A Target Enterprise Architecture Approach for New Mobility Services in Demand-Responsive Public Transport

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Abstract

Demand-responsive public transport, such as new mobility solutions (NMS), like car sharing, urban bikes or e-scooters, have become increasingly popular in big cities. NMS have started to influence the way people move in urban areas, but they are also expected to impact public transport operators and especially their IT landscape. The purpose of this paper is to present and evaluate this issue from a first enterprise architecture (EA) as a target/reference architecture based on ArchiMate (V.3.1). Although EA management is recognised as relevant for public transport companies, there is a lack of an overall architecture fulfilling requirements of needs-oriented local public transport (especially NMS). The purpose of the research and in particular of this paper is to contribute to this area by (a) highlighting the strategic necessity including the required capabilities, (b) presenting a first target architecture and (c) concretising it in a section using the example of the area of planning and resource deployment.

Keywords

enterprise architecture, new mobility services, public transportation, reference architecture, target architecture, demand-responsive traffic, supply-oriented traffic, supply-oriented public transport, demand-oriented public transport

1. Introduction

New or innovative mobility services (NMS) are becoming increasingly popular in cities and metropolitan areas. These include, for example, sharing services, such as car, bike or e-scooter sharing, or on-demand ridesharing services, such as on-demand shared taxis, as well as many other mobility solutions offered in larger cities in pay-as-you-go or subscription models. This influences the way people move within short -last mile- and medium distances in urban areas [1]. These so-called New Mobility Services (NMS) have been the subject of research, e.g. in terms of new architectures [2], business models [3], platforms [4] acceptance by end users [1] or required standards. However, the way new mobility solutions affect public transport companies and in particular the architecture of a company has hardly been researched so far.

Work presented in this paper continues previous research of the authors reflected in three publications. In these publications, we have:

1. Defined the problem under investigation and demonstrated the need for the integration of New Mobility Services (NMS) - demand-responsive local passenger transport - into the enterprise architecture of traditional transport companies [5]. This elaboration had included a literature review.
2. Explored initial enterprise architecture implications in the development and integration of NMSs into traditional transport operations via the use of a reference architecture (ITVU)2 [6].

BIR 2022 Workshops and Doctoral Consortium, 21st International Conference on Perspectives in Business Informatics Research (BIR 2022), September 20-23, 2022, Rostock, Germany
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3. Investigated and evaluated the feasibility of integrating this into certain parts of the enterprise architecture on the basis of existing architectural approaches of classic public transport companies. [7], using the example of an on-demand ridesharing service offered by the largest German public transport company.

The publications above follow the design science approach in the course of a PhD project.
The aim of this publication is to demonstrate the integration of demand-responsive transport into classic public transport companies on the basis of existing architectural approaches (e.g., ITVU core model) and to concretise it in a newly developed reference architecture. In this context, the new enterprise architecture in the area of traffic planning is presented in excerpts in this work with regard to changes and extensions for the integration of demand-oriented traffic.

The primarily used ITVU core model is a recognised reference model in the German-speaking public transport sector. The architectural approaches were identified in a literature review at [5] and were used to create the new architecture during modelling. This empirical approach deals with:

a. the consideration of the connections between the strategic and motivational levels.
b. a modern target architecture at the business and application level.
c. the link between the strategic and motivational level (a.) and the business/application level (b.).

Following the presentation of the created artefact, a first evaluation according to uniform quality characteristics is carried out. In future work, the artefact will be evaluated by experts so that it can be optimised further.

2. Research approach and delimitation

The working paper presented in this seminar is part of a research programme that investigates methodological and instrumental support in the form of a reference or target architecture for the integration of demand-responsive public transport, such as New Mobilitiy Services (NMS) into classic supply-oriented public transport companies. This programme follows the paradigm of design science research [8].

This study concerns the explication of the problem and the creation of a design artefact: EA method support for the integration of demand responsive public transport especially NMS including tool support. The part of our research presented in this paper started from the following research question based on the motivation presented in section 1: RQ: What does a reference architecture or target architecture that integrates demand responsive transport into a traditional public transport company look like?

The research method used to answer this research question is a combination of literature review and conceptual-deductive work. Starting from the (already outdated) ITVU core model [9, 10] which is a de facto industry standard for supply-oriented local passenger transport, further literature, such as the VDV publication 7046 - User requirements for an open mobility platform [11] and expert publications, e.g. [12], [13] and [14] were used.

Added to this is the expertise of the first author who worked in the field for more than 10 years, which forms the basis of the conceptual-deductive work. The extended reference/target architecture was modelled on the basis of ArchiMate. The aim of this work is not to compare the old and new architectures, but to model and present an extension of the old architecture. One challenge in the creation of this new Enterprise Architecture (EA) was to consolidate the various approaches in different modelling forms and to model them anew and extended in ArchiMate.

The work concentrates on the administration-oriented areas of the provision of services by public transport companies. The focus is on the interaction between the specialised departments and the use of IT. In this paper, the most important components of an overall architecture were presented first. Based on this, we examine the area of transport planning

The modern reference/target architecture was modelled with ArchiMate and is presented in the following sections.

Based on the results from the extended enterprise architecture, we argue that an integration of demand-driven transport (esp. NMS) -based on the strategic requirement- is efficiently possible on the basis of a reference/target architecture.

3. Target enterprise architecture of a public transport company

Based on the results from [7], an initial consideration of the demand-responsive NMS BerlKönig (Berlin's taxi-based service) and the resulting requirements for a demand-responsive local transport system was prepared. Based on this, this section (especially subsections 1 and 2) concentrates on the presentation of the components of a reference/target architecture that integrates a demand-responsive local passenger transport (or NMS) into a classically oriented public transport company. In the third section (3) of this section, the modelled reference/target architecture (EA) is present-ed as an example based on a selected process (transport planning).

In the last section (3.4), the sub-architectures (strategic/operational) created in 1 and 2 are linked to check whether the capabilities are supported by the operational sub-architecture.

3.1. Strategic consideration of demand-responsive transport in the context of classic public transport companies

In this section, the strategic connections, such as the capabilities and control of resources, which a classic public transport company must fulfil if it wants to integrate demand-oriented transport into its organisation, are presented. The strategic view is flanked by the motivation level, which connects and maps requirements, results, end states and changes of the organisation with the responsible stakeholders of the organisation.

With this view of the goal architecture, a better understanding of the connection between the strategic level and the motivational level is created.

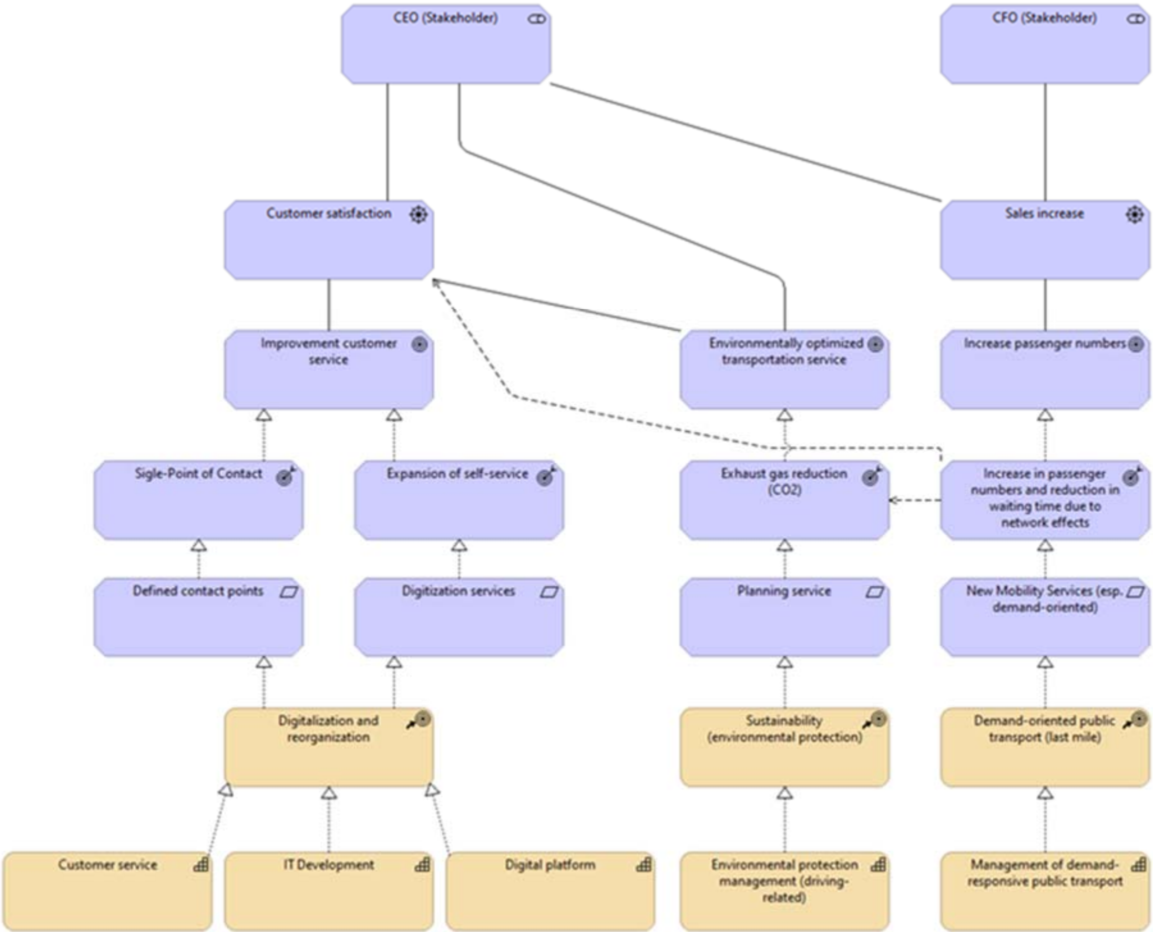

Figure 1: Strategic consideration of demand-oriented local passenger transport - especially NMS - in classic public transport companies, Source: own illustration.

In Figure 1, the lowest level shows the skills that a modern public transport company must have in order to be able to offer demand-responsive transport. In addition to the skills that a classic public transport company needs as well, such as customer service and IT development, there are skills such as digital platforms and the management of demand-oriented local passenger transport. In addition, there is (nowadays) the ability to conduct driving-related environmental protection management. In Germany, environmental protection is embedded in the statutes of all public transport companies and must be taken into account.

Figure 1 further illustrates how capabilities affect the requirements that a corresponding enterprise must realise through the control of resources. The implementation of the requirements leads to a result, which brings about the fulfilment of an end state. This end state changes the organisation, which in turn is desired or respectively must be accepted by stakeholders.

In this context, it should be emphasised that the ability to manage demand-responsive public transport opens up the possibility of serving customers on the last mile. This increases the number of customers and ensures shorter waiting times through better connection options. The improved utilisation of means of transport and the increase in the number of customers leads in total to a reduction of exhaust gases within the area of operation of the public transport company. Customer satisfaction increases due to improved connections and the environmentally friendly transport service. In addition, turnover increases due to increased demand. These drivers pay into the goals of the respective stakeholders CIO and CFO.

3.2. Consideration of the business/application level

In this section, we consider the relationship between the processes and the respective roles/actors that a public transport company must have in place for the provision of driving services, as well as at the application level.

The arrangement of the process elements within this architecture artefact follows the usual representation of (value-added) processes, according to which the processes are arranged by input to output from left to right.

Figure 2: Process structure of the reference/target architecture, Source: Own representation

All further element types of this architectural representation are oriented towards this. In order to develop a modern architecture that can be adapted to the new challenges, the following two approaches were considered for the implementation of the artefact:

1. Service-oriented architecture approach at business and application level to increase the flexibility of the organisation, and
2. Central communication between the components with the help of an enter-prise service bus on the application side, which standardises and technically channels the communication.

Figure 3 shows the overall architecture with the business and application levels. In this context, the required data objects were assigned to the applications and explained in more detail.

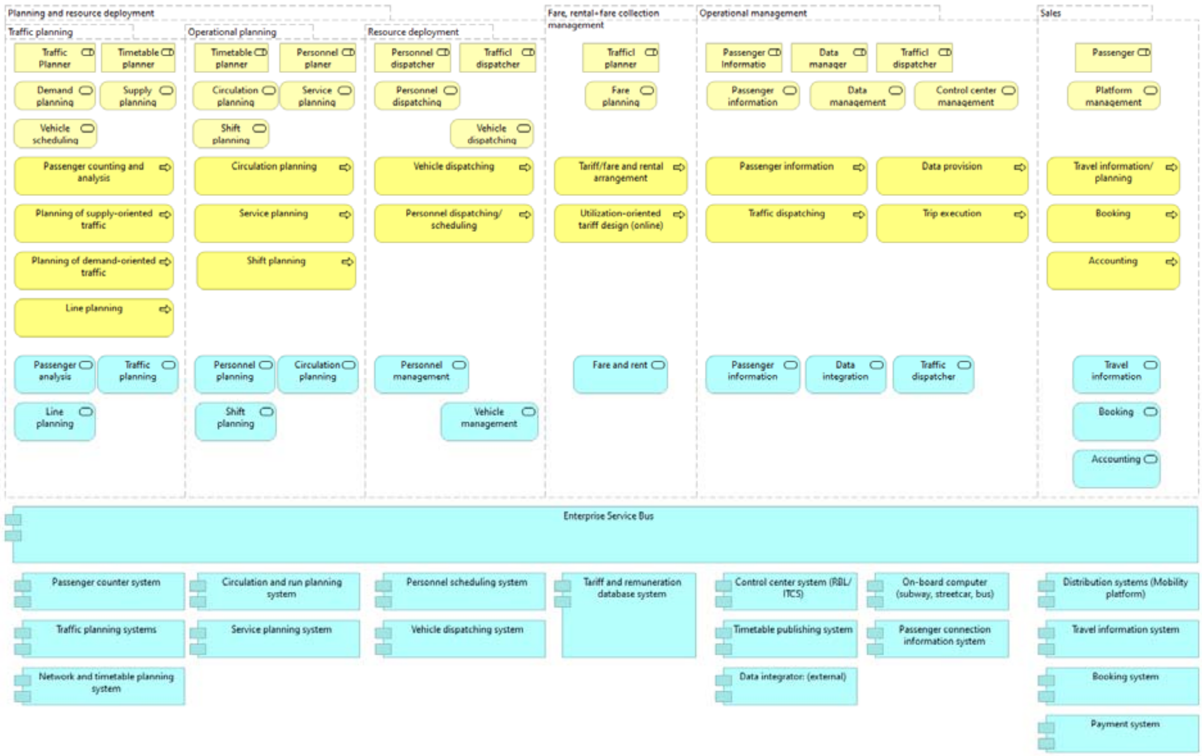

Figure 3: Components of a reference/target architecture of a public transport company with demand-oriented NMS. Source: own illustration.

The architecture presented here is structurally divided into the executive business roles, services and processes as well as the application services and applications. As presented at the beginning of the section, the EA is divided into the analysed process structure of public transport companies and thus into the following main areas:

- *Planning and use of resources*
  This area contains the planning components for service provision. Here, traffic is combined with operational planning and resource deployment. The goal is to create an integrated, interdependent traffic and operational planning for efficient service delivery.
- *Fare-/rental-fare collection management*
  Here, on the one hand, the supply-oriented planning results are transferred into products and tariffs and, on the other hand, the demand-oriented services are provided with rental prices or rental prices from ex-ternal service providers are consolidated and made available for billing.
- Operational management
  In operational management, the services are provided or their provision is supported by business services such as traffic dispatching, trip execution or passenger information.
- *Sales*
  This area includes the complete travel planning, booking and billing of the fare or rental. The central point of this customer-oriented area is a mobility platform that connects all forms of mobility - whether supply- or demand-oriented - of a public transport company with each other.

After the presentation of the architectural components of an architecture that fulfils the requirements, in the next section this work will exemplify the architecture in the area of "traffic planning" and the identified requirements that must be taken into account in the integration of demand-responsive traffic.

3.3. Architecture using the example of traffic planning

In this section, we present *traffic planning* in the context of an EA. The architectural parts shown are oriented towards the process sequence. In Figure 4, these parts are shown as a section of the overall architecture.

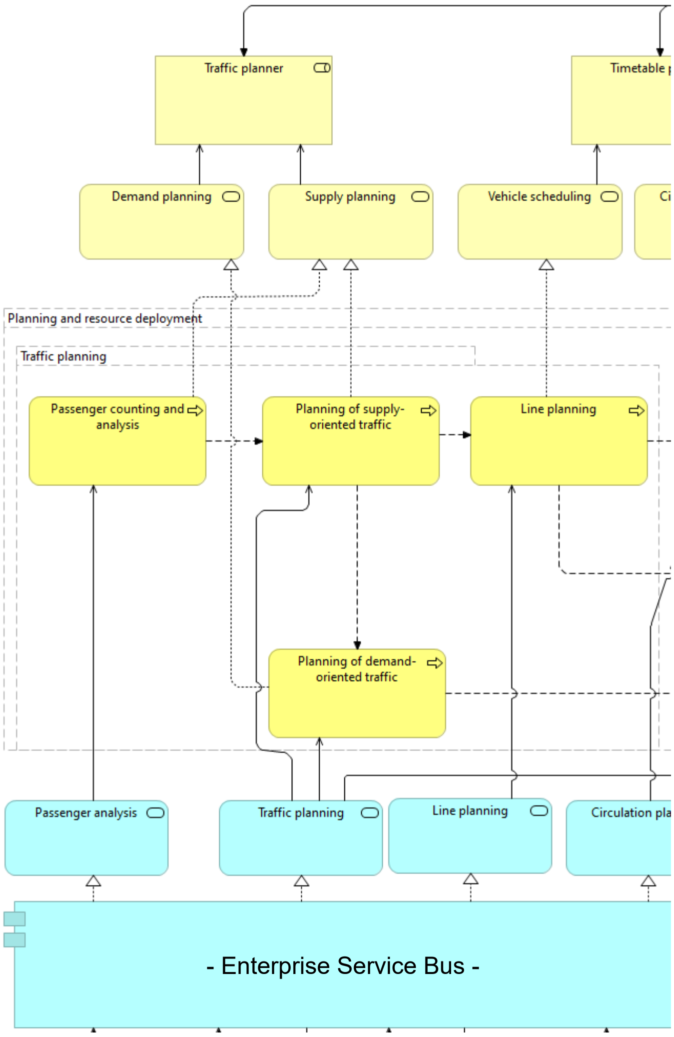

Figure 4: Traffic planning - section of the overall architecture. Source: own illustration.

The roles Traffic *Planner* and *Timetable Planner are* involved in *traffic planning*. They carry out the following process steps via the defined business services *Demand planning*, *Supply planning* and *Vehicle scheduling:*

a. *Passenger counting and analysis*
In this process step, the *passenger counting* and *passenger survey* activities are combined. The output (data on passenger numbers and flows) of this process is passed on to the following process step (b.).

b. *Planning of supply-oriented traffic*
This process step can be found in every classic public transport company. At this point, the traffic is planned on the basis of count data, traffic data (usually from the traffic office etc.) and e.g., holiday data.
The output of this step is processed traffic data that structures the demand for supply-oriented traffic (lines). In classical companies, this is followed by the process step *Line-planning* (d.). In public transport companies that have integrated demand-oriented traffic, the process *Planning of demand-oriented traffic* (c.) follows in parallel.

c. *Planning of demand-oriented traffic*
This step in the process implements the key requirements that a public transport company must fulfil in the planning area if it wants to integrate demand-responsive transport and manage it within its sphere of influence.
The output of this step is traffic data, such as the establishment of mobility hubs, such as stations (e.g., Jelbi stations in Berlin or hvv switch in Hamburg) where demand-oriented transport systems are made available for rent. In addition, neuralgic points that are important

for strengthening last mile transport are identified and noted for the provision of sharing services. This also includes the mobility hub mentioned above.

The subsequent process step *Shift planning* belongs to operational planning rather than transport planning.

d. *Line-planning*

Line planning shapes the supply-oriented traffic in the form of lines on the basis of the output of (b.). The output -planned lines- of this process is made available to the two processes of *vehicle scheduling* and *duty scheduling* in the operational planning area.

The processes relevant here are served by application services supported by an *enterprise service bus*. The corresponding applications that organise the functionality and data storage are accessible via the service bus. This fulfils the requirement for a flexible, decoupled modern enterprise architecture that offers the advantages described in 3.2.

3.4. Supporting the strategy (capabilities) through the operational architecture

This section examines to what extent the strategy is supported by the business and application level. This examination focuses on the demand-oriented transport con-text - but not on environmental protection, which was still taken into account in the motivation strategy.

The model shown in Figure 1 is used as the basis for this review. The following diagram shows which elements of the business support/fulfil the achievement of the overarching strategic capabilities:

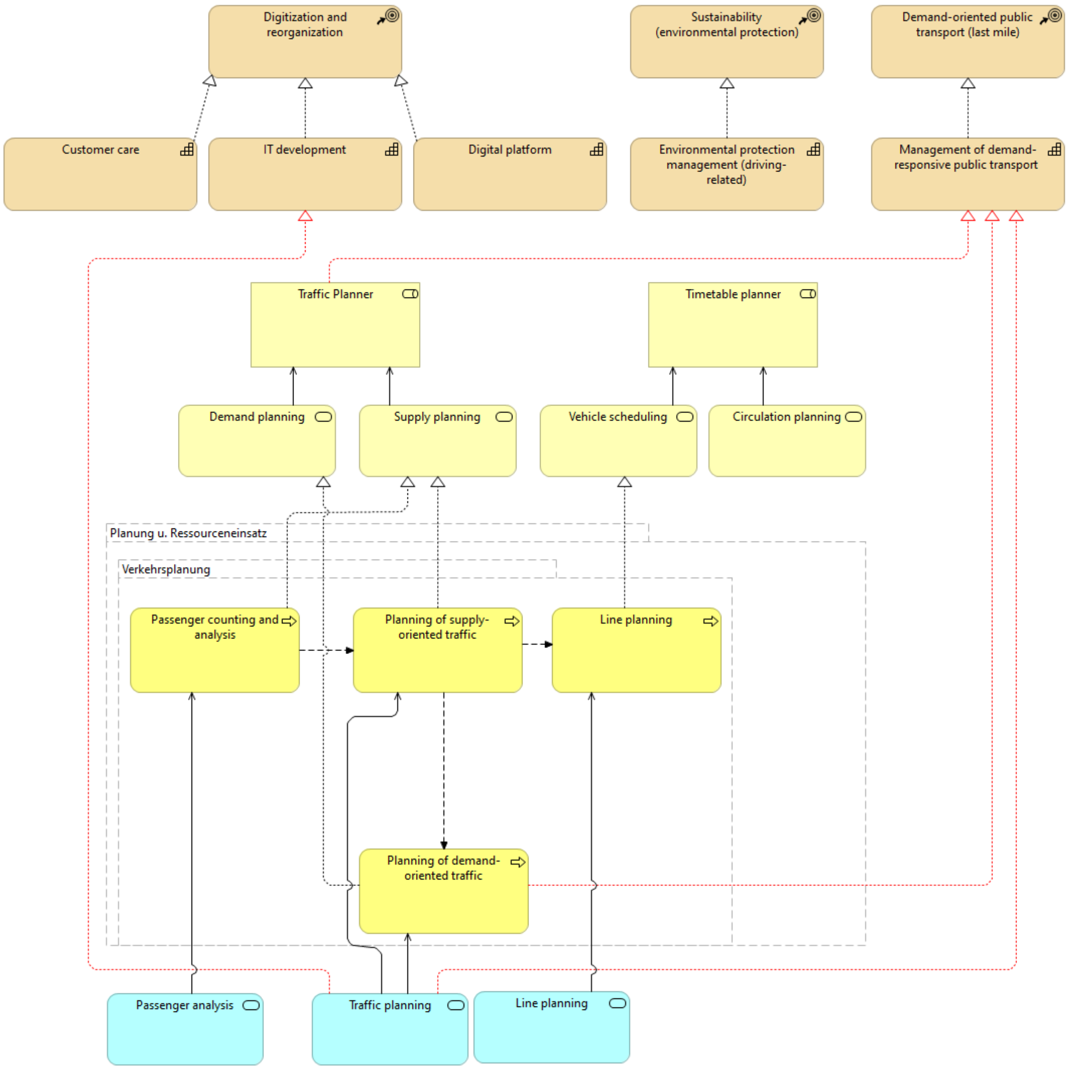

Figure 5: Traffic planning in the context of strategic requirements, source: own presentation

Figure 5 identifies the operational components that act on the capabilities as strategic behaviour. The Business Service *Demand planning*, the Business Process *Planning of demand-orientated traffic* and the Application Service *Traffic planning* contribute to the realisation of the Capability *Management of demand responsive public transport*. Furthermore, the Application Service *Traffic planning* additionally contributes to the realisation of the capability *IT-Development*.

Traffic planning will have several effects on the most important capability *management of demand responsive public transport* of a demand integrated public transport company.

4. Conclusions and future work

In order for public transport companies in German-speaking countries to continue to fulfil the control function in local public transport in the long term, they must be able to understand and manage the core services of demand-responsive transport in the context of their traditional work. This does not necessarily mean providing the services themselves, but rather establishing administrative and control processes and the systems that enable central planning and control. The autonomy of demand-responsive local transport should not be questioned in this context.

In this work, an initial target or reference architecture was developed on the basis of the strategic requirements and the most important enterprise components identified. Subsequently, these were operationally concretised in the sub-area of transport planning.

The developed reference/target architecture shows in its excerpt that changes in the area of planning of public transport companies arise in the context of the integration of demand-oriented transport. Not only do new business services and processes have to be developed, but also additional application services and applications have to be expanded or adapted.

The architecture is encapsulated by services at the business and application levels. This enables the organisation to integrate new NMSs quickly and easily or to out-source individual areas. In addition, an enterprise service bus makes it possible to combine a wide variety of applications and data sources into new services or for inter-application communication. Flexibility is thus fulfilled in the future.

In further scientific publications we plan to:

a. present the entire target/reference architecture,
b. provide evidence of the operational architecture's support for strategic requirements,
c. carry out a first own evaluation of the developed architecture according to quality attributes for enterprise architectures, based on [15].
d. evaluate the research programme on the basis of the Design Science approach by experts and present the resulting changes or expansions again.

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