions, the existing and altering ones as well as the new functions have been investigated in process and system oriented approach. We have considered the most relevant technological novelties and their application opportunities, and then the required abilities (skills) of travelers. We have revealed correspondences among functions and human abilities. The shifting of intensities of human abilities (cognitive capability) have been estimated. Personnel groups with altering or new functions have been introduced and the functions of the replaced driver have been assigned to the groups or the machine components. Both the gains and the occurrent drawbacks have been assessed. The presented results appoint the research and innovation trends and directly facilitate the developments (e.g. design of smart devices and services as human-machine interface).

Keywords: passenger handling, automatization, autonomization, human abilities, cognitive capability.

1. Introduction

Mobility is to be considered as a complex service, not only providing transportation, infrastructure, etc., where humans are the key elements. Investigation of human components in the passenger transportation system is one of the most challenging tasks as perceptions are strongly heterogeneous, dynamic (evolves in time as an individual goes through different life stages), context dependent and also influenced by the environment. Several smart city and autonomous vehicle projects have already focused on either the city or the vehicle itself but not on the citizens or passengers, who are the end users of the services (Pribyl and Horak, 2015). On the other hand, the role of personnel (drivers, staff) is to be reduced and replaced by machines, where it is required or possible. As these two types of human components are strongly interrelated, introduction of autonomous vehicle (AV) based services requires and implies significant transformation of passenger transportation. The research questions were:

1. which functions and how to be automatized (opportunities)?
2. how does the future traveler’s sensations and cogitation change?
3. what kind of modifications are possible in role of personnel?

The automatization in transportation has retrospected for decades. The first autopilot system in flight was introduced in 1912, the first automatic train operation started at 1967 in London. Air transportation has been always foregoer, as the functions and services are especially advanced and automatized (e.g. check-in, baggage sorting system). Nowadays, the manufacturers are developing autonomous road vehicles, which have been already introduced also in everyday operation. Generally, five stages are distinguished in development of AVs which has been identified how the driving tasks are transferred from human to machine. The technological development enables widespread automatization, however several aspects and issues are to be tackled (e.g. safety-security issues, acceptance of the new technologies). The major social impacts of AVs have been described: safer roads (less accidents), travel time reduction, more personalized services, improvement of energy efficiency and parking benefits (Fagnant and Kockelman, 2015).
The future urban mobility system is envisaged by scientific literature as follows: majority of the vehicles are electric, motorized transportation modes are served by autonomous vehicles (Godoy et al., 2015), most of the transportation modes merge into one ‘new’ integrated, telematics-based, shared mode, ownership of individual motorized vehicles is decreasing, the emphasis is taken on the service instead of the vehicle and sharp boundaries between infrastructure elements are also declining (e.g. AVs drive in buildings arriving as close to the destination as possible). Model about operation of fleet of Shared Autonomous Vehicles (SAV) has been elaborated by Fagnant and Kockelman (2014). According to the model each SAV travels to its final destination only if at least one passenger is carried on the board. The vehicles do not serve defined stop points between origin and destination. The concept of ‘Mobility as a Service’ (MaaS), which offers convenient door-to-door transportation without the need to own a private vehicle, covers tariff and payment integration, ICT integration and introduction of various mobility packages. An evaluation index about the level of mobility integration has been elaborated in order to compare MaaS systems (Kamargianni et al., 2016).
The future urban transportation modes have been revealed and summarized by Földes and Csiszár (2016). The individual cars are used for the most flexible travel purposes. The other modes (existing conventional public transportation services, demand responsive public transportation, car-sharing, taxi, chauffeur service, car-pooling, ride-

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sourcing) are merging into the new mode (Telematics-based Shared Demand Responsive Transportation - TS-DRT) and the ride-sharing gains more and more importance. A simulation model has been developed by Winter et al (2016) which determines the minimal and optimal fleet size with minimizing the total operational and travel costs for operating a demand responsive, autonomous shuttle service in a campus. The introduction steps of AVs and their effects have been investigated by Davidson and Spinoulas (2015). They found that the increasing share of AVs in the mixed traffic (AVs and manual cars on the road at the same time) causes worse traffic flow parameters at an early stage (Tettamanti et al., 2015), but after achieving homogeneous AV traffic, the parameters are getting much better (Li et al., 2015). According to their vision, share of public transportation and cycling/walking will slightly decrease as a consequence of taking over passengers by new modes based on AVs. The autonomous transportation requires more intensive use of ICT tools and services by passengers (trip planner, electronic information, ticketing, etc.). However, the citizens are different, their requirements and expectations are rather diverse. Bak and Borkowsky (2015) found that users in different regions with very various characteristics (as e.g. wealth, GDP, cultural background) can be represented by surprisingly similar attitudes towards ICTs (e.g. purpose of using an application).

The remainder of the paper is structured as follows. Definition of basic terms are provided in Section 2. The method of investigation of passenger handling functions forms the body of Section 3, where the functions and the required human abilities have been also revealed. Section 4 presents the results, namely the transformed functions and the altered human behavior in the future transportation system. Results are discussed in Section 5. Finally, in Section 6 the conclusions are drawn and the future research directions are summarized.

2. Definition basic terms

We have defined the basic terms:

- **Automated functions** are operated by machine which follows very clearly described, step by step rules. The rules have been programmed into them one by one.
- **Autonomous functions** are operated by machine which is able to make individual decisions using cognitive capabilities and learning abilities. Not all situations have to be mapped in advance, the new situations are perceived, understood and properly managed.
- **Autonomous public transportation**: a system using autonomous technology by vehicle, infrastructure and traveler in order to improve operation and enhance service quality. Most of the components are equipped by sensors, cameras, etc. and communication channels in order to realize V2X cooperation. Technologies either imitate human procedures (e.g. sensing, learning) or realize human-independent new procedures (e.g. localization). The efficiency of operation can be refined and perfected by the new information that is collected by new sensing technologies and was not available before by human sensing. The personnel (e.g. dispatcher, driver, inspector) is eliminated and replaced by machine components in several cases. The mobility service consists of both services on fixed, high capacity arterial routes (mostly based on railways) with regular schedule and flexible, demand responsive services, which may have either feeder or point-to-point role. The latter one is efficient where the demands are low and/or dispersed (International Transport Forum, 2015). The vehicles are in public property. The passenger handling functions are mostly performed without direct human interventions.
- **Passenger handling functions and services**: the functions that are connected to passengers' basic movement and information management before, during and after travel in case of both normal and emergency situations. The functions are realized by either automated (e.g. ticket validation with electronic devices) or autonomous (e.g. providing value added personalized information by recognizing the traveler and learning his/her habits) services. In the first case pre-programmed operation is performed; whereas in the second case the system is able to react to the actual situation using its cognitive capability. One service may cover one or more functions.

3. Method of investigation of passenger handling functions

In order to determine the development potential and effects of automatization on both the machine and the human side, the functions and the human abilities have been investigated in process and system oriented approach. The elaborated method produces quantitative results to compare and prioritize the future developments (Fig. 1.). The main result is the automatization (Computerization) potential value (C_i) on machine side and the Aggregated Ability alteration value (AA_j) on human side. (Computerization word is used as a synonym for automatization in order to create distinct acronyms). They are calculated as difference of future and current indicators and being highlighted by grey colored boxes. C_i expresses the relevance of automatization of the function, where i is the index of function. AA_j expresses how the alteration of the functions influences passengers' required abilities, where j is the index of ability. The higher values indicate higher development potential and more significant alteration. Using the method other important values may be calculated as results of comparison of indicators: automatization level alteration (l_i), human ability indicator alteration (A_{ij}) in the given function, and human ability intensity alteration (a_{ij}) in the given function. The revealed functions are almost the same currently and in the future, however their properties alter (e.g. required human and machine actions). The identified passenger handling functions have been categorized into function groups (Table 1).

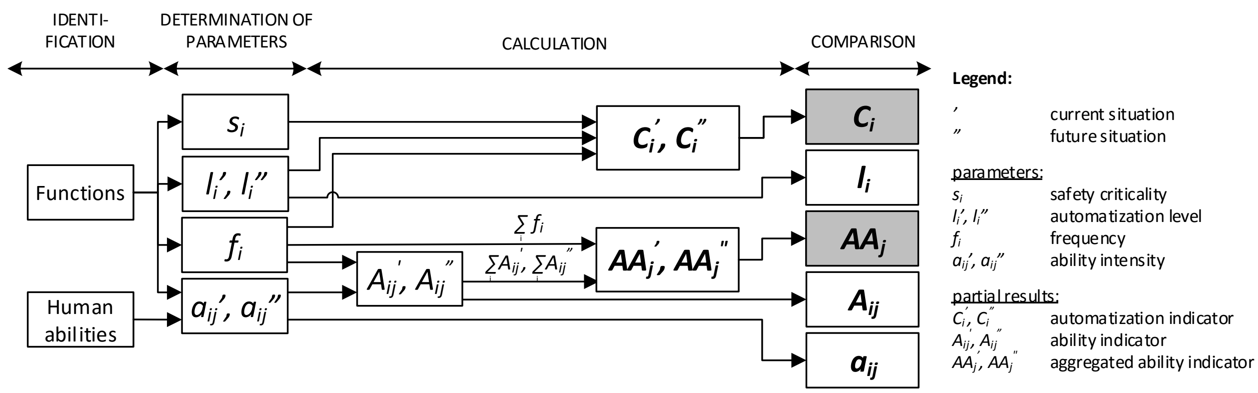

Fig. 1.
Flow-chart of method

Table 1
Functions

function groups nr.	function groups name	functions sign	functions name
1	infotainment	F_{11}	information provision about general conditions and supplementary services
		F_{12}	information provision about current situation
		F_{13}	personalized journey planning and guiding/ navigation
		F_{14}	activity chain planning
		F_{15}	information provision by installed devices (in the stop/station)
		F_{16}	on board information provision by on board devices
		F_{17}	on board complaining/information request
		F_{18}	communication between vehicle-passenger
		F_{19}	entertainment
2	management of entitlement	F_{21}	seat reservation
		F_{22}	payment
		F_{23}	ticketing
		F_{24}	check-in (ticket validation)
		F_{25}	control of entitlement (ticket inspection)
3	safety	F_{31}	avoiding accidents between vehicle and passengers
		F_{32}	handling boarding process (warning, open/ close door)
		F_{33}	handling passengers in diseased conditions
		F_{34}	handling fire cases
		F_{35}	handling traffic collisions - evacuation
		F_{36}	handling vehicle technical failures (broke down)
		F_{37}	handling equipment technical failures
4	security	F_{41}	property protection (individual/common)
		F_{42}	life protection
		F_{43}	emergency call
		F_{44}	safeguard against terrorism
5	management of passenger room/ cabin conditions	F_{51}	management of comfort (e.g. heating, lighting, cleaning)
6	management of feedbacks	F_{61}	complaining
		F_{62}	crowd sourcing
		F_{63}	lost and found
		F_{64}	data collection from/about passenger
		F_{65}	data collection from/about vehicle/infrastructure

3.1 Calculation of indicators on machine side (functions)

Determination of parameters:

- safety criticality (s_i): how much the function should be reliable in safety critical circumstances/situations (Table 2). Same safety criticalities are assumed also in the future.

Table 2
s_i values

value	safety criticality	description
1	not	not safety critical
2	medium	slightly jeopardize human safety/life
3	high	sorely jeopardize human safety/life

- automatization level (l_i): in what degree the function can be automatized, in other words how it is possible to replace the human operations or presence by machine (Table 3). It is a general parameter which does not reflect particular aspects of operators/users. The current (l_i') and the future (l_i'') parameters have been assessed.
- frequency (f_i): average frequency of the function during travels (Table 4). Same frequencies are assumed also in the future.

Calculation of C_i' and C_i'' – Automatization indicators (1): The strong effect of safety criticality is expressed by power function. Calculation method of indicator is similar in both the current (C_i') and future (C_i'') situations. $C_i \in [0..625]$ in case of the introduced values.

$$C_i' = f_i \cdot l_i'^{s_i} \quad (1)$$

Table 3
l_i values

value	automatization level	description
1	low	no machines
2	rather low	slight machine support
3	medium	significant machine support
4	rather high	humans are needed only in safety critical situations
5	high	humans are unnecessary (only supervisors for remote control)

Table 4
f_i values

value	frequency	description
1	very rarely	in case of safety critical situations
2	infrequently	during some travels
3	occasionally	during many travels
4	frequently	during each travel a few times
5	very frequently	during each travel several times

Calculation of differences of indicators (2) or parameters (3) regarding future and current situations (Table 5). Difference between l_i values makes independent analysis possible. C_i is a complex indicator, because frequency and safety criticality are also included. Difference values are to be used for specification of software and hardware requirements during development of the certain functions.

Table 5
Calculation of differences on machine side (functions)

sign	calculation	description
C_i	$C_i'' - C_i' = f_i \cdot l_i''^{s_i} - f_i \cdot l_i'^{s_i}$ (2)	relevance of development
l_i	$l_i'' - l_i'$ (3)	required or foreseeable development

3.2 Calculation of indicators on human side (passenger)

During development of functions the alterations of required human abilities and cognition are to be investigated and considered as they significantly influence the perceived quality of service. The elaborated analysis method provides results mapping this alteration in a quantitative way. The most relevant human abilities have been identified.

1. eyesight,
2. hearing,
3. speaking,
4. touching,
5. typing,
6. reading,
7. operations by hand,
8. vibration sensing,
9. cognitive capability.

Vibration sensing is an important ability to sense vibration of a device placed in pocket or hand. Cognitive capability is defined as recognition and persistent learning capability. Travelers are able to create new, reliable, value-added information using previous experience, existing knowledge and ambiguous, incomplete secondary information sources. Cognitive capability is rather complex, it includes sensing and processing methods too.
The required abilities are altering as consequence of automatization. We have revealed the ability intensities (as parameters) for the current (a_{ij}') and future (a_{ij}'') situations in case of each function (where j is the index of the ability). Intensity expresses how long the ability is required during the function (Table 6). The low intensity is more convenient for the passenger. AA_j is created by consideration of frequencies and then aggregation of multiplied ability intensities.

Table 6
a_{ij} values

value	ability intensity	description
0	never	unrequired ability
1	rather low	for only a moment
2	low	for a short time
3	medium	cca. half of the time
4	rather high	all time with small pauses (almost continuously)
5	high	all time (continuously)

Calculation of A_{ij}' and A_{ij}'' - Ability indicators (4): frequency influences ability demands during travels, therefore it is considered as a multiplier. Calculation method of indicator is similar in both the current (A_{ij}') and future (A_{ij}'') situations. $A_{ij} \in [0..25]$ in case of the introduced values.

$$A'_{ij} = f_i \cdot a'_{ij} \quad (4)$$

Calculation of AA_j' and AA_j'' - Aggregated Ability indicators (5): as the same ability is required in case of several functions, the demand of this ability can be calculated as a sum of Ability indicators by functions (i), which is divided by the sum of frequencies of all functions. The indicators are calculated for both the current (AA_j') and future (AA_j'') situations. $AA_j \in [0..5]$ in case of the introduced values. The highest the AA_j value is, the more required the ability is.

$$AA'_J = \frac{\sum_i A'_{ij}}{\sum_i f_i} \quad (5)$$

The alteration can be represented by the differences of indicators (6), (7) and parameters (8) regarding future and current situations (Table 7). If the values of differences are negative, the required ability is less than currently, which is advantageous for the traveler.

Table 7
Calculation of differences on human side

sign	calculation		description
AA_j	$AA_j^{"} - AA_j'$	(6)	indicates human sensing and cognitive effort alteration in aggregated way (regarding all functions); it is useful for training and preparation of traveler's senses to autonomous processes
A_{ij}	$A_{ij}^{"} - A_{ij}'$	(7)	indicates what ability how alters at the given function considering all the travels; it is useful for specification of software and hardware requirements during development
a_{ij}	$a_{ij}^{"} - a_{ij}'$	(8)	indicates what ability how alters at the given function; it is useful for specification of software and hardware requirements during development

3.3 Analysis of tasks of personnel

As drivers have passenger handling functions in many cases, their replacement by machine significantly modifies performance of the functions. Therefore, the tasks of personnel have been analyzed and the current driver functions have been identified and assigned to the future personnel groups or the new machine components.

4. Results

The presented results have been calculated by the elaborated method. The used parameters have been determined by assumptions or literature review and were applied for demonstration purposes. More precise determination of the parameters requires further researches (e.g. questionnaire surveys, analysis of human behavior).

4.1 Assessment of functions

The most important properties of functions are summarized in Table 8. Functions with high automatization level alteration ($l_i \geq 2$) are marked with red numbers. Functions with significant automatization potential ($C_i \geq 100$) are presented with grey background and bold numbers. They are safety critical and having high automatization level alteration. If both l_i and C_i are high, development requires special attention, as in the case of F_{18}: communication between vehicle-passenger, F_{24}: check-in (ticket validation), F_{31}: avoiding accidents between vehicle and passengers and F_{34}: handling fire cases.

Table 8
Properties of functions

	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{21}	F_{22}	F_{23}	F_{24}	F_{25}	F_{31}	F_{32}	F_{33}	F_{34}	F_{35}	F_{36}	F_{37}	F_{41}	F_{42}	F_{43}	F_{44}	F_{51}	F_{61}	F_{62}	F_{63}	F_{64}	F_{65}
f_i	4	5	4	4	5	5	2	5	4	4	4	4	5	3	5	5	2	1	1	1	2	5	5	2	1	5	2	5	2	5	5
l_i'	3	3	3	3	3	3	1	1	3	3	2	2	2	1	3	4	1	1	1	1	2	2	2	2	2	2	1	4	1	4	4
l_i''	4	5	4	4	5	5	3	5	4	5	4	4	5	3	5	5	4	4	4	3	3	4	4	3	3	5	3	5	3	5	5
s_i	1	1	1	1	1	1	1	3	1	2	3	3	3	2	3	3	3	3	3	3	1	2	3	3	3	2	1	1	1	2	3
C_i'	12	15	12	12	15	15	2	5	12	36	32	32	40	3	135	320	2	2	1	1	4	20	40	16	8	20	2	20	2	80	80
C_i''	16	25	16	16	25	25	6	625	16	100	256	256	625	27	625	625	128	128	128	27	6	80	320	54	27	125	6	25	6	125	125
l_i	*1*	*2*	*1*	*1*	*2*	*2*	*2*	*4*	*1*	*2*	*2*	*2*	*3*	*2*	*2*	*1*	*1*	*3*	*1*	*2*	*1*	*2*	*2*	*1*	*1*	*3*	*2*	*1*	*2*	*1*	*1*
C_i	*4*	*10*	*4*	*4*	*10*	*10*	*4*	***620***	*4*	*64*	***224***	***224***	***585***	*24*	***490***	***305***	***126***	***126***	***126***	*26*	*2*	*60*	***280***	*38*	*19*	***105***	*4*	*5*	*4*	*45*	*45*

Legend: *high automatization level alteration*, ***significant automatization potential***

4.2. Assessment of human abilities

The role of several abilities is changing as consequence of automatization. Table 9 presents an excerption of the alteration of the required human abilities. The higher the value of cells is, the more the ability is required. Fig. 2. represents the required human abilities (*j = 1-8*) currently and in the future. As cognitive capability (*j=9*) is much more complex than sensing by organs, cognitive capability is not illustrated in the figure. The Aggregated Ability alteration values (AA_j) is used to illustrate the shifting.

Table 9
Required human abilities - excerption

	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{21}	F_{22}	F_{23}	F_{24}	F_{25}	F_{31}	F_{32}	F_{33}	F_{34}	F_{35}	F_{36}	F_{37}	F_{41}	F_{42}	F_{43}	F_{44}	F_{51}	F_{61}	F_{62}	F_{63}	F_{64}	F_{65}	AA_j' AA_j''	AA_j
$a_{1,i}'$	4	5	4	3	4	4	1	2	3	3	3	3	4	4	3	4		5	5	5	3			2			2	1	3				
$a_{1,i}''$	4	4	3	0	3	3	1	5	4	3	3	2	2	2	5	4		5	5	5	5			2			2	1	3				
$A_{1,i}'$	***16***	***25***	***16***	***12***	***20***	***20***	***2***	***10***	***12***	***12***	***12***	***12***	***20***	***12***	***15***	***20***		***5***	***5***	***5***	***6***			***4***			***4***	***5***	***6***			*2.46*	***-0.16***
$A_{1,i}''$	***16***	***20***	***12***	***0***	***15***	***15***	***2***	***25***	***16***	***12***	***12***	***8***	***10***	***6***	***25***	***20***		***5***	***5***	***5***	***10***			***4***			***4***	***5***	***6***			*2.30*	
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
$a_{9,i}'$	3	3	4	5	3	3	1	2	2	3	2	3	4	3	5	3	2	3	3	3	2			4		2	3	3	3	2			
$a_{9,i}''$	2	2	3	3	3	3	4	5	4	2	3	2	2	2	4	2	3	4	4	4	3			3		1	4	2	4	1			
$A_{9,i}'$	***12***	***15***	***16***	***20***	***15***	***15***	***2***	***10***	***8***	***12***	***8***	***12***	***20***	***9***	***25***	***15***	***4***	***3***	***3***	***3***	***4***			***8***		***10***	***6***	***15***	***6***	***10***		*2.55*	***-0,22***
$A_{9,i}''$	***8***	***10***	***12***	***12***	***15***	***15***	***8***	***25***	***16***	***8***	***12***	***8***	***10***	***6***	***20***	***10***	***6***	***4***	***4***	***4***	***6***			***6***		***5***	***8***	***10***	***8***	***5***		*2.33*	

Legend: not relevant

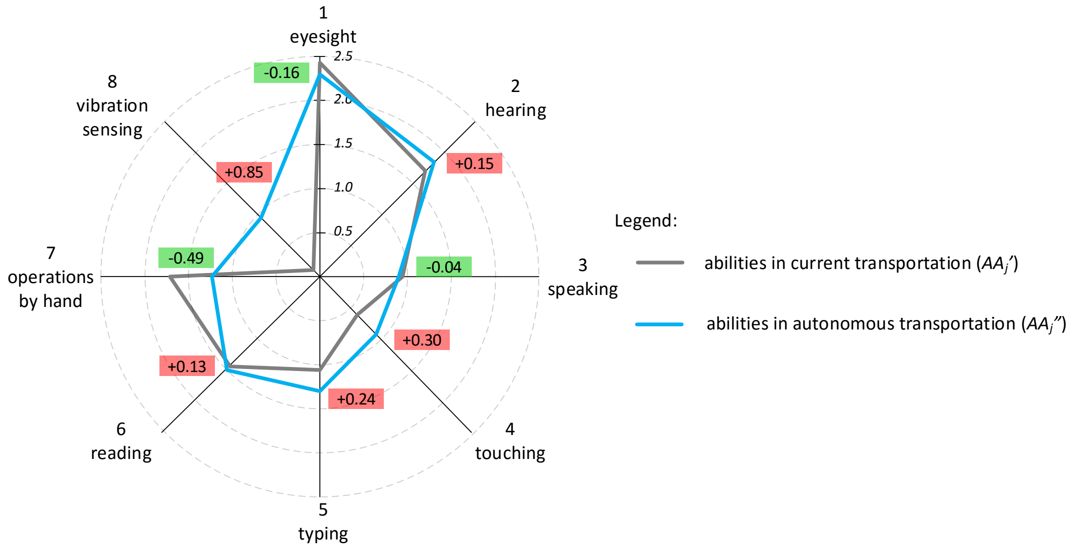

Fig. 2.
Required human abilities (AA_j', AA_j'') and their alteration (AA_j)

4.3. Alteration in personnel tasks

The driver functions have been assigned to the different groups (types) of personnel and machines (installed in vehicle or station). This alteration in personnel tasks is represented by 'X' in cells of Table 10. These groups of personnel already nowadays perform several functions, however, their actions are altering as a consequence of modification of function properties and taking over driver functions.

Table 10
Reallocation of driver tasks among personnel groups

whom	F_{12}	F_{17}	F_{18}	F_{23}	F_{24}	F_{25}	F_{31}	F_{32}	F_{33}	F_{34}	F_{35}	F_{36}	F_{41}	F_{42}	F_{43}	F_{51}
machine	*X*		*X*	*X*	*X*	*X*		*X*								*X*
dispatcher	X						X		X	X	X	X			X	
supervisor		X							X	X	X	X				
customer service		X														
security team													X	X	X	
rescue team									X	X	X	X			X	

5. Discussion

The analyses pointed out the most relevant development potentials of functions. The first research question, which functions and how to be automatized, is to be answered by results of (2), (3), (7), (8) equations. (2) and (3) assesses the technological opportunities, whereas (7) and (8) provides the required human abilities. The second research question, how the future traveler's sensations and cogitation changes, is to be answered generally by results of (6) and in details by (7) and (8). The third research question, what kind of modifications are possible in role of personnel, is answered by results of Table 10. All the results are interrelated. The most relevant properties of future functions are described considering the results, then the general alteration of human abilities and tasks of future personnel are discussed. Not only the results presented in Table 9, but alteration of all relevant human abilities are discussed in this section too.

Information provision (F_{11}, F_{12}) becomes more location based, personalized, however, the automatization level does not change significantly /$l_{11}=1$/. The location has an impact on e.g. traffic, weather, business ads, coupons, free parking lots, etc. (Rao and Giuli, 2011). The speaking as an ability becomes more important only in case of these functions as consequence of voice-based communication /$a_{3,11}=2$, $a_{3,12}=1$/ and it replaces typing /$a_{3,11}=a_{3,12}=-1$/. Journey planning (F_{13}) and activity chain planning (F_{14}) play more important role as future mobility becomes more pre-planned and personalized (Esztergár-Kiss and Csiszár, 2016). Setting personal characteristics or route expectations requires more time in the first phase, however, later on less time is enough due to cognitive and persistent learning capability of the journey planners. Accordingly, less user cognitive capability is needed /$a_{9,13}=-1$, $a_{9,1}$ $=-2$/. Multimodality between modes or region can be achieved by integration of multiple journey planners (Nykl et al., 2015). The installed information provision (F_{15}) devices provide more information in more automatic way /$l_{15}=2$/, not only about transportation related news, but e.g. about weather, touristic information too. Smart stops are installed as service hubs where travelers receive several information in automatic way. Information about current position, route, next stop, or other location based services are provided via on board devices (F_{16}). The travelers cannot complain to the driver or other personnel directly. The complaining process (F_{17}) occurs mostly via telecommunication devices (e.g. using video call or writing a message). The most significant alteration is foreseeable in the communication between the 'vehicle'

and other participants, especially passengers (F_{18}). The human reactions, mimicry, eye movement, gesticulation play important role in the current traffic. In the future, the vehicle has to indicate its intention unambiguously /$l_{18}=5$, $C_{18}''=625$/. However, the communication comes about via electronic devices. The vehicles recognize each other's, pedestrians' and bikers' location (if they have e.g. smart phone), and can warn all the participants in this way. The entertainment (F_{19}) (browsing on the internet; wireless charging of personal devices) during travel becomes more important, which is also consequence of exemption from driving. Delay-insensitive downloads (DID) enable downloading multimedia content (e.g. audio, video, movies) requested by users (Karagiannis et al., 2011). Role of function seat reservation (F_{21}) becomes more significant. as future mobility is more pre-planned, travelers have to be more conscious. Functions regarding payment, ticketing and check-in (F_{22}, F_{23}, F_{24}) require less direct human acts, however more touching /$a_{4,22}=2$, $a_{4,23}=a_{4,24}=1$/ and typing actions /$a_{5,22}=2$/ (e.g. e-ticketing, using vending machine). Validation of the ticket (F_{24}) becomes more simple (less touching) or entirely automatic /$l_{24}=3$/ (e.g. by tracking user). However, in special cases control of the entitlement (F_{25}) requires human inspectors aided by advanced devices /$l_{25}=2$/.
The CCTV surveillance and advanced sensor technology have important role to prevent safety critical situations. These situations and technical failures should be recognizable by implemented sensors and automatic image processing or remote monitoring by humans. The function of avoiding accidents between vehicle and passengers (F_{31}) is currently the most critical issue in regards of autonomous vehicles /$l_{31}=2$, $C_{31}=490$/. The entire boarding process becomes automatic (door opening/closing and warning), however these systems are rather common (F_{32}) /$l_{32}=1$/. The most safety critical functions (F_{33}, F_{34}, F_{35}, F_{36}, F_{41}, F_{42}) require automatic machine recognition, strict regulations, elaborated intervention plans and fast human actions /$l_{33}=l_{34}=l_{35}=3$, $l_{36}=l_{41}=l_{42}=2$/. The sense of security can be improved by implementation of more static emergency call devices (F_{43}). Avoiding hacking and terrorist attacks require advanced identification of suspicious persons (F_{44}). Management of the passenger room/cabin conditions (F_{51}) becomes completely automatic in the future /$l_{51}=3$/. According to defined rules the machine switches on/off the devices (e.g. heating) based on sensor data. Cleaning processes of the vehicle do not change, however, dirty room is recognized by remote monitoring or passenger complains (feedbacks) via electronic devices. After travel the complaining (F_{61}) mostly does not require personal contact, however, it cannot be eliminated entirely /$l_{61}=2$/. Handling lost belongings (F_{63}) is also changing; travelers should be more aware of its risk and inform the remote monitoring services about the belongings. Data collection from/about passengers (F_{64}) becomes highly automatic if user gives permission. If a passenger provides data, he or she may receive more value-added information. Data collection from/about vehicle/infrastructure (F_{65}) becomes also highly automated.
In the future eyesight still remains significant but its usage intensity slightly decreases. Most relevant reduction can be noticed in operations by hand /$AA_7=-0.49$/ (less direct contact – e.g. during ticket validation). As the significance of smart mobile devices increases, the requirements towards the related human abilities rise. Vibration sensing will be eight times more relevant than nowadays. Significant increasing is expected in touching /$AA_4=+0.39$/ (e.g. during entertainment, boarding), and typing /$AA_5=+0.24$/ (e.g. using personal mobile devices during seat reservation, journey planning, etc.). Whereas sensing abilities alter differently, the required human cognitive capability all in all reduces /$AA_9=-0.22$/, as the machine support is growing. The human thinking (e.g. route planning) is in many cases replaced by machine.
The personal interactions of human personnel groups are particularly needed in case of special passenger groups (e.g. disabled, elderly or technically underdeveloped persons) and situations (e.g. foreign passenger in an unknown city). Therefore, employment of personnel in some functions is more effective than an automated solution (F_{17}, F_{22}, F_{23}, F_{61}, F_{63}). Handling of emergency and security situations (F_{33} – F_{37}, F_{41} – F_{43}) also require human interventions, however, the recognition of these situations can be appreciably automatized. Autonomous functions must be supervised by humans. The attendants' processes are aided by machines, so the number of humans may decline and their operation processes are more efficient (less wrong decisions, faster decision making). The personnel of future public transportation consist of:

- dispatchers: their processes are already currently aided by advanced infocommunication procedures, however some decision cannot be programmed. In the future dispatchers remain as a supervisor.
- supervisors: security attendance and information provision by human presence is important at eventful passenger facilities. Their tasks are broadened with former driver tasks (e.g.: checking cleanness in the vehicle).
- customer service: their role remains significant as several situations require human contact.
- security team: although image recognition systems reliably recognize the critical situations they are unable to interact. Therefore, quick moving human security teams are necessary (e.g. remove abandoned package).
- rescue team: in case of any emergency situation humans can more easily guide the passengers (e.g. during evacuation) and the medical interventions also require personal presence.

6. Conclusions

The main contribution of the research is the elaborated analysis method of passenger handling functions. In this method safety issues, automatization potential, frequency of function usage and human abilities are mapped by parameters. The method is applicable to determine indicators which fairly describe the automatization potential of the functions and the implied alteration of abilities. It has been found that the required eyesight as an ability and the cognitive capability slightly reduce, however, the relevance of vibration sensing, touching and typing significantly increases. In the future travelers receive value-added information and guidance from more sources; some human sensing becomes more intensive, but intensity of cogitation reduces. Less personnel are sufficient and most of them are employed as supervisor. We faced that collection of passenger handling functions require system- and process-oriented approach. Determination of alteration of function caused difficulties as only a few scholar publications related directly to the future transportation and passenger handling functions are available. Our future research focuses on the supplementary operational functions (e.g. parking, cleaning, maintenance), as these functions influence directly the mobility service. The research question is the same, how they to be automatized. Furthermore, we intend to model the entire autonomous public transportation system and its operational processes from several aspects. For instance, one current relevant hot topic is, how do the demands and capacities alter and how the pure traffic situations are to be modelled and simulated.

Acknowledgements

The publication of the work reported herein has been supported by ETDB at BME.

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