Delivery Robots for Smart Rural Development

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Abstract

Rural areas in Europe suffer under demographic change and migration to urban areas which caused problems in supply, mobility and medical care for remaining population. Thus, new solutions are required for rural areas to solve shortcoming in retailing, waste disposal, postal and administrational issues since all related services become more and more inefficient from the perspective of service providers. Here, the concept of "smart rural areas" can contribute to solutions since it targets on non-urban areas and tries to improve the development perspectives of rural areas by using digitalization and smart approaches to overcome all mentioned shortcomings in rural areas.

Delivery robots represent smart logistics systems and they are able to solve important logistics problems in rural areas. Originally, autonomously driving delivery robots were constructed for last-mile deliveries of packages with a focus on urban environments but recent research also highlights the possibility of their application in rural areas. Since the use of autonomous delivery robots represents a neglected research topic until now, this paper analyses tentative applications of delivery robots in rural environments and develops concepts to overcome shortcomings in logistics with these robots. Delivery robots can be considered as cyber-physical systems in the sense of Industry 4.0 so that this research also contributes to the field of smart rural development. The underlying research question focuses on how autonomous delivery robots might facilitate smart rural development. The empirical measures of the paper are based on semi-structured expert interviews, research group meetings, secondary data, and results from case studies from Estonia and Bulgaria.

Key words: delivery robots; autonomous transport; smart rural development; digitalization, rural areas

1. Introduction

Smart concepts are mainly associated with manufacturing activities and logistics in urban environments and they are often neglecting the context of rural areas. One reason for that is related to fact that approaches like "Industry 4.0" aiming to integrate digitally value networks of manufacturing and supply chain systems and which to big extent are touching urban areas (Prause, 2015; Prause & Atari, 2017). Otherwise, Prause and Boevsky (2015) showcased that there exist powerful concepts like "smart specialisation" and "smart rural areas" targeting on non-urban areas and which are able to improve significantly the development perspectives of rural areas by applying digitalization approaches to overcome rural shortcomings in logistics, mobility and supply. Such concepts are of high importance since rural areas suffer more than urban areas from brain drain, an increasing share of elderly population and shrinking work-force which are accompanied by mobility, supply and health care problems on the countryside. These developments can be mitigated and even partly reversed by applying smart rural concepts which has been discussed and showcased by Prause and Boevsky (2015, 2016).

A closer look to the ongoing research on "Smart Rural Areas" reveals that rural development is closely linked to a number of challenges that have to be overcome in order to make country life more attractive compared to urban areas. Fraunhofer-Institute for Experimental Software Engineering (IESE) in Kaiserslautern highlighted that the countryside has to be proactive to counteract depopulation by supporting the creation of workplaces as well as the rural economy. Typically, rural challenges are related to supply, retailing, waste disposal, postal and other logistics services and for their solution there are formulated already some specific ideas (IESE, 2015):

- "Postbus", i.e. to use regional bus transport for people and for packages and cargo delivery between fixed stations. The related cargo streams can be controlled by mobile IT solutions.
- Sensors for medical care in houses of risk patients and older people.
- Digitalization of agriculture to improve rural entrepreneurs through remote consulting, coaching and training from central competence centres.
- Remote work places in rural areas as well as access of rural SMEs to high qualified workforce through digitalization.
- E-governmental solutions to improve administrational tasks including application of agricultural subventions or taxation.
- Mobile IT systems to improve the cooperation among rural entrepreneurs and farmers by organizing the use of shared resources (i.e. machines), shared transportation and common product marketing.
- Renewable energy sources can be used, managed and shared more efficiently.

E-governmental solutions for rural areas have been discussed already be Prause and Boevsky (2016), but a deeper view to the formulated ideas reveals that delivery services, mobile solutions and internet-based applications play the same key role in the list of smart rural approaches like in the world of smart manufacturing, smart logistics and Industry 4.0 Avramov (2017). Thus, these ideas for smart rural development are based on the same pillars like Industry 4.0, i.e. the fusion of the virtual and the real world in form of cyber-physical systems (CPS) that work in dynamic networks using machine-to-machine (M2M) communication and interaction (Kagermann et al., 2013).

Recent developments in smart logistics disclose an existing hype concerning flying and land-based drones but it seems that current focus of R&D activities is shifting towards land-based delivery robots, being the most suitable technology to solve the last-mile problem. A large number of scholars centered their research on the last-mile problem in the context of retailing and e-commerce but mainly in the context of urban environment (Lee & Whang, 2001; Song et al., 2009; Boyer et al., 2009). When it comes to the practical part of last-mile delivery, the key players comprise the established traditional logistics service providers as DHL, UPS, and others, but during the last years more and more start-up from all around the world were attracted by the research field. First serious business applications of delivery robots are already tested in the context of urban areas for the delivery of perishable goods as food and flowers and other applications in retailing and warehousing sector (Hoffmann & Prause, 2018). A literature review shows that the research for delivery robot use in rural areas has been neglected until even if benefits can be expected.

Thus, the paper highlights the current status of autonomous delivery robots for distribution and investigates tentative applications of self-driving delivery robots in rural areas for smart rural development. Besides that, the authors evaluate the benefits and usability of possible applications of delivery robots in rural areas and investigate the role such robots can play in the concept of smart rural areas. The research uses an empirical analysis based on semi-structured expert interviews, research group meetings, secondary data, and results from case studies from Estonia and Bulgaria.

2. Theoretical background

The still growing e-commerce market volumes raise the question of efficient product delivery to the client. The last-mile delivery includes three stakeholders, namely the seller, an intermediary and the client. Punakivi et al. (2001) discussed the last mile-issue in the traditional context of B2C and e-commerce; they proposed an unattended reception of goods which could reduce home delivery costs by up to 60%. The unattended delivery approach is based on the two main concepts of a reception box or a delivery box. The reception box is installed at the customer's home, whereas the delivery box is an insulated secured box that is equipped with a docking mechanism. Based on simulation, the authors came to the result that home delivery solutions enabling secure unattended reception are operationally the most cost-efficient model for last-mile distribution. They also confirmed that a secured delivery box solution potentially enables a faster growth rate and higher flexibility of the investments because of a smaller investment being required per customer.

A new approach for solving the last-mile-problem represents an autonomously driving delivery robot. The background idea is linked to the research of Punakivi et al. (2001) in that sense that the delivery robot can be considered as an autonomously moving delivery box finding his way from the supplier to the client. Realisations of these delivery robots exist already in form of prototypes and they are tested in several countries around the world for the last-mile delivery of packages, mainly in urban areas. Estonia plays a leading role in this field with start-up Starship Technologies, which operates not only in Estonia but also in foreign countries like Germany, Great Britain, and the United States of America (USA), where it seems to provide a promising solution of the last-mile problem (Starship, 2018). A competitive advantage of the use of these autonomous delivery robots, compared to other delivery modes, is a cost advantage for the last-mile delivery that is estimated to be up to 15 times cheaper than the current delivery costs and yield costs of less than 1€ per delivery (Hoffmann & Prause, 2018). For the customer, additional convenience is gained since the robot delivery provides a 15-to-20 min delivery window as standard, which is much more precise than traditional home deliveries that currently are only able to provide a calendar day for the delivery.

Despite the term "autonomous delivery robot" these vehicles are not fully self-driving because during about 10% of the time they are remote-controlled from a command centre, which is linked via Wi-Fi and telecommunication networks to the robot. Thus, the technical realisation of such robots can be placed in the context of Industry 4.0, since they represent cyber-physical systems (CPS), which requires internet–based linked machine-to-machine (M2M) communication and interaction. Existing M2M concepts are mainly researched by technical scholars so far. Cha et al. (2009) discuss different use cases for M2M communication together with common security requirements to clarify the security requirements on M2M systems. Their business cases include logistics-related M2M applications and come to the conclusion that information security and trustworthiness of the operations involved grows from the predictability and observability of the behaviour of the devices. Wu et al. (2011) investigated M2M systems in the context of embedded internet and identified low cost/high performance devices, scalable connectivity, and cloud-based device management and services as vision for the Internet of Things (IoT). By considering M2M cases for mobility support, they investigated frame conditions for standards and M2M networks. Zhang et al. (2011) highlighted, besides security issues, self-organization and quality of service support as important factors for M2M-communication. Self-organization was stressed due to low human intervention as a major requirement for M2M systems, which for that aim ought to comprise self-configuration, self-management, and self-healing, which are recognised as being characteristic for Industry 4.0 systems as well as for organisational structures in the context of smart specialisation (Olaniyi & Reidolf, 2015).

3. Delivery robots: A case study

Starship Technologies Ltd. is a Tallinn based startup, founded in 2014 by two of the Skype founders with the aim to tackle the last-mile problem by developing autonomous delivery robots. Today, Starship Technologies is a European technology startup with subsidiaries in Estonia, the UK and the USA. The credo of Starship

(2018) is to build the first commercially available autonomous delivery robots in order to "revolutionize the local delivery industry". This target shall be achieved environment-friendly, since Starship robots do not emit $C0_2$. It also claims that their robots contribute to reduction of on-road traffic and congestions, and that Starship provides a solution for retailers and logistics firms to increase supply chain efficiencies by reducing costs. Starship's small self-driving vehicles with a weight of less than 20 kg are electric-powered and are designed for driving on sidewalks with a speed of maximal 6 km/h, being capable to locally deliver their goods within 15–30 min and within a radius of up to 5 km for a price of under 1 Euro per delivery. The robots are able to deliver freight of up to 10 kg for a shipment price, which is up to 15 times lower than the normal price for last-mile deliveries in high-salary level economies, which makes the delivery robots interesting for e-commerce applications as well as for food deliveries or postal services. In practice, Starship delivery robots have been tested already by online food ordering service providers in Tallinn (Volt), as well as by Domino's pizza delivery services to use them as "personal delivery devices". Until now all known tests have been executed in urban areas showing the main focus of such robots.

To safeguard safe circulation, the robots are equipped with a couple of sensors and tracking systems comprising nine cameras, GPS, and an inertial measurement unit (IMU) for special orientation. They are also equipped with microphones and speakers enabling them to communicate with humans. Even if the robots are called autonomous vehicles, they, at present, are only self-driving around 90% of the time. The rest of the time, mainly around complex road crossings and the final meters to the receiver, the robot will be remote-controlled from a command centre, which is linked via Wi-Fi and telecommunication networks. While their entire journey, the robots are continuously supervised by a responsible, natural person in the command centre. This remote-control means that the operation of a delivery robot implies a permanent exchange of data, including life-video transfer-between the robot and the control centre via public telecommunication networks and internet links.

In order to create a smart solution for bridging longer distances of delivery, the company started collaboration with Daimler in order to develop the "RoboVan", which forms a mobile robot hub on the base of a MB Sprinter mini truck and would considerably extend the range of the robots. This approach for delivery realizes a "hub and spoke" concept, which is a well-known standard model in logistics (Seeck, 2010). A RoboVan-Mercedes-Benz Sprinter is to that aim equipped with a storage system for 54 delivery boxes and eight Starship robots. The Sprinter performs the long distance elements of transport as a mobile hub and it brings the robots together with the delivery boxes right into an area were a multitude of individual deliveries has to be performed. From this spot, the robots disembark from the RoboVan autonomously and cover the last-mile to the client in order to individually deliver the goods to the clients and return to the Sprinter afterwards. The approach realizes a "hub and spoke" concept with robot delivery for the last short distance.

Starship Technologies considers its delivery robots as a supplemental form of shipment, not as a replacement, i.e., the logistical models that can be used with robots are different than those models of traditional delivery methods. Ahti Heinla, the co-founder of Starship Technologies, illustrated in an interview the different areas of complementing delivery with bicycle couriers operating in very dense urban environments, since they are able to overcome gridlocks and traffic jams, whereas autonomous vehicle is predestinated for the delivery in suburbs with low traffic (Heinla, 2017). Access to the cargo in the robots is arranged by a smartphone app, which enables the client to unlock the robot cover lid and retrieve the goods. If someone tries to steal the robot, the cameras will take a photograph of the thief, and alarm will sound. Additionally, multiple tracking devices can track the robot's location via GPS, and the remote operator is able to speak through two-way speakers with the thief; and, obviously, the robot will stop working and will not open the cargo unit unless re-programmed by Starship.

In January 2017, Starship Technologies announced $17.2 million in seed funding for building autonomous robots that are designed to deliver goods locally. The funding round was led by Daimler AG and included a couple of other venture capital funds, among which were Shasta Ventures, Matrix Partners, ZX Ventures, Morpheus Ventures, Grishin Robotics, Playfair Capital, and others (Starship, 2018). This amount of seed funding makes Starship Technologies rank among the worldwide leading companies of delivery robots for the last-mile.

4. Delivery robots in Smart Rural Areas

The Starship case study underlines the importance of internet and access to broadband networks for smart rural development. This observation was already pointed out by Prause and Boevsky (2015, 2016). And the Starship case further shows that a bridging of missing internet links cannot be safeguarded by smartphones since the exchanged data volumes in the case of delivery robots are too huge due to video sequences. But this need for access to fast internet and broadband networks is not new, since it has been already by Prause and Boevsky (2015) in the context of smart rural solutions for international operating SME from rural areas. One important reason for that are research results showing that those companies that make greater use of the Internet for their business processes are indeed those that have greater and sustainable growth (Amoros et al., 2007).

Beside the technical requirement for the use of delivery robots in rural areas, also a regulatory framework is necessary but the discussion is still open. On one hand, it is possible to build on the steps towards a regulatory framework for Industry 4.0; on the other hand, it is also possible to follow the discussions that are taking place in the context of autonomous mobility (Hoffmann & Prause, 2018). Scheurs and Stewer worked on a regulatory framework of autonomous driving and analysed the political, legal, social, and sustainability dimensions of mobility. Their investigations highlighted competitiveness, innovation, safety, harmonization, and coordination (Maurer et al., 2015: pp. 151–173). Basu et al. (2018) recently researched the legal framework for small autonomous agricultural robots with the restriction that "agribots" roam usually only on private land, the unresolved traffic law dimension has not been covered by their paper. In this paper the authors continue with the conviction that delivery robots are part of the Industry 4.0 environment so that their regulatory framework path belongs to the context of Industry 4.0 by perceiving. Consequently, all issues related to liability, data protection, privacy, and legal developments around delivery robots belong to the sphere of Industry 4.0 (Hoffmann & Prause).

The paper of Hoffmann and Prause (2018) shed light on legal issues arising from liability for accidents that are caused by delivery robots under traffic law and on violations of privacy regulations, i.e. the General Data Protection Regulation (GDPR) requirements which entered into force on 25. May 2018 and replaces the Data Protection Directive of 1995 of the European Commission. The consideration of the GDPR rules is important due to the delivery robots' data collection and transmission mechanisms, representing severe risks for the entrepreneur deciding of making use of delivery robots. Another, aspect that may impede the future success of delivery robots as business model is the question how much society – and municipal governments – will indeed welcome an excessive use of pedestrian walkways by delivery robots. The related legal framework, which evolves around the sector of delivery robots, represents a patchwork of different rules on national, regional and municipality level, making it complicated to realize the competitive advantage of the business model of the delivery robots for the last-mile.

When it comes to possible applications of delivery robots on the context of smart rural development, it makes sense to remember to the already identified main topics, which have to be solved in order to overcome the obstacles in rural development comprising rural retailing, waste disposal, postal and other logistics services. Since the distance between housings in rural areas is usually large, the use of a delivery robot only makes sense, together with a "RoboVan", to extend the range of the robots and to bridge the distances and to act as mobile robot hub. Thus, the RoboVan is placed in the centre of the spokes that will have a length of maximal 5 km, i.e. the RoboVan then has to be routed so that the placements cover most of the destinations within a radius of 5 km and with up to maximal 54 service destinations, since each RoboVan is equipped with a storage system for 54 delivery boxes and eight Starship robots. The cargo of the delivery robots can include all types of goods up to 10 kg that fit into the delivery box of the robot, including retail goods, food, medicine, mail or packages that are delivered directly to the home of the client, which is a significant advantage for elderly or ill people. On the way back to the RoboVan the delivery robot can take again mail or packages but also waste and return goods that have to be treated specially like old batteries, expired medicine or other hazardous goods from the households that have to be transported to central collection points. In this sense a delivery robot can contribute remarkable to the logistics and distribution problems in rural areas. Since the RoboVan requires only one driver and the related shipment costs are up to 15 times cheaper than the normal price for last-mile deliveries, the rural robot delivery service turns out to be additionally more efficient than the classical solutions.

5. Implications and Discussions

The case study of the application of delivery robots in rural areas stresses the importance of internet and broadband networks to overcome the rural development obstacles like low accessibility, remote location to market and public and private service providers, availability of high-qualified work-force and reduced mobility of goods and personnel. This applies especially for Bulgaria due to large rural areas, underdeveloped infrastructure and to high importance of agricultural sector for national economy. In this sense the case of delivery robots stresses again the findings of Prause and Boevsky (2015, 2016) who pointed out the importance of a smart rural infrastructure by discussing success stories of Bulgarian SME from different branches with up to 200 employees operating from the Bulgarian countryside all over the world. Comparable results were presented by Prause (2016) in the context of e-services for rural areas. A closer look to the Digital Economy and Society Index (DESI) reveals that the reality concerning smart development, especially in Bulgaria, still shows a delayed and underdevelopment situation (DESI, 2018) (Fig. 1).

But DESI-index only sheds light to digital infrastructural situation among the EU countries. A more interesting question is related to the readiness of the EU countries concerning Industry 4.0, which has been investigated by Roland Berger Strategy Consultants. In this study, the Industry 4.0 Readiness Index is bundling production process sophistication, degree of automation, workforce readiness and innovation intensity into a category called “industrial excellence” (Dujin et al., 2014). Furthermore, the study combined high value added, industry openness, innovation network and Internet sophistication into a category labelled “value network”. Each category was measured using a 5-point scale, with “5” indicating that a country is excellently prepared for the Industry 4.0 landscape. The combination of these two categories determines a country’s position in the Readiness Index. The horizontal axis represents the traditional industry measure – the manufacturing share, i.e. it is possible to depict the results of the study in the following chart (Dujin et al., 2014) (Fig. 2).

By analysing the chart, it turns out that concerning Industry 4.0 readiness Bulgaria is placed at the end of the ranking, i.e. Bulgaria is worst considered EU country when it comes to internet-based linked machine-to-machine communication and interaction, as well as the ability to get integrated into cross-company processes, safeguarding the capability to operate in a networked supply chain environment. But the chart also expresses that all issues placed in the sphere of autonomous delivery robots are complicated to implement in Bulgaria.

Another important aspect of the use of autonomous delivery robots is to which degree the society is willing to accept an excessive use of delivery robots, since this means a shared use of sidewalks and streets between delivery robots

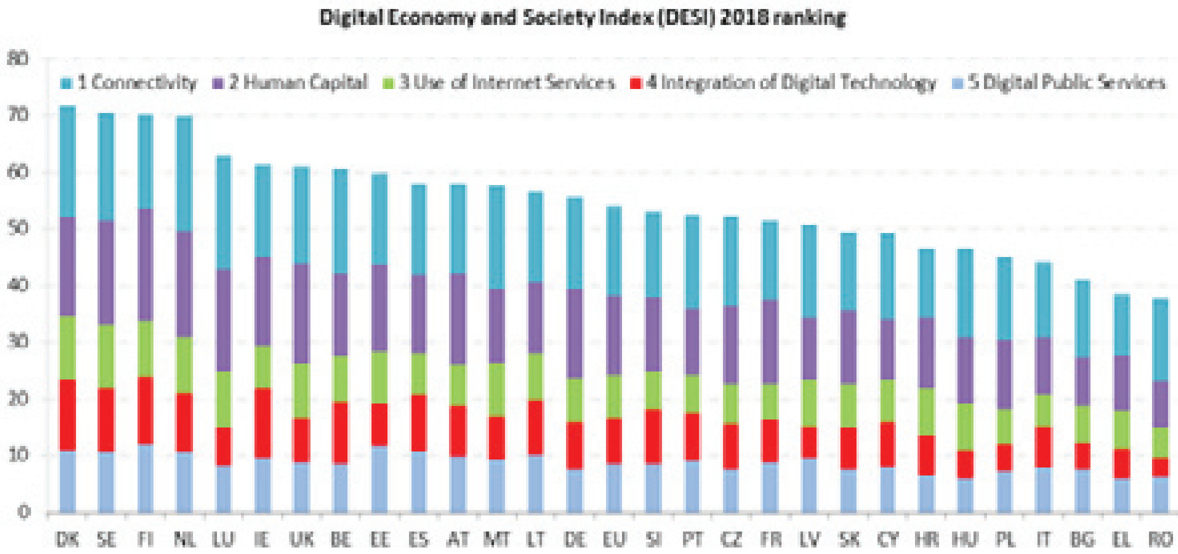

Fig 1 Digital Economy and Society Index (DESI, 2018)

Source: INDUSTRY 4.0: The new industrial revolution, RB Strategy Consultants (Dujin et al, 2014)

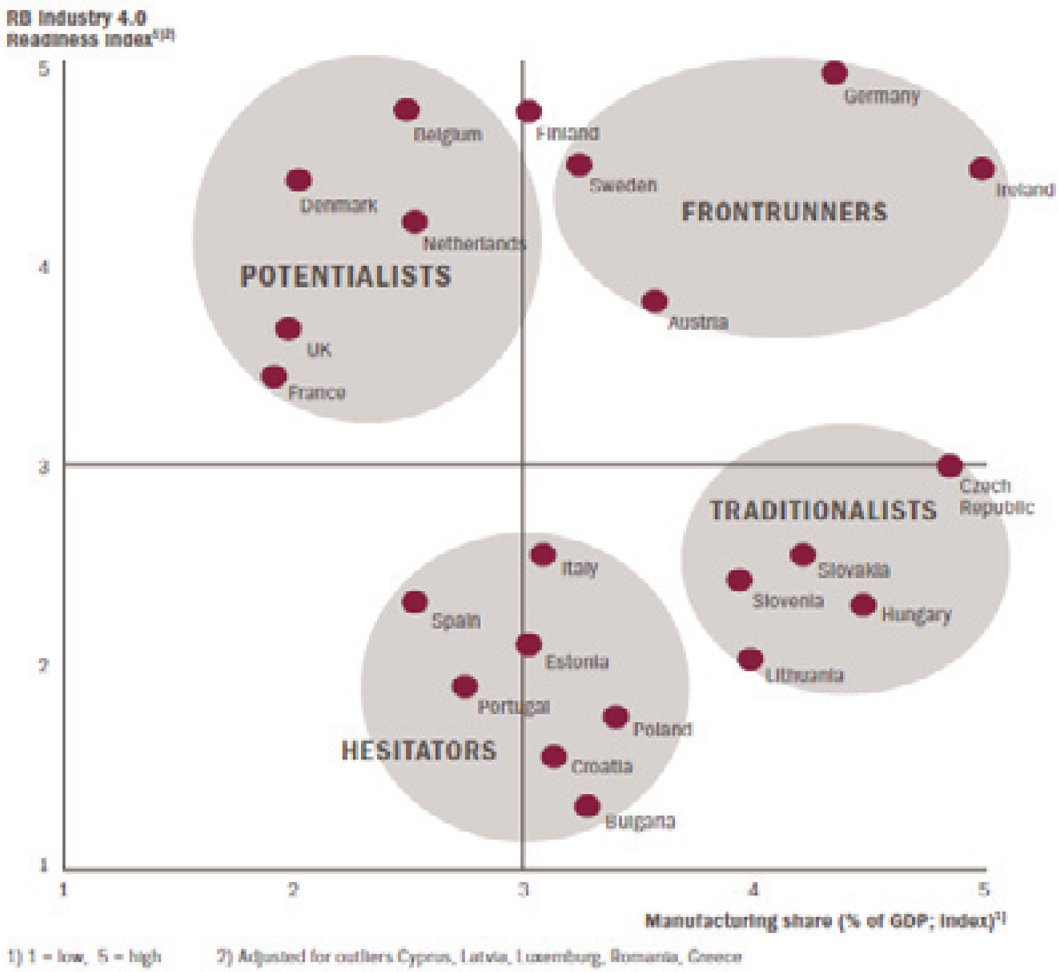

FIG. 2. INDUSTRY 4.0: The new industrial revolution, RB Strategy Consultants (Dujin et al, 2014)

Source: Digital Economy and Society Index (DESI, 2018) and pedestrians, causing already today considerable acceptance problems in some places, which are expressed in different legal frame conditions, depending on the location. Some of them can seriously endanger the business model of delivery robots. Estonia for example has already adapted its traffic laws for the shared use of space for humans and robots (see reform act on Estonian traffic act from 14 June 2017 on amendments of sec. 2 of the same act), but other countries are still hesitating (Hoffmann & Prause, 2018). In the USA, as another example, not all parts of society welcome sharing sidewalks with robots by nature, i.e. currently, a number of US States allow robots to participate in the traffic and adapted accordingly their state traffic laws, whereas some other States cities or municipalities formulated their own traffic law concerning robot use in the public, making the USA to a legal patchwork for robot operations in traffic. Recently, the case of San Francisco's anti-robot laws gained extensive media coverage when they banned autonomous delivery devices from most sidewalks entirely and permitted them only in low-foot traffic zones (Hoffmann & Prause, 2018). Thus, now robot operations will only be allowed in certain industrial neighbourhoods or in suburbs under special conditions. Finally, the new EU data protection regulation formulates new challenges for the development and operation of delivery robots (EUGDPR, 2018). The considered cases disclose that, until now, data protection issues are not ranging in the top of agenda of the delivery robot world. But, since the new European General Data Protection Regulation took effect on 25 May 2018, a huge set of data, necessary to operate a delivery robot, have to be considered as personal data that are not only locally processed in the robot, but are also transferred and stored via internet links. Consequently, the applicable new data protection rules have to be taken into account in the design of the robots. But interviews with the management and developers of robot companies have shown that there is little to no awareness concerning the new privacy rules so that more dissemination of GDPR framework is necessary to safeguard compliance by delivery robots collecting these information (Hoffmann & Prause, 2018).

Conclusions

Smart approaches are often neglect rural areas, since smart concepts like Industry 4.0 are often attributed to smart manufacturing, smart logistics or smart cities. Common to all smart approaches is the necessity of access to internet and broadband networks and the use the Internet of things and services. In recent years these smart concepts are extended to rural areas in order to use these new technologies for rural development aiming to make the country life more attractive. Case studies from Bulgaria, Estonia and Germany point out how effective the development of "smart rural area" concepts are linked to company success, especially for small and medium rural companies. In this context, autonomous delivery robots seem to be another technical solution to overcome logistics-related shortcomings in rural areas.

Delivery robots by design aim to provide the "missing link" between supply logistics and the consumer on the countryside equipped with additional service options. The use of delivery robots in rural area can solve the last-mile-problem in the cooperation with "RoboVans" in near future and several problems appearing in urban areas like sharing sidewalks with pedestrians are of less importance in low populated areas. The current technical solutions for delivery robots are based on Industry 4.0 concepts so they need to get access to internet and other broadband networks to deploy their full potential. Here countries like Bulgaria have to invest more in the IT infrastructure in rural areas to be able to benefit from the new technologies. But besides technical infrastructure requirements the use of delivery robots has to be accompanied by corresponding regulatory framework which is currently under development and which must be implemented in each country.

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