Virtual ITS European Congress, 9-10 November 2020

Paper number ITS-2166

Towards a uniform process model for deploying and operating autonomous shuttles on public roads

Karl Rehrl[1*], Thomas Piribauer[2], Klemens Schwieger[3], Norbert Sedlacek[4], Patrick Weissensteiner[5]

1. Salzburg Research, Austria, karl.rehrl@salzburgresearch.at
2. Prisma solutions, Austria
3. HERRY Consult, Austria
4. Austrian Institute of Technology, Austria
5. Virtual Vehicle Research, Austria

Abstract

Autonomous shuttle trials are carried out all over the world. So far, these trials are predominately based on trial and error approaches. During the last years, shuttle suppliers have developed their proprietary deployment and operation processes, whereas a more generalized process model is missing so far. In the Digibus® Austria flagship project, a consortium of 13 partners joined forces to develop methods and technologies for deploying and operating autonomous shuttles in public transport. Among other goals, the project aims at the definition of a generalized process model for autonomous shuttle trials, building on existing models as well as individual learnings. The proposed model consists of actors, components, decisions and activities and has been tested in the context of several shuttle trials in Austria. Although the process model so far only reflects the state in Austria, most activities should be applicable to other countries as well. The model is considered as a first step towards future standardization.

Keywords:

autonomous shuttles, deployment and operation, process model

Introduction

During the last years, autonomous shuttles have been trialled in different countries all over the world (Guala *et al.* 2015, PostAuto 2016, SOHJOA 2016, Hunsicker *et al.* 2017). Before an autonomous shuttle trial can be started, a comprehensive list of preparatory activities has to be executed. So far, each coordinator of a shuttle trial has to define a suitable procedure, predominately being based on trial and error approaches. To optimize the process, shuttle suppliers have developed their own deployment and operation process models. In parallel, public authorities issued exceptional regulations (BMVIT 2016), however, due to the rapidly evolving technology in most cases without clear validation, evaluation and approval procedures. With more and more trials in diverse environments and with the increase of automation levels, public authorities (e.g. road or transport authorities) have to prepare for a stronger supervision of the deployment and operation process in alignment with international, national or local regulations. If public authorities have to take over the role of issuing test or operation permissions for autonomous shuttles, they have to rely on standardized validation and approval procedures. The generalization from existing deployment procedures for a future standardization is a necessary step with respect to the further development of autonomous shuttles. Despite different exceptional regulations in different countries (or even in different federal states of the same country), a generalization seems feasible.

In the Austrian flagship project Digibus® Austria, a consortium of 13 partners under the coordination of Salzburg Research has joined forces to develop methodologies and technologies for deploying and operating autonomous shuttles on public roads being fully integrated into the public transportation system. Among other goals, the consortium works towards a generalization of deployment and operation procedures for autonomous shuttles. The work partly builds on existing deployment and operation procedures of the shuttle supplier EasyMile (consortium partner) and tries to generalize the proprietary procedures to a uniform process model with clear phases, activities and decision points. In order to cope with varying regulations in different countries as well as the fast evolving technology, the general process model provides anchor points for considering national or regional regulations as well as the integration of more specific sub-models for single process activities such as risk analysis or high-definition mapping of the road environment as examples. Besides proposing the model, the work also discusses experiences from applying the model to different shuttle trials in Austria.

Process model

According to literature, a process model is a precise description of activities that have to be executed by some actors in a defined order for achieving a specific goal (McDonald 2018). Each activity of the process model consists of specific sub-activities and decisions. The method for building a process model is called process engineering (Rolland 1998). The proposed process model has been engineered by taking into account the proprietary EasyMile process and by generalizing the learnings from individual shuttle trials. For describing the model, we introduce the following concepts: *Actors*, *Components, Decisions* and *Activities.*

Actors

Actors are legal entities (more specifically the persons representing the legal entities) that are executing the different activities of the process model. We identified the following actors:

- **Coordinator**: The trial coordinator is typically a staff member of a transport operator, a research organization or any other legal entity being responsible for coordinating the trial.
- **Public authorities**: As public authorities, we consider representatives of national or local authorities such as transport authorities, road authorities or local administrations (e.g. municipalities or cities).
- **Shuttle supplier**: The company supplying the shuttle.
- **Deployment engineer**: An engineer being responsible for deploying the shuttle on the track.

This person can be a staff member of the shuttle supplier or another person being trained to do the deployment.

- **Vehicle Operator(s)**: Vehicle operator(s) is/are typically staff member(s) of a transport operator or any other legal entity being responsible for operating the shuttle during the trial.
- **General public**: The general public are all persons being not directly involved in the trial.

Components

As components, we describe the constituent parts of a shuttle trial. We consider the following five components as relevant:

- **Shuttle**: The autonomous shuttle should at least provide autonomy on SAE level 3. It consists of the (1) vehicle, (2) sensors, (3) the autonomous driving software, (4) systems for passenger information, (5) intercom system for communicating with a control centre.
- **Service**: The mobility service that should be provided to the passengers. This includes the (1) service mode, (2) timetable, (3) integration into the public transport system.
- **Physical infrastructure**: The physical infrastructure being necessary to operate the autonomous shuttle. The physical infrastructure includes: (1) road, (2) road environment, (3) stops (including a communication system at the stops if necessary), (4) turn areas, (5) parking and (6) charging facility.
- **Digital infrastructure**: The digital infrastructure for operating the autonomous shuttle. This includes: (1) high definition map of the road environment, (2) 3G/4G/5G mobile network, (3) RTK service, (4) control centre.
- **Permissions**: Any permissions being necessary to operate the shuttle on a dedicated route.

Decisions

Decisions are dedicated points in the process model, where some constraints have to be met in order to proceed with activities. Decisions may lead to a stop of the overall process, e.g. if a check during the process fails, or decisions may influence consecutive activities.

Activities

The process model consists of consecutive activities that have to be executed by the different actors in order to reach the overall goal. We propose seven main activities being organized in four phases (start, preparation, deployment, operation), which we recommend to be executed for each autonomous shuttle trial. The following sub-sections list the main activities with their sub-activities.

1. **Feasibility Check**: The first activity during the *start phase* aims at checking the overall feasibility of the trial. This activity includes the following sub-activities:
    a. Definition of the planned mobility service (mode of operation, operation times, need and availability of operation staff)
    b. Getting commitments of all relevant stakeholders (transport operator, transport authority, transport association, regional government, city or municipality)
    c. A first check of the existing physical and digital infrastructure (private or public road,

route options, physical and digital constraints, parking and charging facilities)

d. A vehicle market survey being based on a vehicle requirements specification
e. Vehicle availability and costs
f. Necessity of permissions (e.g. checking with authorities)

This activity ends with a feasibility estimation and the decision to proceed towards a more detailed planning or to stop the trial. This activity should be completed within one month.

2. **Planning**: Given a positive feasibility decision, the second activity during the start phase is to carefully plan the trial. This activity is composed of the following sub-activities:
    a. Definition of a detailed trial plan including a schedule and milestones
    b. Definition of responsibilities (e.g. who is responsible for what)
    c. Definition of constraints (e.g. what are the constraints to conduct the trial successfully)
    d. Detailed cost estimation (investment and operation costs)
    e. Establishment of a risk contingency plan (e.g. what are the risks during the trial and how can these risks be mitigated)
    f. Signing a trial contract (e.g. between the trial coordinator and the financing body or as internal assignment within the trial coordinator).

    This activity ends with a thorough plan and a signed contract to start the trial and can typically be executed in 1-3 months.

3. **Risk Assessment**: After a signed contract, the preparation phase can be started. The first activity of the preparatory phase is a thorough risk assessment. This activity is also an anchor point for plugging in standardized risk assessment models. This activity may be further split up into the following sub-activities:
    a. Applying a risk assessment procedure (if possible according to a standardized risk assessment methodology
    b. Requesting external expert opinions (if the contractor does not have the expertise or if requested by the national or local authorities)
    c. Simulation of driving manoeuvres at risky route sections in order to further assess risk or develop suitable mitigation or minimization measures.
    d. Generation of a risk assessment report including expected severity and probability of occurrence of risks together with proposed risk mitigation or minimization measures (see Figure 2)

    This activity ends with a risk assessment report containing risk mitigation measures, if necessary. According to the complexity of the route, this activity will take between 1-3 months.

4. **Preparation**: After a positive risk assessment, the next activity is concerned with the trial preparation. This activity consists of the following sub-activities:
    a. Getting necessary permissions from responsible authorities (i.e. test license, vehicle approval or exceptions from certain regulations, permissions to use parking &

charging infrastructure)

   b. Shuttle procurement including tendering, contracting, delivery and insurance
   c. Definition of the planned mobility service including timetables, passenger information, passenger interaction and emergency plans
   d. Citizen dialog and public relations (i.e. initiating a citizen dialog about the planned service and informing the general public)

   This activity ends with the confirmation that all necessary permissions have been issued for continuing the process. Depending on national or regional regulations, this activity may take 2-9 months.

5. **Deployment**: The third phase aims at establishing the shuttle service on the selected route. The deployment activity includes the following four sub-activities:
   a. Adaptations of the physical infrastructure (if necessary depending on the results of the risk assessment)
   b. Setup of the digital infrastructure (i.e. high definition map, mobile network, RTK subscription, V2X)
   c. Shuttle setup (e.g. tracks, driving parameters, passenger information)
   d. Integration of the shuttle into the public transport system (i.e. passenger information in the shuttle and at the stations, journey planning, booking, ticketing, vehicle monitoring via control centre)

   At the end of this activity, the service is ready for operation. The deployment activity typically can be completed in one month.

6. **Validation and Approval**: The shuttle deployment should be completed by a validation and approval activity under the supervision of the responsible transport authority. At the current stage, this activity often gets skipped or has informal nature, since official validation and approval procedures for autonomous shuttles are not in place. Some countries have developed their own approval procedures, but these are not standardized yet. In the future, as soon as accepted validation and approval procedures exist, this activity acts as anchor point to plug in the corresponding validation and approval procedures. A combination with issuing a test or operational license may be envisaged. Currently, this activity can be completed within one day, however, in the future, depending on more sophisticated validation and approval procedures, it might take longer.

7. **Operation**: The last activity has to be executed day-by-day by the shuttle operator (as long as an operator has to be in the shuttle) or the remote supervision team (if the shuttle is supervised remotely) during the operation phase. The operation activity is structured in three sub-activities:
   a. Pre-operation (i.e. checking environmental constraints such as weather conditions, driving the shuttle from the parking to the start point, checking operational safety of the shuttle, doing a test run in autonomous mode, confirming operation readiness)
   b. Operation (i.e. executing the planned service in autonomous mode, taking over

manual control if the shuttle exceeds its capabilities, providing passenger information, answering passenger requests, monitoring of vehicle state and drive data, managing incidents and emergencies)

c. Post-operation (i.e. driving the shuttle back to the parking, initiating charging, documenting operation, initiating cleaning and maintenance).

During the pre-operation activity, it has to be decided for each operation day whether a safe operation is possible given environmental constraints and operational safety of the shuttle. These constraints have to be met during the whole operation phase, otherwise operation has to be stopped immediately.

The overall process model is visualized in Figure 1. Given the indicated time spans for each activity, the duration for the whole process from start to operation ranges between 6 months (our experience in Austria) and 18 months (e.g. in countries where getting a permission takes considerably longer).

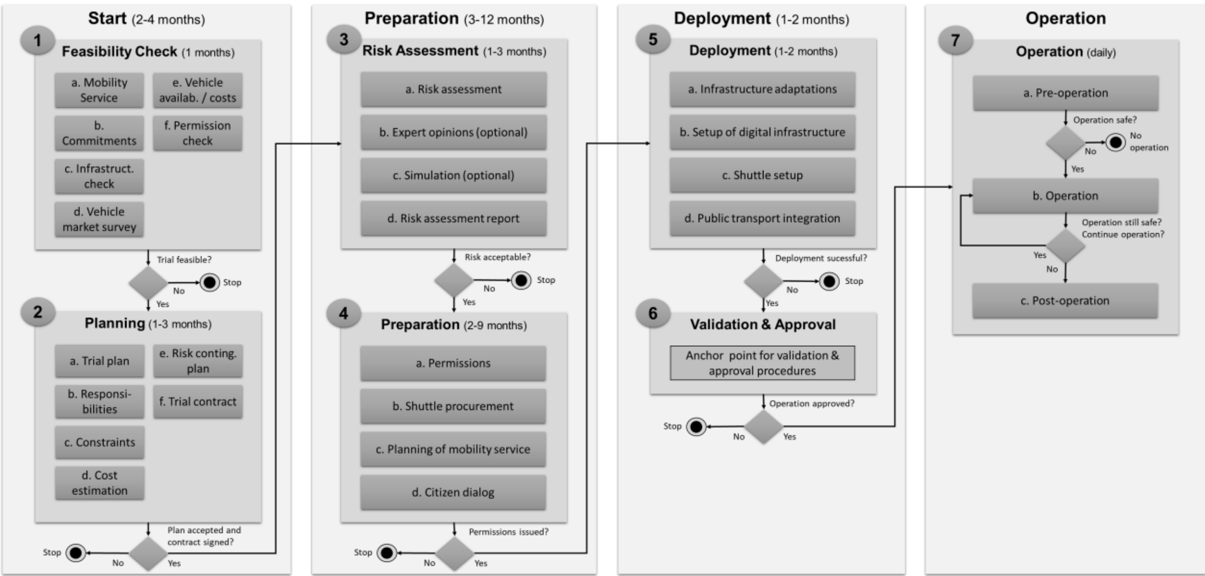

Figure 1 – Visualization of the model including all activities, sub-activities and decisions with estimated minimal and maximal durations

Experiences: Best practices and potential pitfalls

In this section, we describe our experiences from applying the process model to several shuttle trials in Austria we conducted between 2017 and 2020. Due to page limitations, we focus on the most relevant findings that should be useful for upcoming trials in other countries as well.

Feasibility Check

We consider this activity as crucial since it allows an early estimation of the feasibility without causing high costs. Besides specifying the planned service, it is strongly suggested to involve all relevant stakeholders as early as possible. A successful trial can only be achieved with the full commitment of stakeholders. If the trial is conducted in an unknown region, it can be necessary to first identify the responsible authorities on local (i.e. city or municipality), regional (i.e. road authority, transport association) and national (i.e. national transport authority, contact point) level. Another important sub-activity is the check of the infrastructure. Beside the decision whether the trial runs on a private or public road, it is of outstanding importance to do a first check of the physical and digital infrastructure (distance to garage, charging infrastructure, safe stops and turn places, junctions with or without traffic lights, pedestrian crossing, bicycle infrastructure, lanes, on-street parking, speed limits, traffic volumes, inclines, environmental constraints along the road, mobile network coverage). It is strongly suggested to do an on-site inspection with picture or video documentation and to create a first sketch map of the route options with the most relevant physical and digital parameters.

The last important sub-activity during the first phase is the feasibility estimation where all results of previous activities are summarized. In some cases, the feasibility estimation will reveal, that given the current technological readiness level (TRL), the planned route is not suited to be used for an autonomous shuttle trial. In this case, this early decision point should allow to rethink the trial and to switch to another (private) route or to stop the whole process. The most common pitfalls why a planned shuttle trial has to be stopped at this stage are:

- some stakeholders are sceptical and refuse to support the trial
- too less preparation time
- too high costs
- insufficient vehicle capabilities
- missing vehicle availability
- missing or too distant parking or charging infrastructure
- too narrow road
- missing or unsafe turn areas
- too high traffic loads, potentially also concerning pedestrians
- too high speeds of other vehicles

Planning

Before starting trial preparations, it is useful if all involved stakeholders agree on a detailed plan for the trial. This plan has to contain a thorough schedule including responsibilities, milestones and a realistic cost estimation. So far, due to the overall complexity, autonomous shuttle trials induce rather high costs. In many cases, the contracting bodies do not expect such high costs. Therefore, a realistic cost estimation can help avoiding wrong expectations.

Another recommendation is to define a risk contingency plan since unexpected risks may arise throughout the whole project. In most cases, the assignment will also include contracts, e.g. between a trial coordinator and financing body or between the trial coordinator and the shuttle supplier. Sometimes also additional contracts between further parties will be necessary (e.g. for carrying out some sub-activities).

Risk Assessment

One of the most important activities during the preparation phase of a shuttle trial is the risk assessment activity. So far, each shuttle supplier uses its own risk assessment procedures while a common approach is missing. This may result in different risk assessment reports for the same route, depending on the shuttle supplier, which is not the intended goal of a uniform risk assessment methodology. Therefore, a more standardized methodology is needed. In the Digibus® Austria project, the project partner Austrian Institute of Technology (AIT) contributes to this question and proposed a first version of a uniform risk assessment methodology taking the methods of shuttle suppliers but also national risk assessment standards into account. The risk analysis is executed for each road section (see Figure 2) and estimates the maximum risk for each section.

Category	Maximum risk potential
Road layout and visibility	5
Road equipment	4
Signs, signals and roadmarkings visibility, quality and implementation	4
Road lighting	-
Road condition and maintenance	4
Environmental influences	-
Roadside hazards	4
Maximum total risk	**5**

Figure 2 – An example result of the uniform risk assessment methodology

If the route contains complex driving situations, the proposed uniform risk assessment methodology may identify critical spots on the planned route of the autonomous shuttle. These spots are candidates for further investigation via simulation. In Digibus® Austria, the partner Virtual Vehicle Research (ViF) works on the simulation part by simulating the behaviour of the autonomous shuttle in certain driving manoeuvres, which should be executed for spot locations with identified high risks on the planned route. Before the identified situations can be virtually assessed, the virtual world, together with the virtual model of the autonomous shuttle needs to be modelled.

The virtual world can be split up into a static and dynamic environment. The most important part of the static environment is the road layout, which is derived from high-density LIDAR point cloud measurements and modelled in the OpenDRIVE© format[1]. Additionally, certain elements of the

[1] http://www.opendrive.org/index.html

surrounding environment have to be included as well, if they could influence the shuttle behaviour. Most importantly, this includes buildings, trees and hedges in the area of the identified critical spot. The OpenDRIVE© file also defines the underlying logic of the road layout, which enables the enhancement of the virtual world with a dynamic environment. This represents road users like cars and pedestrians, which can be used to model typical situations the autonomous shuttle encounters during a specific driving manoeuvre.

The virtual model of the autonomous shuttle must display the driving dynamics accordingly, as well as the respective sensor setup of the shuttle and the respective driving functions. This also includes the correct positioning of the sensors on the shuttle. As example, Figure 3 visualizes parts of the virtual world along one of our test routes, together with the autonomous shuttle acting in an village environment, including other traffic participants. Varying the respective actors in the simulation environment may lead to measures regarding changes to the current sensor setup or changes to the infrastructure (speed limit, traffic lights, stop signs, …) to safely handle the necessary driving manoeuvres.

Figure 3 – Simulated complex driving scenario in the context of a test route

The risk assessment activity ends with a risk assessment report including not only the estimated risk for driving the route in autonomous mode, but also potential measures to mitigate or minimize risks. For the routes considered in the Digibus® Austria project, the risk assessment revealed quite high risks for many parts (grade 4 or 5 given a 5-grades scale where 1 is the lowest and 5 is the highest risk). Given the current state of technology, we consider this result as a confirmation of the methodology since all autonomous rides within the project are considered trials and for trials a higher risk is acceptable. Nevertheless, on the one hand, knowing the risk eases the communication with the transport authorities and on the other hand establishes a basis for benchmarking further developments.

Preparation

After a positive risk assessment, the preparation of the trial can start. One of the most challenging activities during this phase is the acquisition of all necessary permissions. In Austria, a national regulation for conducting shuttle trials, the so called Automated Driving Regulation – AutomatFahrV (BMVIT 2016), is in force, which defines the rules for getting a test permission. Moreover, a National

Contact Point for Automated Mobility has been established at AustriaTech[2] that can be contacted at any time during the whole application process for answering questions. The contact point also acts as interface to the transport authority being responsible for issuing the test permission. Nevertheless, although the procedure is well documented, the trial coordinator has to provide numerous documents such as vehicle specifications, an insurance certificate, a certificate that the service operator and the vehicle are qualified to get trial number plates, certificates that the vehicle operators are qualified and trained to act as operators, confirmation that the responsible local road authority has been informed about the trials and has no formal objection. Besides the test permission from the national transport authority, additional permissions from the local road authorities may be necessary, e.g. exceptional permissions to operate the shuttle in a pedestrian zone or issuing a speed limit along the test track. Typically, before issuing these permissions, the road authorities will initiate a local negotiation including a site inspection with all relevant stakeholders. Experiences reveal that the existence of a national contact point eases the whole process. Nevertheless, the trial coordinator has to care for negotiations with the local authorities. A close cooperation with all stakeholders from the beginning as well as a political support concerning the trials is essential in order to be successful.
Another important activity during the preparation phase is the citizen dialog and public relation work. It has to be considered that not all citizens are open-minded concerning autonomous shuttle trials and therefore it is necessary to establish an accompanying citizen dialog. From our experience, this can be best achieved by involving representatives of the municipality or city (e.g. the major) and/or representatives of established local associations (e.g. transport association, association of elderly people). At the end of the preparation phase, before the deployment starts, all necessary permissions should have been issued, otherwise the deployment may not be started.

Deployment

The deployment includes activities to adapt the physical environments (according to the adaptation measures proposed by the risk assessment), to setup the digital environment and the shuttle. So far, the deployment is typically under the responsibility of the shuttle supplier being conducted by trained deployment engineers. Consequently, the deployment procedures vary from supplier to supplier without being standardized. If an autonomous shuttle from another supplier should be deployed on the same route, a new deployment has to be accomplished. There is an urgent need to generalize and standardize the deployment procedure. Since a standardized deployment model does not exist so far, the overall process model provides an anchor point to plug in a generalized process model in the future. In Digibus® Austria, consortium partners work towards a uniform process chain for generating the high definition digital map (Figure 4). A first version of this process chain has been trialled in 2019. The goal is to work towards a standardized description of the high definition digital map based on OpenDRIVE©, respectively the Lanelet2 model (Poggenhans *et al.* 2018), which can be used for simulation as well as for driving and is independent of the shuttle provider.

[2] https://www.austriatech.at/en/contact-point-automated-mobility/

Figure 4 – Uniform process chain for generating the high definition digital map

The deployment also includes the operator training for the shuttle, e.g. operators have to learn how to operate the shuttle, how to drive in manual mode and how to react to certain operational states of the shuttle. Moreover, the operators should be trained how to handle abnormal behaviours, incidents or emergency cases. Today, the deployment activity ends with several test drives in autonomous modes along the test route and with the confirmation from the shuttle supplier that the deployment is finished and the shuttle is ready for operation in autonomous mode. In the future, a more formal validation and approval procedure should be established (see next activity).

Validation and Approval

We have decided to define validation and approval as an own activity in the process model, although this activity is missing in todays' deployments. It is upon the shuttle supplier and the trial coordinator to agree, when the deployment is considered finished and the shuttle can be safely operated. To get to this decision, the deployment parameters (e.g. trajectory, stops, speed, driving behaviour, stops at junctions) are set following a trial and error approach as long as a satisfying level is reached and all constraints are sufficiently considered. Currently, there is no defined validation and approval procedure. In the future, when autonomous shuttles become a common part of public transport systems, we consider the validation and approval as a crucial activity for service operators as well as public authorities (transport and road authorities) for getting or issuing an operation permission. Such a permission will be necessary in order to ensure a safe operation while adhering to all legal constraints. However, validation and approval procedures have to be developed on an international level.

Operation

If the deployment is finished (and in the future, it is also validated and approved), the operation of the autonomous shuttle can be started. The operation activity has to be repeated day-by-day for all operation days. From our experiences, every operation day reveals new situations (e.g. due to changing weather or physical environment). Thus, it is of crucial importance for the operational stuff to check operational safety during the pre-operation activity according to a safety checklist. At the end of the safety check, a test run in autonomous mode without passengers has to be performed. If every point on the safety checklist has been successfully confirmed, the shuttle is ready for operation. During operation, it is essential that the shuttle itself monitors the healthiness of all sensor systems. In case of a malfunction, the operation has to be immediately stopped.

Another important sub-activity is the documentation of test drives. Many autonomous driving test regulations, such as the AutomatFahrV in Austria, require the documentation of test drives. For doing so, we suggest a twin-strategy: On the one hand, we recommend an automatic collection of drive data. This can be accomplished via an API being provided by the shuttle supplier. On the other hand, we recommend to document context parameters as well as special events directly by the operation team, e.g. weather conditions, malfunction of the vehicle or challenging driving situations. This documentation can be done via a web-based questionnaire on a mobile device.

Conclusions

With the proposal of a process model for autonomous shuttle trials we pursue a first step towards generalization. Our practical experiences show that such a step-by-step model can be very helpful, especially for trial coordinators setting up a trial for the first time and having no experiences. So far, the process model only incorporates experiences from shuttle trials in Austria, but we tried to generalize the activities so that many activities will be applicable to trials in other countries as well. Moreover, the process model provides anchor points where specific models or national regulations can be plugged in.

Concerning the future development of the process model, we see several research directions: A first direction is to use the model for the setup and operation of shuttle trials in other countries in order to gain further experiences concerning the overall methodology or certain activities. For instance, it should be evaluated, whether the provided anchor points are sufficient and are able to comply with national regulations. A second direction is concerned with the development of more specific models for certain activities of the overall process model. For example, specific procedures can be developed to further specifying the deployment or validation and approval activities. A third direction concerns the further development of the model itself. With increasing driving capabilities of autonomous shuttles, the process model should be continuously evaluated whether it is still valid or it has to be adapted to new constraints. This requires an ongoing process.

Acknowledgements

The flagship project Digibus® Austria gets funding from the Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) as part of the “Mobility of the Future” programme.

References

1. BMVIT, 2016. Verordnung des Bundesministers für Verkehr, Innovation und Technologie über Rahmenbedingungen für automatisiertes Fahren (Automatisiertes Fahren Verordnung – AutomatFahrV) [online]. Available from: https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=20009740 [Accessed 4 Sep 2020].

2. Guala, L., Alessandrini, A., Sechi, F., Site, P.D., Holguin, C., and Salucci, M.V., 2015. Testing Autonomous Driving Vehicles in a Mixed Environment with Pedestrians and Bicycles.
3. Hunsicker, F., Knie, A., Lobenberg, G., Lohrmann, D., Meier, U., Nordhoff, S., and Pfeiffer, S., 2017. Erfahrungsbericht: Pilotbetrieb mit autonomen Shuttles auf dem Berliner EUREF-Campus. *Internationales Verkehrswesen*, 69 (3), 56–59.
4. McDonald, K., 2018. Process Models [online]. *KBP.Media*. Available from: https://www.kbp.media/process-model/ [Accessed 4 Sep 2020].
5. Poggenhans, F., Pauls, J.-H., Janosovits, J., Orf, S., Naumann, M., Kuhnt, F., and Mayr, M., 2018. Lanelet2: A high-definition map framework for the future of automated driving. *In*: *2018 21st International Conference on Intelligent Transportation Systems (ITSC)*. 1672–1679.
6. PostAuto, 2016. SmartShuttle [online]. Available from: https://www.postauto.ch/de/smartshuttle [Accessed 4 Sep 2020].
7. Rolland, C., 1998. A comprehensive view of process engineering. Springer, Berlin, Heidelberg, 1–24.
8. SOHJOA, 2016. SOHJOA Robot Bus Project [online]. Available from: http://sohjoa.fi/ [Accessed 4 Sep 2020].