EXPLORATORY RESEARCH

Goals for collaboration and data sharing

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SYN+AIR

SYNERGIES BETWEEN TRANSPORT MODES AND AIR TRANSPORTATION

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Abstract[1]

The present document is the product of Task 3.3, which aims to determine a list of collaboration and data sharing goals between Transport Service Providers (TSPs). Existing collaborations as well as potential new opportunities for collaborations were examined and many common objectives for the Transport Service Providers were extracted. Deliverable 3.3 presents these common objectives in two categories, Goals, an abstract category, and Subgoals, a more practical category. The deliverable's ambition is to use these extracted goals as convincing points for TSPs to realize the benefits of data-sharing and establish new collaborations. Towards this ambition, the goals are illustrated with the use of UML diagrams, which pictorially explain how a goal can be realized in realistic transportation scenarios. In particular, the diagrams make it possible to emphasize that these collaborations can bring about a seamless multi-modal Door to Door travel.

[1] The opinions expressed herein reflect the author's view only. Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein.

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Table 1: List of acronyms

Term	
ANSPs	Air Navigation Service Providers
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
AVL	Automatic Vehicle Identification
CO2	Carbon dioxide
DFDs	Data Flow Diagrams
DRT	Demand Responsive Transport
D2D	Door-to-door
ECDIS	Electronic Chart Display and Information System
ERTMS	European Railway Traffic Management System
ETCS	European Train Control System
IMO	International Maritime Organization
MTM	Maritime traffic management
MaaS	Mobility-as-a-Service
NAS	Navigational advice and assistance
NTM	Network and Traffic Management
PRM	Person with Reduced Mobility
PT	Public Transport
TSPs	Transportation Service Providers
UML	Unified Modeling Language

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1 Introduction

1.1 T3.3 relation with other tasks of SYN+AIR

This deliverable is the result of task's T3.3 activities as mentioned. T3.3 is a conclusive task for SYN+AIR as it utilises the work implemented in previous tasks of work packages 3 and 4. The relation between other tasks and Task 3.3 is presented in the following figure.

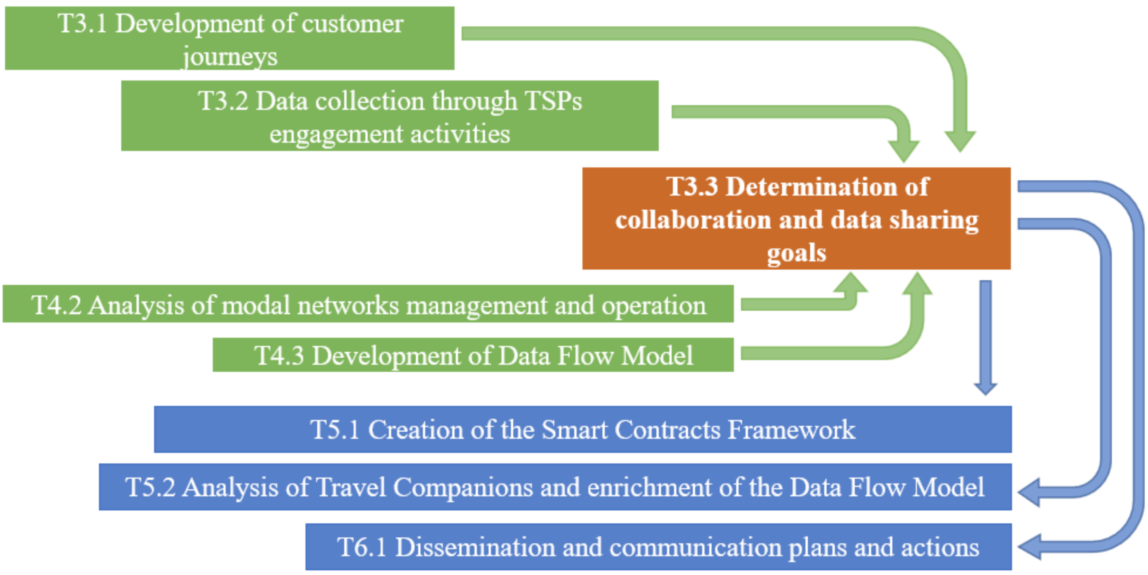

Figure 1: Relation of Task 3.3 with other SYN+AIR tasks

1.2 Main Objectives

The main objective of this deliverable is to present a list of goals shared between TSPs for data sharing. A goal is defined as a common idea towards achieving a desired result. From the user's perspective seamless doo-to-door (D2D) travelling is the pinnacle of efficient multimodality. Intermodal itineraries are only possible through data sharing between involved TSPs. Data are not monolithic assets and even though data sharing can enable the development of many innovations in the field of mobility, many TSPs are still reluctant to share their data due to fear of losing control of data when made available for re-use by third parties.

Efficient and high-level collaboration of modes must overcome various hindrances related to quality, accessibility, and usability of mobility data as well as a still-evolving legislation around data sharing. This deliverable aims to highlight the significant benefits of data sharing towards the system (i.e., TSPs) and illustrate specific use cases of collaboration and consequent achieved goals.

In Chapter 2, literature review is documented. SYN+AIR's deliverables 3.2 and 4.2 are the main sources of argumentation in the main chapters of this deliverable, therefore their conclusions are summarised in detail. UML diagrams, a modern tool of illustrating business processes and software, is introduced in section 2.2 to be used later to visualize the goals determined.

In Chapter 3, the main part of the deliverable, the determined goals are presented. As explained above, the main objective of these goals is to convince TSPs of the potential benefits of collaborations, especially data sharing collaborations. The goals are clustered into two categories, Goals and Subgoals. The former serves as first-contact selling points, summarising what TSPs want to achieve from a macroscopic point of view. The latter zoom in on those general Goals and examine more practical situations and what benefits data sharing collaborations can unlock for the TSPs.

In Chapter 4, the Subgoals determined are presented as UML diagrams. Each diagram depicts a realistic use case and examines how exactly a collaboration of TSPs can bring about the realisation of one or more of their common goals in that case. A multimodal passenger journey is taken as the main perspective in all the UML diagrams. The passengers' actions along with the TSPs' respective actions are depicted highlighting how the potential collaborations bring about a seamless Door to Door travel in real conditions.

2 Literature research and relevant work

2.1 Collaborations between Transport Service Providers

The collaboration and data sharing goals between TSPs will be defined utilizing the outcome of Deliverable 3.2. Existing TSPs collaborations, corresponding types as well as insight and willingness of TSPs to collaborate are all examined within Deliverable 3.2.

In more detail, D 3.2 ([1]) identifies the motives, hindrances, and opportunities for TSPs' collaborations. An extensive literature review was carried out documenting all the existing collaborations as well as reviewing journal papers in which possible collaborations were researched. The willingness of TSPs to collaborate was investigated, especially for collaborations with data sharing in the epicentre. Existing collaborations were classified into different types in terms of their function and goals. Collaboration motives were further explored with the implementation of interviews with TSPs and the participation of TSPs in a hybrid workshop. Their feedback from the interviews, as well as their comments on survey results and customer journeys created in the previous task, were collected. Their insights thoroughly informed the opportunities and hurdles for collaborations. TSPs identified policies and business logics but also clarified data sharing possibilities and constraints.

In particular, the results imply that the TSPs are willing to collaborate provided that some conditions will be addressed. TSPs should follow common data protocols in order to coordinate and exchange data efficiently.

The main motives for TSPs are to increase the number of their customers and to increase passengers' satisfaction by reducing their travel time and/or guaranteeing them a disruption-free travel. The main idea proposed which tackles these motives is the creation of a single ticket. For this technology to be in place, a clear definition of the profit and the responsibility sharing between involved TSPs must be determined. In summary, the single ticket, timetables' alignment, and information dissemination (e.g., at the airports) are the success factors for a seamless journey.

2.2 UML diagrams

UML stands for Unified Modeling Language ([2]), and it is a modelling language that is most often used for software engineering but has extended its use to business processes and other project workflows. Essentially, UML is visualizing software and business processes through diagrams and flow charts. In the present deliverable, the goals determined will be presented visually through UML diagrams. The use cases of TSPs in collaboration servicing passengers in multimodal journeys are effectively visualised via the use of UML diagrams (chapter 4). For this purpose, in this section a short introduction to the concept of UML diagrams is given.

Each diagram can be divided into two categories: structural diagrams and behavioural diagrams ([2]). A structural diagram breaks down the project by the process or way the project is set up. A behavioural diagram breaks down the project by how the system behaves and how its components and actors are involved.

Structural UML diagrams

- Class diagram
- Package diagram
- Object diagram
- Component diagram
- Composite structure diagram
- Deployment diagram

Behavioural UML diagrams

- Activity diagram
- **Sequence diagram**
- **Use case diagram**
- State diagram
- Communication diagram
- Interaction overview diagram
- Timing diagram

UML diagrams can be used as a way to visualize a project before it takes place or as documentation for a project afterward. But the overall goal of UML diagrams is to allow teams to visualize how a project is or will be working, and they can be used in any field, not just software engineering. In the present document, in chapter 4, UML diagrams are utilised in the context of transportation to visualise passengers' journeys and TSPs' collaboration. In particular, sequence and use case diagrams, analysed further below, are created and presented.

Sequence diagrams describe interactions among classes in terms of an exchange of messages over time. They're also called event diagrams. A sequence diagram is a good way to visualize and validate various runtime scenarios. These can help to predict how a system will behave and to discover responsibilities a class may need to have in the process of modelling a new system.

Use case diagrams are graphical tables of contents for the use case. They show the actors, the use cases, and the relationships between them:

- Which actors carry out which use cases
- Which use cases include other use cases.

3 Determination of collaboration and data sharing goals

3.1 Introduction

Many TSPs' collaborations have already taken place in the past but also take place at the moment, as documented in D3.2 [1]. Still, technological breakthroughs of recent years (e.g., Internet of Things, GPS, digital currency, blockchain technology) increasingly provide opportunities for many more collaborations. If used correctly, they can allow different sections of the transportation industry to offer more efficient combined services to their customers that were not possible in the past. The ultimate goal of the transportation industry is to achieve seamless Door-to-Door (D2D) travel. In particular, the EU has put forth a target of a 4-hour journey between any two places in Europe, realizable by 2050 (ACARE - FlightPath 2050 goals [3]). Reaching this target would require all TSPs to collaborate within a framework. When shared, their data could enable more effective combined decisions across a customer's journey in multiple directions. For example, waiting time within the total travel-time can be reduced, transport services in cooperation can be more reliable and disruptions can be bypassed when other alternatives are in place.

According to the conducted interviews, one TSP from a specific mode is not always fully aware of the operations and planning activities of a different TSP from another mode, thus, not able to grasp the opportunities available by data sharing and the magnitude of the potential benefits.

3.2 Possibilities of collaboration

In this chapter, we will determine the goals that are shared among TSPs. Following the definition of the collaboration and data sharing goals, the next chapter will provide visual tools (UMLs) to inform TSPs about their common goals and the means to achieve them in collaboration. The following questions will be addressed within this chapter: Why should a TSP collaborate with another TSP? What are the benefits of data sharing collaborations?

To answer this question, a detailed analysis of the TSPs interviews was conducted and the existing collaborations were investigated in D3.2 [1]. Since the references to D3.2 are numerous, when [1] is referenced, the page is given as well. Moreover, with the assumption that all TSPs are interested and need to adjust their services in the main direction towards achieving seamless D2D travel, the goals were refined to reflect those needs. Finally, the datasets that TSPs generate and could share, as analysed in D4.3 ([4]), were utilized to inform the goals and the possible use cases further analysed in the next chapter. All these considerations culminated in the determination of the goals presented below. It has to be noted that the goals below focus on collaborations of TSPs in pairs because every multimodal journey consists of a sequence of pairs of TSPs. Still, all those pairs are working together and in harmony in order to achieve the major goal of a seamless D2D travel.

The structure of the next two sections is as follows. Firstly, a general layer of goals is introduced and presented, called ***Goals***, and then a more specific and technical layer is determined and presented, called ***Subgoals***. Then, in the following section all subgoals determined will be analysed and explained

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with specific examples and use cases. These subgoals go a step further and include more technical situations that illustrate how exactly TSPs' collaboration can unlock benefits for both.

By the end of the chapter, the analysis will have specified and clarified the benefits of collaboration and data sharing for TSPs. The determined goals will motivate TSPs to search and initiate partnerships, especially via data sharing.

3.3 Determination of goals

Why should a TSP collaborate with another TSP? What are the benefits of data sharing collaborations?

The prominent answer is to increase their profit. This chapter does not delve into this prominent benefit of TSPs collaborations, but it shall be noted that profit is an immediate by-product of offering better services towards all the other collaborative goals determined below.

Beyond increased profit, three incentives for collaboration were concluded in ([1] page 19):

(i) TSPs will gain more customers,

(ii) the customer satisfaction will be increased and

(iii) by doing so a positive network effect will be generated.

Moreover, TSPs' willingness to serve the society and minimize their environmental impact are considered. All those incentives will be disseminated further into the extracted goals that follow.

The first layer of ***Goals*** determined, analyses and highlights those incentives in order to convince TSPs to get into collaboration and data sharing. The goals present clear win-win situations for TSPs and explain in high-level what the TSPs will achieve at a macroscopic level. Zooming in on those major goals, more refined and practical goals, namely ***Subgoals***, were determined. Those are more specific and concrete, and they are analysed through past collaborations, examples, and use-cases. Some of the Subgoals do not apply to all TSPs but only to a subsector of the transportation industry e.g., public transportation only. Subgoals can fit within more than one Goal, reflecting the generality and the importance of the latter for the TSPs. The Goals can be thought of as clusters of the more technical Subgoals. The Goals were selected as first-contact selling points for the TSPs while the Subgoals reflect the more practical matters that TSPs should and want to deal with, towards the direction of offering seamless multimodal travel to their passengers.

The goals were determined after the following two analyses:

(i) The interviews with the TSPs were analysed in multiple brainstorming sessions to understand the TSPs' needs and what collaborations they can and cannot achieve

(ii) Existing collaborations were studied and analysed, especially through the data sharing lens

From these two pillars, common points were collected and expanded. The abstractness versus the practicality of these objectives of the TSPs layered these goals into the two groups, which were selected to be able to disseminate the importance of the goals in a more effective way. The subgoals, more practical in nature, were developed closer to established collaborations and created partially having in mind the realistic use cases which will be presented in the UML diagrams.

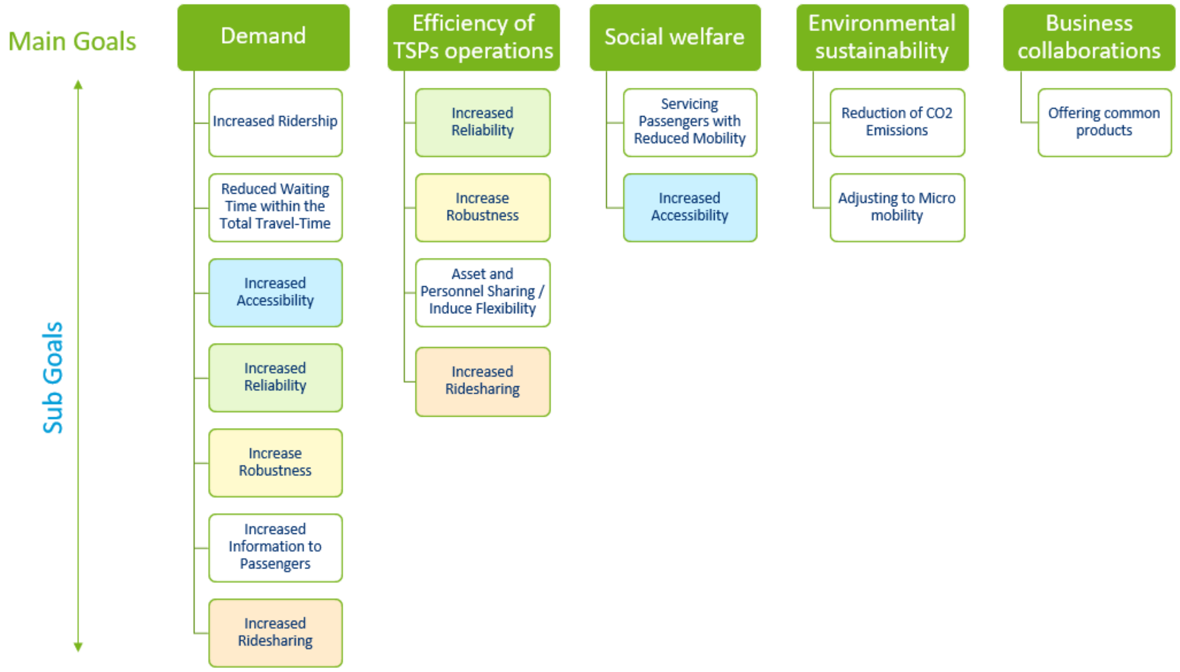

Figure 2 – Goals and Subgoals

3.3.1 Goal 1: Demand

Increasing ridership, managing service disruptions efficiently, and increasing market share form some of the main goals for all TSPs. Collaborations can greatly increase the number of passengers that select services of a given TSP for their journey. This can be achieved either directly by reaching more customers or indirectly through increasing their satisfaction ([5]), so customers are more likely to use the services again and recommend them to their peers ([6]). When data are shared between two TSPs at the tactical level, the passenger’s journey can become faster and more reliable. Passenger satisfaction can be increased through receiving constant updates about their journey but also through TSPs’ assurance that any disruption can be dealt with in a timely manner. When data are shared at the strategic level, TSPs can reach more customers by increasing their services’ access. Moreover, by organizing their trips in cooperation TSPs can have multiple economic benefits by planning for ridesharing. Strategic decisions on new infrastructure, such as dedicated bus lanes, can relieve traffic congestion ([7]).

TSPs can increase demand if they collaborate with each other because that will coordinate their services and provide a consistent offering to the traveler. To coordinate more efficiently, planning and services need to be integrated.

The main idea that can unlock this is the Single-Ticket, which is the best form of synchronization and the ultimate consistent offering, and the main technology that can realize this is a Smart Contract Framework. Passengers buying a single-ticket will be keener to change modes and perform the shift from private vehicles to bus and train, thus breaking the car and public-transport vicious cycle ([8] page 7). Passenger journey becomes more convenient because everything is arranged and they have constant access to information for their travel. When TSPs collaborate, they can offer cheaper combined tickets, for example a train+plane can be cheaper than plane+plane ([1] page 14).

List of subgoals:

- Subgoal #0: Increased Ridership
- Subgoal #1: Reduced Waiting Time within the Total Travel-Time
- Subgoal #2: Increased Accessibility
- Subgoal #3: Increased Reliability
- Subgoal #4: Increase Robustness
- Subgoal #5: Increased Information to Passengers
- Subgoal #9: Increased Ridesharing

3.3.2 Goal 2: Efficiency of TSPs operations

The transport service industry has been traditionally comprised of distinct TSPs offering their own service to their passengers. By doing so, they have tried to offer the most efficient and disruptions-free service they can. Towards the goal of a seamless D2D travel, a new important variable must be considered which was not in the picture when TSPs planned individually. Every passenger travelling using their services is only executing one of the parts of their full journey. Having that in mind, and planning for the future, every TSP must deal with this new variable by adjusting their service to accommodate passenger’s transition from the previous leg and to the next leg. This brings into play a need for efficient cooperative operations with other TSPs. Furthermore, it unlocks opportunities to achieve goals that were not possible before.

There are many ways to increase their quality of service enabled by new collaborations. TSPs can become more reliable and robust. They can also induce flexibility by utilising each other’s resources and personnel. Working together, TSPs can reduce the level of crowdedness and design more efficient routes.

List of subgoals:

- Subgoal #3: Increased Reliability
- Subgoal #4: Increase Robustness
- Subgoal #8: Asset and Personnel Sharing/Induce Flexibility
- Subgoal #9: Increased Ridesharing

3.3.3 Goal 3: Social welfare

The transportation industry supports the mobility of every country's population and is thus, one of the central components of a modern society. A transportation's network capacity to service every citizen affects the society in a core way. In particular, accessibility of the transportation network is one of the major concepts that affects society at large. The easiness with which a citizen can access public transportation is a major factor that can have impact even in a country's markers such as unemployment and social inequalities. Traffic congestion has societal impact as well and can also be addressed through TSP collaboration and planning. Alleviating traffic congestion can improve health problems and positively affect local economies ([9]).

TSPs are aware of the societal impact of their services. But similarly to Goal 2, their strategic decisions were traditionally limited by considering their services individually and not as part of a larger network. Societal goals can be achieved when collaborations are established. By offering combined services, the transport standards and the passengers' satisfaction can be greatly increased. TSPs have individually planned for servicing passengers with reduced mobility but they have not considered that when those passengers change modes, they face problems in the transition because common infrastructure is not in place. When collaborations are in place, accessibility is increased, and higher-quality service is offered to more customers, they can bring about the desired shift from car to PT and increase social welfare.

List of subgoals:

- Subgoal #7: Servicing Passengers with Reduced Mobility
- Subgoal #2: Increased Accessibility

3.3.4 Goal 4: Environmental sustainability

In recent years, attitudes towards the environmental impact of travelling have shifted. A growing percentage of passengers considers the environment when choosing their mode of transport ([10] page 10). Simultaneously, TSPs consider their CO2 emissions footprint and they are interested in reducing it. The transportation service industry is one of the major components of the green movement and it must adjust appropriately by providing environment-friendly services. Collaborations offer many ways to achieve that, either directly or indirectly. For example, bus operators can send their buses to the airport, or the train station based on demand so they can avoid empty rides. Also, indirectly, when passengers stop taking their cars and use more environmental-friendly ways of traveling.

Another shift towards a greener future for transportation, is the transition to micromobility. The big city centers are increasingly closing for cars ([11], [12]). That means that there is a need and an opportunity for citizens, who always need to travel, to reach the centers with other modes. The most environment-friendly, inexpensive, and sustainable way to achieve that will be a combination of public transportation and micromobile means such as bikes and e-scooters. Already, passengers increasingly need to be able to carry their bikes in the PT vehicles. Similar to the problems that PRMs face, there is not currently universal infrastructure for that. TSPs in collaboration can take that into account at their common strategic level decisions and provide solutions.

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List of subgoals:

- Subgoal #10: Reduction of CO2 Emissions
- Subgoal #11: Adjusting to Micromobility

3.3.5 Goal 5: Business collaborations

TSPs are corporate organizations so they have a business side apart from their transport service side. They need to be profitable to continue providing their services. In collaboration, TSPs can offer combined services and products like common loyalty cards or common insurance. Deals and common discounts for picking the services of a collaborator TSP can be offered.

For another way to increase revenue, TSPs want to be more visible to customers so that customers are aware they have this option of travelling. When collaborations are in place, TSPs can increase their market visibility through mutual advertising. The Train vehicle can have advertisements of the Bus TSP servicing at the end of the current leg, making the passengers more likely to use the Bus instead of MaaS when they arrive. Increasing the representation of Public Transport options, will create a positive network effect when customers are aware of their available options. This is yet another way to induce the shift to PT.

List of subgoals:

- Subgoal #6: Offering common products

3.4 Determination of subgoals

3.4.1 Subgoal #0: Increased Ridership

First and most, TSPs, as profit driven organizations, aim for more customers. Attempting to maximize demand is the most standard approach for a transport company to increase revenue. As explained below, collaborations open new doors from the viewpoint of solving this passenger maximization problem.

It has been documented repeatedly in the interviews ([1]) that many individual TSPs do not grasp the value and utility of the data they possess and generate every day. Even just for using generated data for their own purposes, let alone to share generated data with other TSPs or utilise data provided from other TSPs. After been convinced about the benefits of data sharing and using data to take decisions, the actual collaborative actions towards increasing the number of passengers can take many forms. In every other subgoal below, even the societal ones, there is always the effect of increasing demand by simply making the service more attractive, either directly or indirectly.

One direct way is to use data to offer synchronized (Subgoal #1) and reliable (Subgoals #2, #3) services, leading passengers to make the shift from using their own private vehicles to public transport. Passengers want to arrive at the airport by PT, not by their own cars, but they do not trust them enough because they are unsynchronized/uncoordinated. Via the use of data, and let's assume for example that a passenger needs to take first the bus and then the train to go to the airport, the two modes can become synchronized and reliable, not only with each other, but with the airline flight schedule as well! This kind of multi-modal service, which of course needs technological and other innovations in place (SCF for example), can be extremely attractive to passengers when it gets seamless enough. Synchronization of services and managing disruptions and delays in real-time has the necessary precondition of constantly open gateways for data flow between the TSPs.

The other direct way is simply to be able to reach more customers (Subgoal #2, partial results of Subgoals #7, #11).

3.4.2 Subgoal #1: Reduced Waiting-Time within the Total Travel-Time

As a core part of a seamless D2D journey, total travel-time of a passenger's journey and its reduction is one of the main goals of all TSPs. Individually, a TSP tries to minimize the travel-time of their own leg as much as this is possible when holding all the other variables of the trip constant (fuel cost, passenger's comfort etc). In a collaboration though, two or more TSPs, can take actions to minimize the travel-time of the full journey of their passengers. Enabled by modern technology (e.g., internet, gps, weather prediction etc), collaborations between TSPs can realize a faster journey for their customers in multiple ways. Decisions informed by data sharing and specifically synchronization of their timetables, can immediately lead to a much faster mode transition, so the users will not have to wait at the transfer station ([13]). Another way to save time, enabled by recent technology, is to offer an integrated full-trip ticket so that users will not have to waste time in lines to buy a new ticket at each leg of their trip.

3.4.3 Subgoal #2: Increased Accessibility

Public Transportation's main objectives are to become more accessible ([14]), more reliable and more efficient ([15]). The existing network and infrastructure of the PT of every country has been planned and is being planned without collaborations between TSPs in mind. When two TSPs collaborate, their combined services can reach many more customers than each one of them individually. This increase of reach can even expand beyond countries' borders ([15] [16]). The impact of such kind of cooperative decisions can be invaluable for the TSPs and the society. With decreasing and ageing populations in many rural parts, it is becoming increasingly difficult to maintain public transport and other services that depend on mobility, such as care at home and home deliveries. This reduced accessibility of services impacts the quality of life of people living outside urban centres (MAMBA project, [17]).

When informed by data sharing, TSPs at the strategic level, could add railway routes, engage more shuttle buses, build new highways, and build new infrastructure. New transit hubs can be created on urban or suburban regions with historically inadequate PT access in order to serve people and societies.

More efficient bus service to/from the train station can result in the train service being more attractive. A train TSP may offer an excellent service, but if the passenger's last-mile options at the train station are limited and ineffective, the passenger will prefer another way of traveling. Another example: A passenger would be more willing to use a TSP if there was affordable parking near the TSP's station (

[18]). In city centers people do not want to use their private vehicles because of heavy traffic and they would prefer to take the subway to reach their jobs but only provided that there are enough parking spots near the subway's station. By achieving this goal, a great revenue stream will be unlocked for TSPs.

3.4.4 Subgoal #3: Increased Reliability

Provision of reliable services for TSPs, is an always relevant goal. Passengers want to arrive at their destination in time, with minimal difficulty and without exceptions. Each additional time spent travelling from the travel time of an un-disrupted journey is an economic loss for the individual and the society ([19]). In addition, many cascading effects may arise from a delay such as additional delays in transitions from one mode or one leg of a trip to another. TSPs must and do target to increase the reliability of their services through various means, such predicting issues downstream or indirectly, by increasing frequencies to alleviate the effect of disruptions. Increased reliability evidently increases TSPs services' usage (e.g., the transition of a certain number of passengers from using their own cars to using the Train in the city of Vienna due to train service's high reliability). In addition to the solutions that a single TSP can employ, the collaboration between TSPs is a much easier and more cost-effective way to increase reliability. Synchronization of services between TSPs can allow the utilization of other TSPs' vehicles for executing a trip if they have higher availability in the area of the disruption or the execution of ad-hoc and quasi-on-demand routes. A precondition to this is the exchange of information at the tactical and strategic level in order to provide good dissemination of disruption information and plan for a mitigation plan accordingly among TSPs.

3.4.5 Subgoal #4: Increased Robustness

As a core part of a seamless D2D journey, offering more robust services is one of the main goals of all TSPs. Robustness indicates the influenceability of a service by disturbances. A robust TSP's service can function well under difficult circumstances. When a service is not robust, small external influences cause large delays and induce great dissatisfaction to passengers. TSP want to guarantee their service when disruptions occur, and this can be achieved in cooperation with other TSPs. Disruptions can take many forms characterized by high unpredictability. A small accident or heavy rainfall may be all it takes to trigger huge delays affecting large parts of the network in a short period of time ([20]). Planned works on roads, demonstrations and cultural events can induce great traffic congestion. When a disruption like this happens, it can lead to big time delays or even to full shutdown of the transport operation. In those situations, tactical collaborative actions can be taken by the TSPs to retain the seamless experience of the passengers as much as possible. For example, MaaS can cooperate with Bus in case of a blocked bus route. If a flight is cancelled due to extreme weather conditions, Bus and Train could accommodate those passengers in order to reach their destination.

Some modes are inherently more robust than others. The Train is more robust than the Bus in general because the Bus uses the city's roads. In the case of a riot or march along buses' routes, the buses will not be able to operate, while the Train will continue to operate using its independent network. With that in mind, collaborations can be fostered to increase a TSPs robustness by cooperating with a TSP of a more robust mode. This should not be thought of as sending customers to a competitor since disruptions are rare. MaaS can serve as the on-demand alternative to PT, when the situation calls for it, but in general PT will remain the main way of transit.

3.4.6 Subgoal #5: Increased Information to Passengers

When travelling, especially in a multi-modal journey, all passengers want to be informed about their journey's status. They want to know gate information, route changes, potential disruptions, and all that in real-time. One of the biggest hurdles for (even experienced) passengers is navigation within the airport. This is younger people's main request ([1] page 11). This goal is very important for the shift to PT, many passengers prefer to take the taxi because PT transit information was not available to them or it was not precise enough. Through real-time data sharing, TSPs from every leg of the passenger's journey's chain can inform them before they even onboard them. They can make them aware about operational changes in their trips and present them with options for solving trip conflicts and issues.

A single platform (such as a travel companion application) which operates in multiple languages can be developed and used from all TSPs to provide such information to the end user – the passenger. It can also offer a multi-modal journey planning to the user having integrated all datasets the corresponding TSPs need to share.

If an airline traveller is informed with the available PT of their destination, this information improves the airline product itself ([1] page 15). For example, the Stansted Airport rail station, provides passengers the opportunity to experience the station through a virtual tour ([21]). In a collaboration between the Airport operator (Fraport), the main airline at the airport (Lufthansa) and the railway company (Deutsche Bahn), a check-in area at the rail station has been installed, which has a direct link to the airport's automated baggage handling system ([1] page 29). To encourage citizens and tourists to use public transport. Rome's Mobility Agency (RSM) provided an online, wireless, multimodal, multilingual system with information about the most appropriate public transport services and a journey planner which calculates the best public transport routes with an interactive map, provides information on the availability of shared bikes. It provided information on the availability of shared bikes, and parking spaces in four city car parks, and information and advice on services and relevant contact details. Following its development, the number of visitors to the website rose by 197 percent between 2002 and 2005 and mobile users performed an average of 10,000 queries per month, deeming the measure a success.

3.4.7 Subgoal #6: Offering common products

Business-oriented collaborations like mutual advertising between TSPs can be of great economical advantage to all involved parties. A TSP can advertise their services in the vehicles/coaches and infrastructure buildings of another TSP. By implementing such collaboration, each TSP gets more visible and recognizable towards the public, inducing market visibility. Public Transportation in particular, can increase its visibility in multiple ways and promote its services. Passenger using the collaborating TSPs may benefit from exclusive services, discounts, and common loyalty cards. Airport and airline advertisements can also be promoted in Metro or Taxi. In such an established collaboration, customers who fly with a certain airline can get profitable deals from a car-rental TSP ([1] page 7).

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3.4.8 Subgoal #7: Servicing Passengers with Reduced Mobility

A principal societal goal is to provide services to passengers with reduced mobility (PRMs) ([22]). In many vehicles and stations, access for PRMs is not a given and they face considerable difficulties which many times cut them off the transportation network completely. It is very important to have appropriate access facilities in the transfer points and this can be designed cooperatively in the strategic phase, considering stations utilized by more than one TSP (especially if the infrastructure provider differs from the service provider, which is very common in the EU member states). The necessary infrastructure can be costly but common decisions informed by data-sharing collaborations can minimise some of them. In a multi-modal journey, the burden of providing service to PRMs fall on both TSPs of a transition point and it should be seen as a common endeavour to undertake. But when in place, data sharing can enable anticipation of passenger flow and actions taken can make PRMs trips as seamless as possible. Apart from creating the necessary infrastructure and keeping in mind that the number of PRMs is small compared to the total number of passengers, operational day decisions can be taken as well for better servicing PRMs. For example, with passenger PRM‘s status information exchanged automatically, a TSP can anticipate them and be ready to accommodate them, as is frequently done in the airport when a flight arrives. Such kind of decisions can extend to all modes of travel, realizing more consistent multi-modal seamless trips for everyone. Upon realization of this goal, the total number of passengers using the transport service is increasing, resulting indirectly in economical profit as well.

3.4.9 Subgoal #8: Asset and Personnel Sharing/Induce Flexibility

When TSPs collaborate, they can utilize others' unused or underused resources and personnel. Efficiency of operations is an important objective for TSPs. Collaborations allow for methodical utilization of resources and personnel that were not possible when a TSP operates alone. Some occupations operate in an on-demand fashion, where they are idle for most of the working time until they are needed for a crucial application of their skill (e.g., IT employees, shuttle drivers). Such kind of employees can easily lend their skills to a TSP in collaboration when they are not occupied. Many resources such as unused vehicles or materials with an expiration date could be shared between TSPs instead of been left unused and thrown away. This direction can initiate collaborations towards a circular economy and increase resources' utilization. Vehicle or general maintenance tasks can be addressed simultaneously. Productivity can also be increased as a by-product. Achieving this goal will even result in TSPs becoming more reliable and robust. Finally, beyond physical resources, sharing ideas and information allows everyone to gain a new perspective, which can lead to new paths and solutions of problems which cannot even be imagined now.

Airlines already have global collaborations where they exchange bus shuttles and human resources (e.g. IT employees). The Star Alliance collaboration, consisting of 26 member airlines, is a horizontal collaboration which allows the TSPs to share facilities, resources, and know-how ([1] page 5). In Attica, Greece, in an existing collaboration, the Intercity Bus Company (KTEL) provides 200 buses to OASA, in order to strengthen the transport service ([1] page 6).

3.4.10 Subgoal #9: Increased Ridesharing

In many cases travelers have the same destination but they have different origins. If information is shared from the airline concerning the passengers of a certain flight or event passengers with a flight of close departure times to a share mobility TSP (e.g., transport on demand that uses shuttle buses or cabs). As a by-product, the cost of traveller's ticket can be reduced and at the same time the gains of the TSPs can be increased as the bus will work at maximum capacity. At the same time, the airline can be aware of the traveller's location and manage the check in process in a faster way if necessary. TSPs in collaboration can offer dynamically routed shuttles that arrive when called for trips that public transportation does not serve well. Effective ridesharing can potentially lead to TSPs saving on fuel, human resources, drive time, and overall operating costs. Achieving this goal will even result in TSPs' reducing their impact on air pollution.

Recent mobility services like Uber bring significant opportunities for ridesharing and new collaborations. Combined with information disseminated from the airport or the train station about passengers' arrival, allows for possibilities of ridesharing, offering better matches of passengers with drivers and cheaper routes.

3.4.11 Subgoal #10: Reduction of CO2 Emissions

As the main environmental goal for all TSPs, collaborations can help TSPs reduce CO2 emissions moving towards a more sustainable future. Transport is currently ranking second as the most polluting sector in the EU. Transport-related air pollution is linked to numerous health problem ([23]). Introduction of recent technology (e.g., electric, and alternative-fuel vehicles/coaches) can reduce carbon emissions resulting in less air pollution. Sustainability and the environment are becoming especially important for passengers and public consciousness as well, so TSPs will need to adapt to this recent change of attitudes. A shift from least sustainable per capita modes of transport (e.g., bus/taxi) towards modes of transport with lower emissions (e.g., train/metro) is inevitable and has already been taking place ([24], D4.4 and shift to PT). In Japan, a world leader in the transport sector ([24]), the modal share of rail is increasing and there are strategies to revitalize urban centres, giving a large share to public and low-impact transport. Common cooperative decisions between TSPs can also promote this goal by designing their vehicles to operate on demand. That way buses can travel at full capacity more frequently. The collaboration might seem more important for bus and taxi companies since airlines already address this issue.

3.4.12 Subgoal #11: Adjusting to Micromobility

Transportation using lightweight vehicles such as bicycles or scooters, especially electric ones, is referred as micromobility. Modern environmental norms have changed, and such ways of transportation are becoming increasingly more attractive. The ideal green trip, for example, is bike+train+bike, which is as environmentally friendly as possible. In the future, walking and cycling will be an even bigger part of all journeys so TSPs will inevitably have to align their policies with this emerging concept of micromobility ([1] page 25, [25], [26]). In Japan, cycling has already become more popular in cities as it is being encouraged by an urban planning with a high commercial density ([24]). The primary choice for first mile/last mile transit options is increasingly shifting to bikes and electronic light transport vehicles which are the best option after walking. The big city centers are increasingly closing for cars allowing only the subway and micromobile ways to reach them. Passengers already need to be able to carry their bikes everywhere including PT. Similar to actions described in the case of servicing PRMs (Subgoal #7), such passengers can also be anticipated and accommodated. TSPs in collaboration can take common strategic but also tactical level decisions and provide solutions. This will come with both economic and environmental benefits.

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4 Presentation of UML case diagrams

The following chapter aims to contextualise relevant use cases corresponding to concrete scenarios where one or more of the defined subgoals presented in the previous chapters are being actualised through collaborations and data sharing. The previous subgoals are illustrated via the use of UML diagrams (concept introduced in section 2.3). For designing those diagrams, a use case, was selected which shows a multimodal journey and/or one or more TSPs collaborations. The use case was selected to be as most representative of achieving the goal as possible. The use cases reflected in the UMLs are also tackling the main elements to achieve a seamless transport facilitated by data sharing among TSPs. At each section below, the corresponding use case is analysed and described to aid and clarify the visual. Some UMLs present more than one subgoals, especially when the use case is more complex and closer to a real-world scenario.

The UMLs diagrams contain most or all the following sections explained below:

- Passenger's chronicle of actions: In the passenger's chronicle of actions, the various triggers are depicted at approximately the time in the passenger's journey that they initiated.
- TSPs in collaboration: The TSPs in collaboration are placed in the sequence that corresponds to the order of using their services by passenger.
- Data flow: The data section depicts only the necessary datasets need to be exchanged by the TSPs in the given scenario. There is always a reference to Deliverable 4.3 where all those datasets have been studied in much more detail.
- Triggers: The triggers' section shows the relevant events which spawn actions needed to be taken by the TSPs. These triggers are placed below the TSP they belong to or the TSP that disseminates them. The same triggers, numbered by the time order they fire, are also depicted in the passenger's chronicle of actions section.
- Actions by TSPs: The actions by TSPs section analyzes the action need to be taken by the TSPs when certain condition, like triggers invoked, are satisfied and the phase (strategic, pre-tactical and tactical) that they happen. Exchange of data is a precondition for all the cases, and it is not mentioned in the actions section since it belongs better in the special data flow section.

In the following sub-sections, ten different use case diagrams are provided, trying to encompass different situations. The focus of the UML diagrams are on the passengers' journeys and in how the TSPs in collaboration enable them in a seamless manner. To highlight this and illustrate the journey in an understandable manner, a few simplifying assumptions have been made in the creation of the UML diagrams:

1. The modes are depicted instead of the actual TSP. For example, when an Airplane is depicted, this is usually the Airline TSP that provides the service and sometimes the Airport TSP if, for example, the passenger's baggage is handled.

2. Only the most important triggers relevant to the particular use case are illustrated. In a real-world scenario, countless more triggers and interactions between the TSPs and the passengers are happening, but they are not depicted.

3. The time phases have been condensed into three levels: strategic (when plans and infrastructure is designed), pre-tactical (a few days before the day of operations) and tactical (the day of operations). For more nuanced and detailed analysis of the actual phases, the reader is directed to D4.1 ([27]).

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4.1 Single-Ticket

Four TSPs offer a common Single-Ticket service enabled by an electronic platform. They have established pairwise collaborations by exchanging data, synchronizing their timetables, and taking common decisions to handle disruptions and delays efficiently. Multiple passengers are depicted using the Single-Ticket service and their number affects the course of actions depicted.

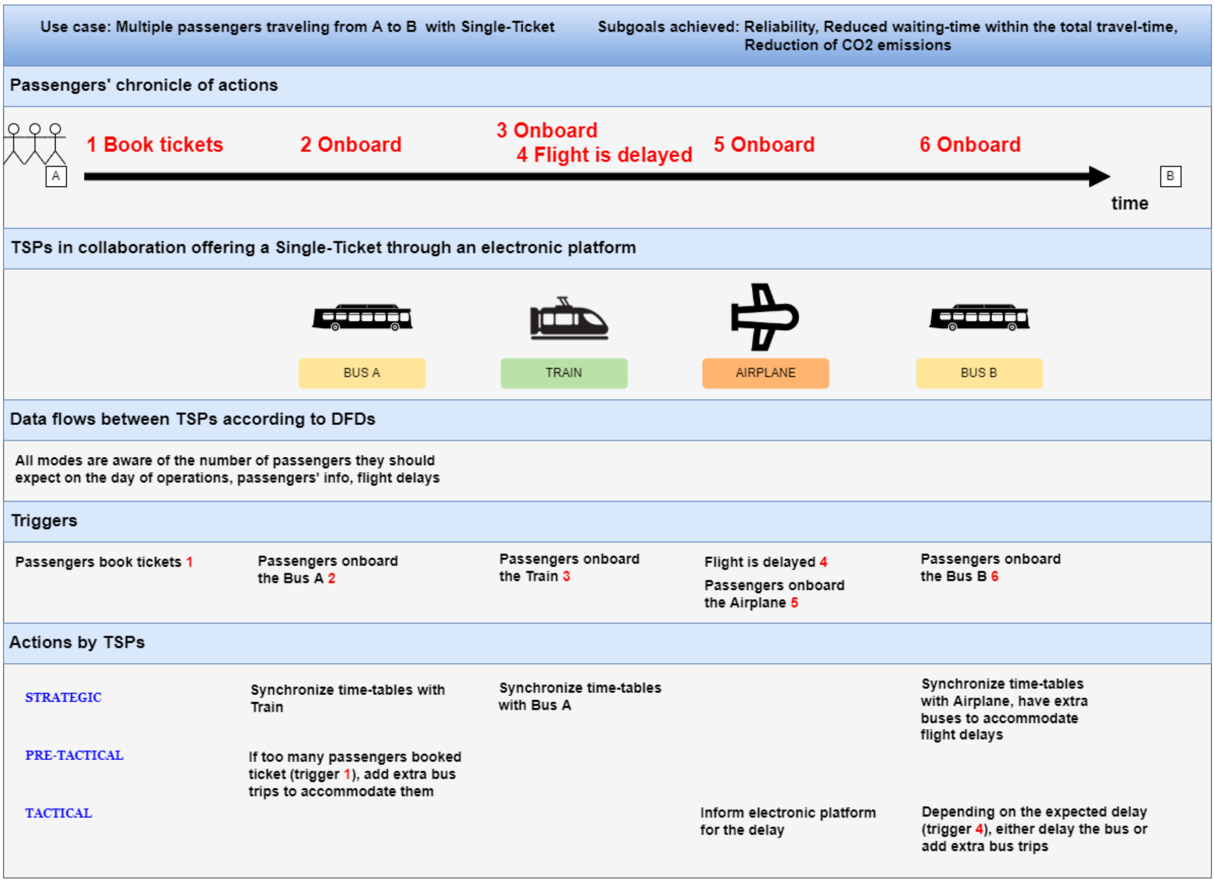

Figure 3 – Single-Ticket

4.2 PRM serviced

A passenger with reduced mobility (PRM) is going through a multimodal travel using the services of a Taxi, an Airline, and a Bus TSP. The purpose of this UML diagram is to showcase how a data sharing collaboration between these TSPs can induce a seamless travel for the PRM. A taxi arrival delay, a flight delay and the corresponding TSPs' actions are also depicted in the same use case.

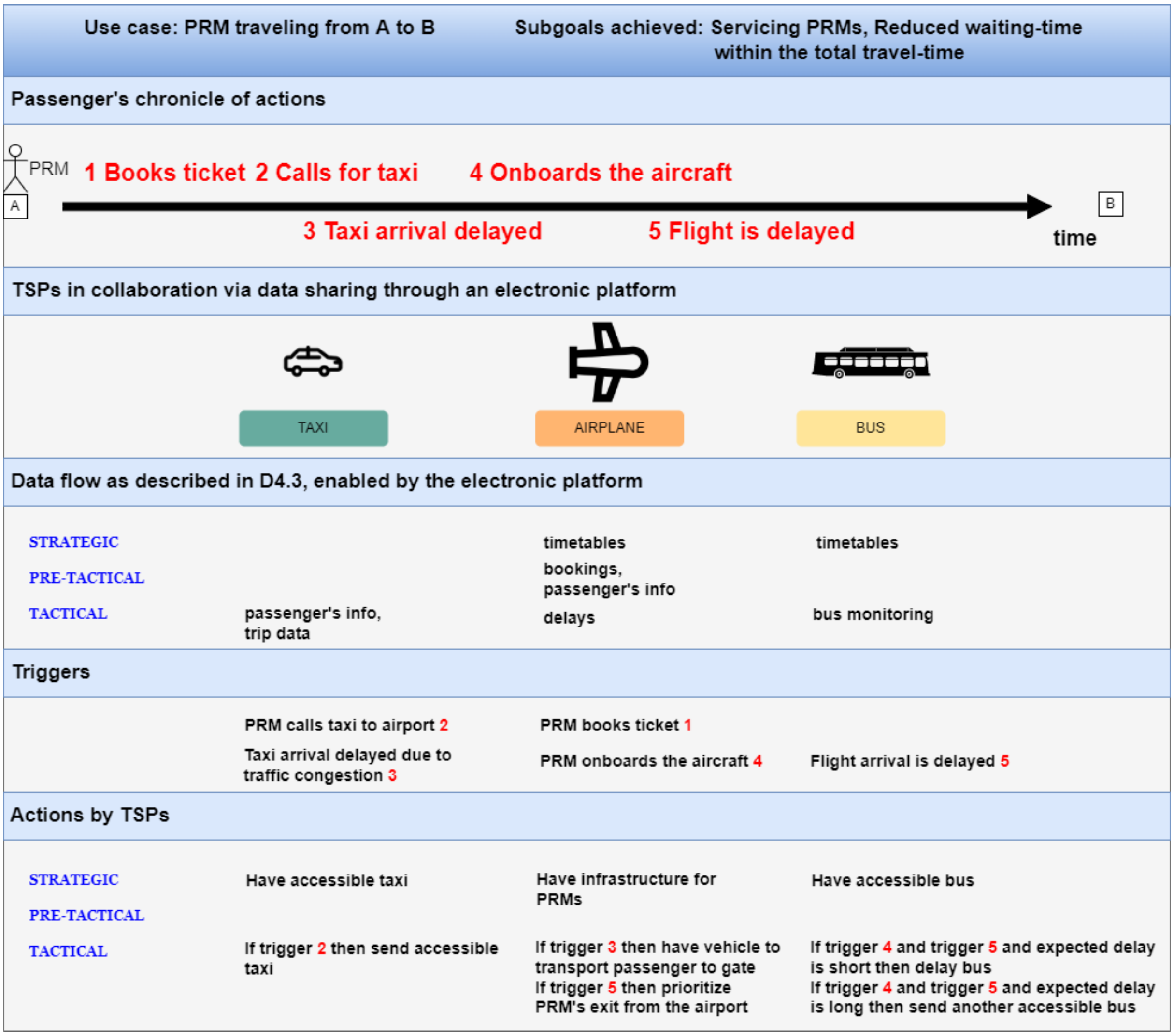

Figure 4 – PRM serviced

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4.3 Ridesharing in multimodal chain

Two passengers travelling to point B from close origins A1 and A2. A collaboration between a MaaS (A) TSP and an Airplane TSP, enables them to offer ridesharing services in order to use a single vehicle and a single trip to collect both of the passengers. While passengers are onboard the MaaS A, the Airline can start the check-in process faster.

Similarly, since the passengers have the same destination, their final leg trip can be traveled by a single vehicle of a MaaS (B) TSP.

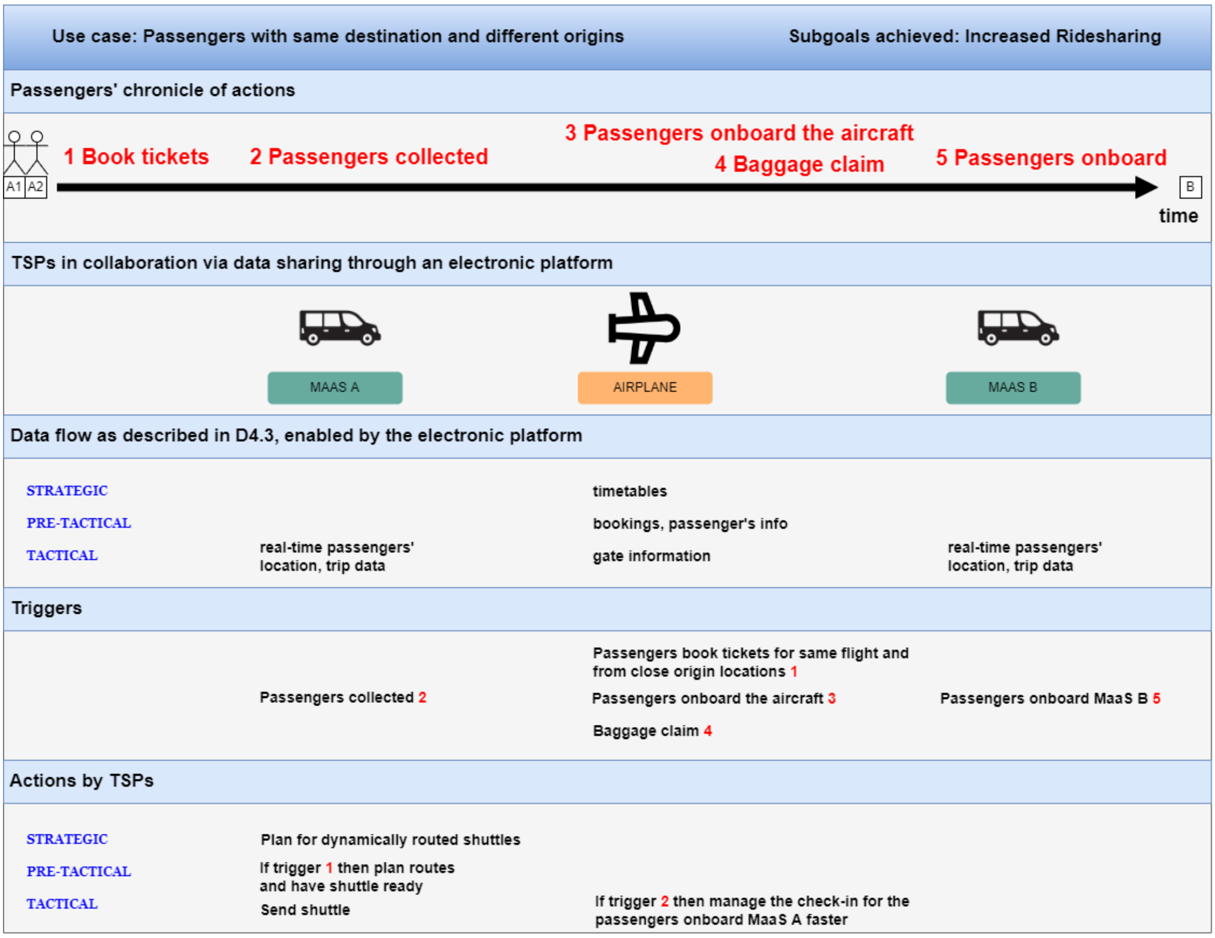

Figure 5 – Ridesharing in multimodal chain

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4.4 Trip cancellation

A group using a Bus, an Airplane, and a Train collaboration for their travel, decides to cancel their tickets. Data sharing enables the TSPs to efficiently act to allocate the unoccupied seats to other passengers.

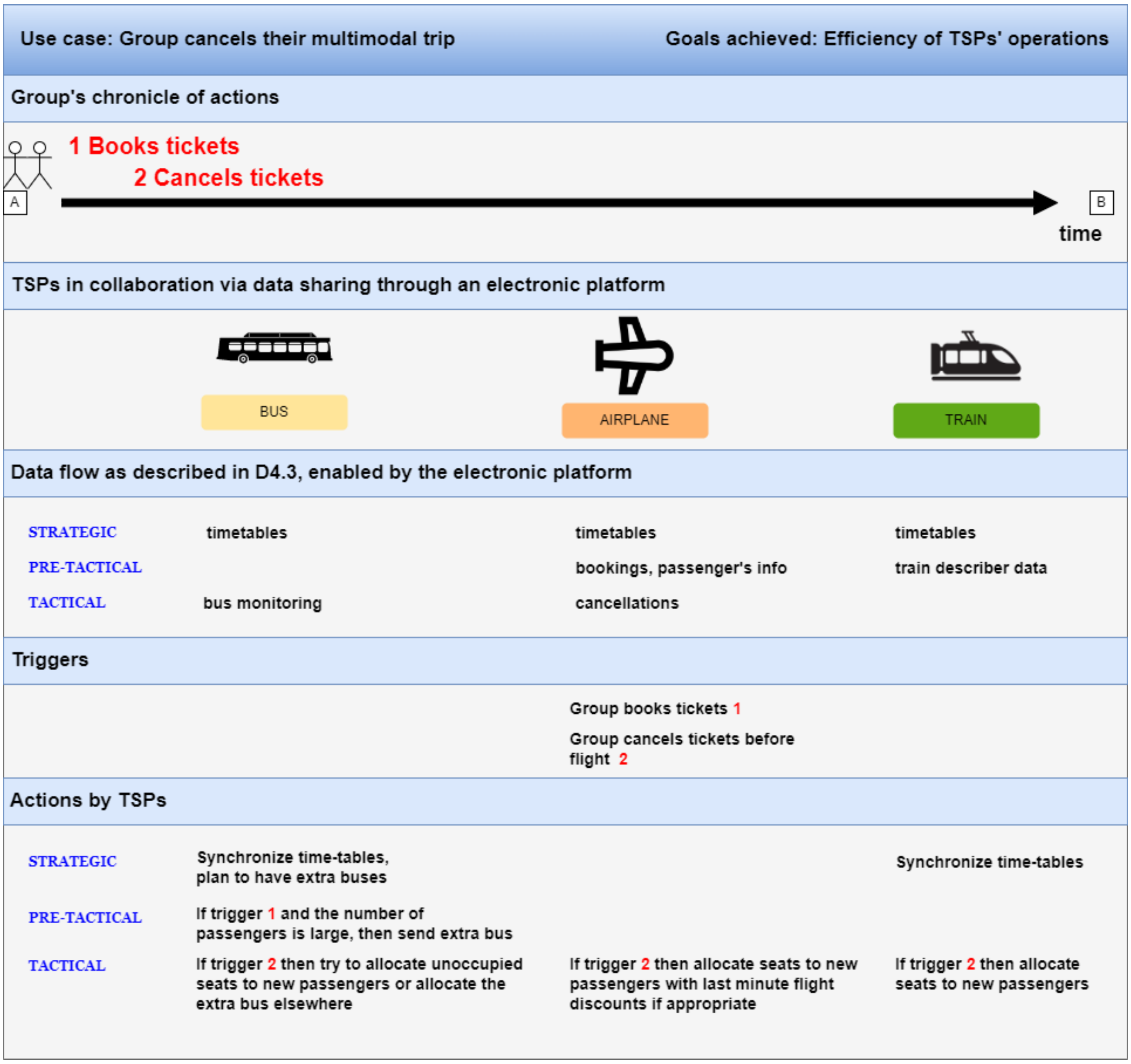

Figure 6 – Trip cancellation

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4.5 Horizontal collaboration

A horizontal collaboration between a Bus (A) TSP and a MaaS TSP offer customers a reliable service to the airport. When a disruption of the bus service occurs, MaaS immediately sends vehicle to collect the passenger so that they arrive at the airport in time for their flight.

A vertical collaboration of those two TSPs, an Airline TSP and another Bus (B) TSP is depicted as well.

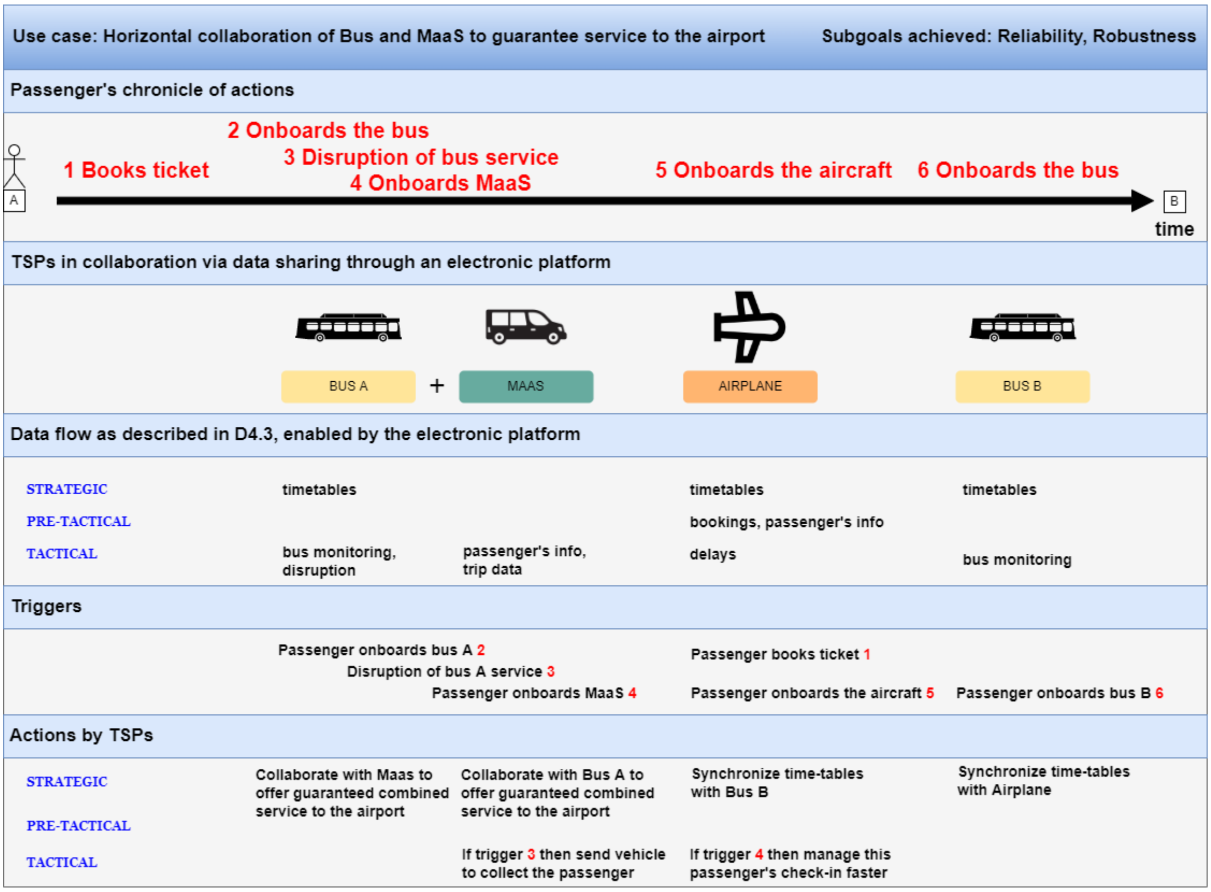

Figure 7 – Horizontal collaboration

4.6 Adjusting to micromobility

A passenger carrying a bike is going through a multi-modal journey, using the services of collaborating TSPs which provide infrastructure as well as operational actions to accommodate them. With strategic decisions, they offer time-specific options for bike travelers in order to avoid crowding their vehicles with bikes in peak hours.

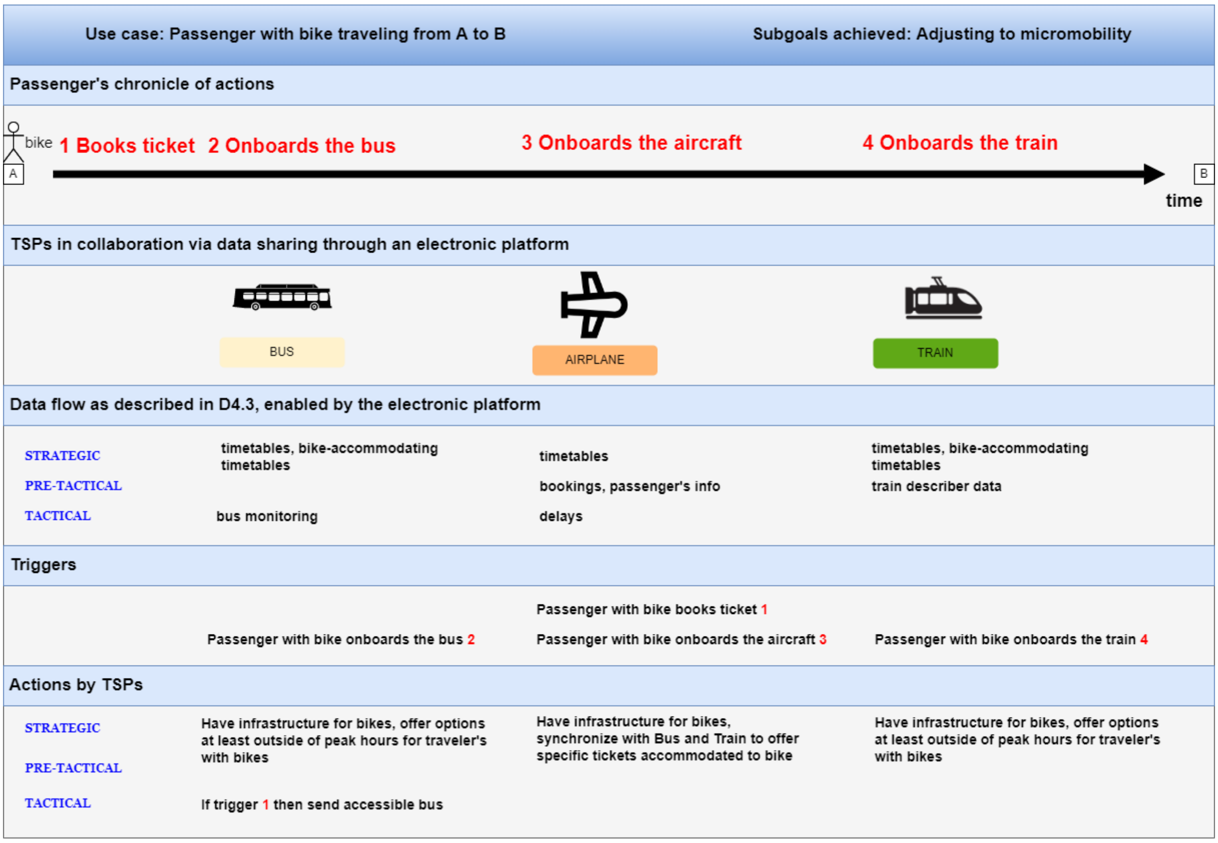

Figure 8 – Adjusting to micromobility

4.7 Passenger informed via a Travel Companion App

A passenger uses the combined services of a Train, an Airplane, and a Bus TSP. In their collaboration, they provide the passenger with constant updates about the passenger's journey by sending updates to a travel companion application.

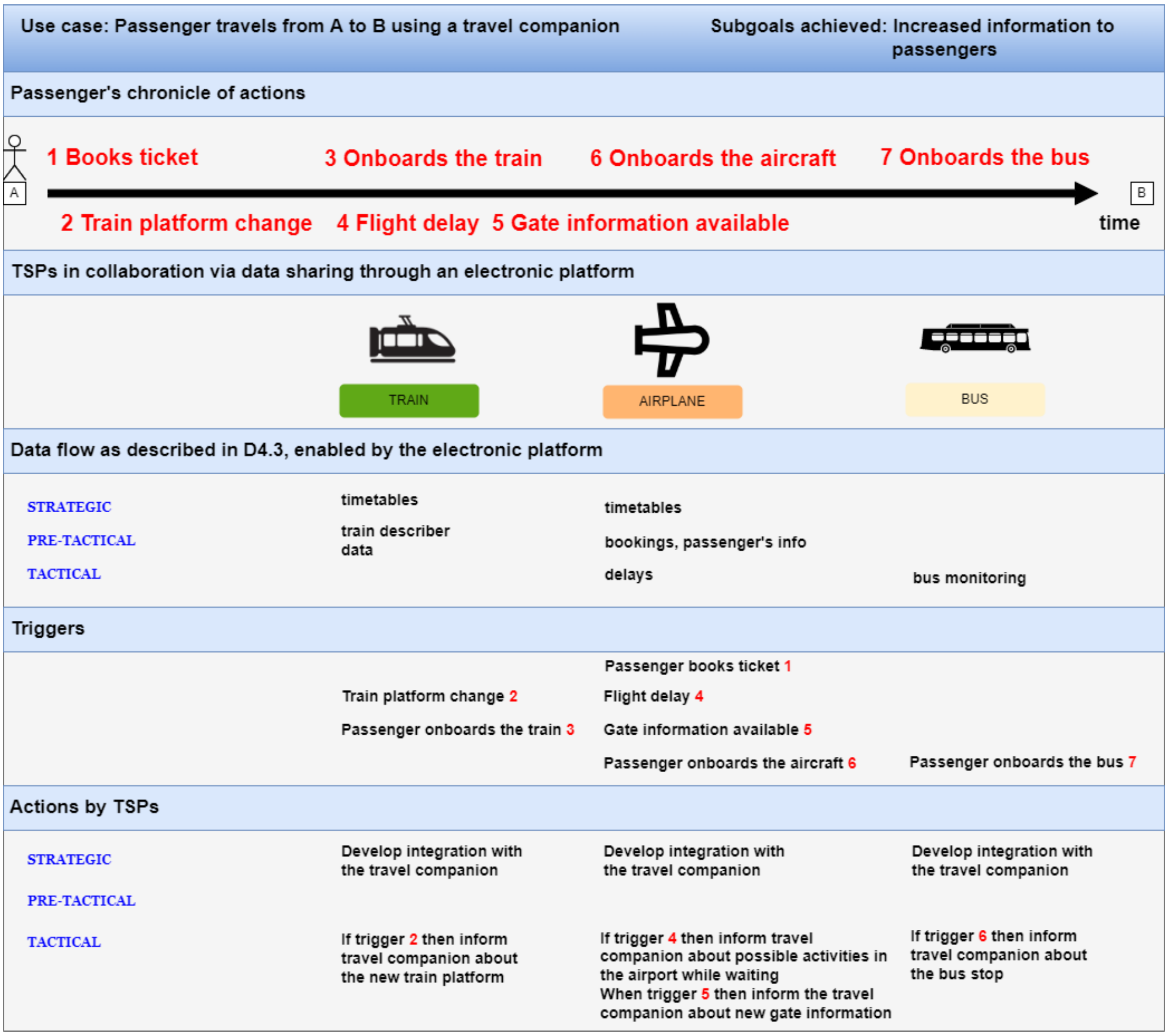

Figure 9 – Passenger informed via a Travel Companion App

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4.8 Offering common products

In the following use case, an example of a business collaboration is depicted. A Train, an Airplane and a Bus TSP offer new products, e.g., travel insurance, to their customers. A horizontal collaboration between them allows them to combine these separate insurances in a common product with the effect of guaranteeing the multi-modal trip through their services. Data on their customer preferences can be exchanged providing a more personalized user experience.

The new train insurance covers costs on incidents like medical emergencies, cancellation or delays, lost baggage etc. The Airplane insurance absorbs these costs into the standard plan of similar services. Similarly, the bus insurance offers the same services and these are also incorporated into the airplane's insurance in their turn.

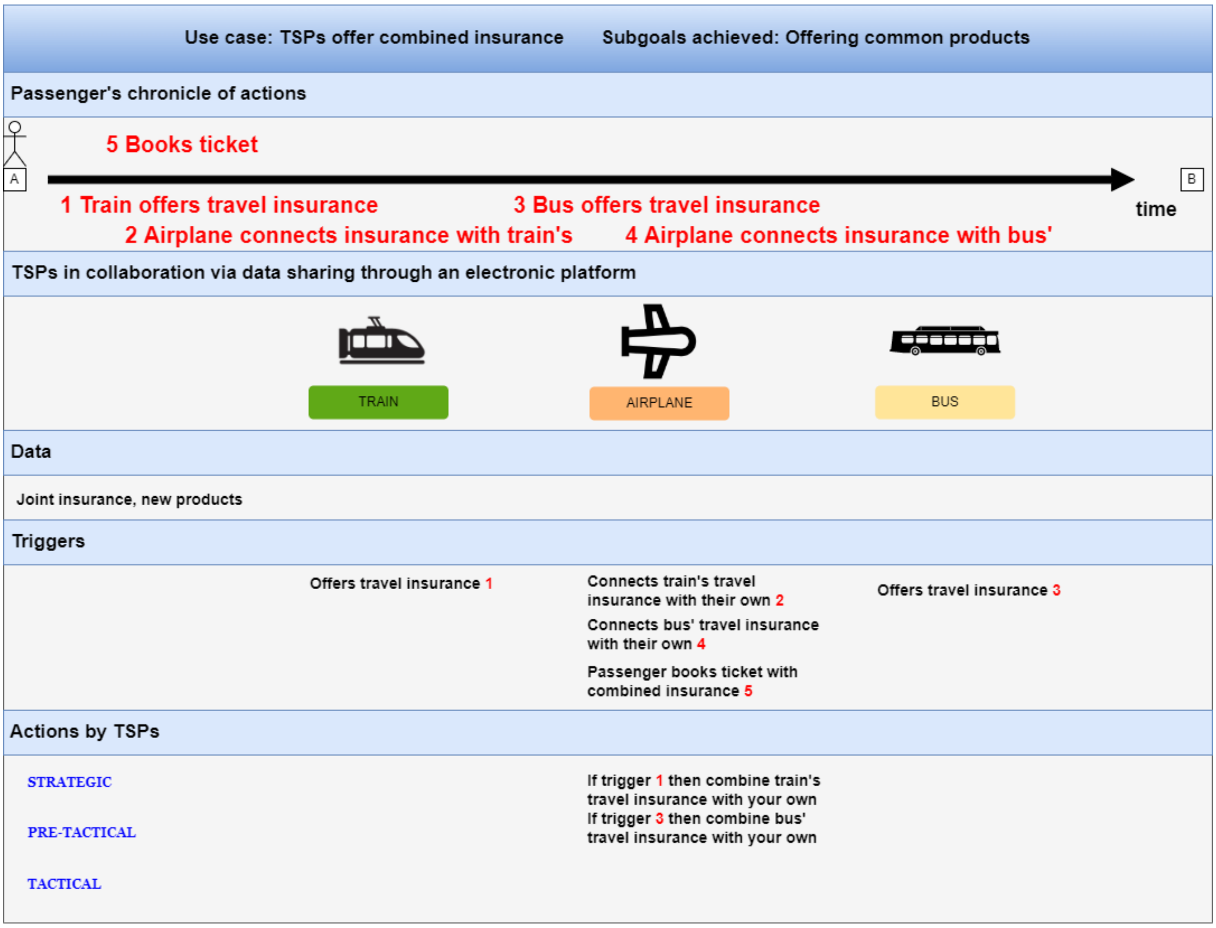

Figure 10 – Offering common products

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4.9 Increased Accessibility

A Train TSP offers a service from location A to location B. After initiating collaboration with a Bus TSP, they decide, through insights from data sharing and pair research, that it is mutually beneficial to cooperate and offer public transport access to place D. The Train adds a stop at place C, while the Bus creates a route and offers trips from place C to place D. After these additions to the network, any passenger who wants can travel from A to D, from B to D or from C to D through the combined services of the Train and the Bus.

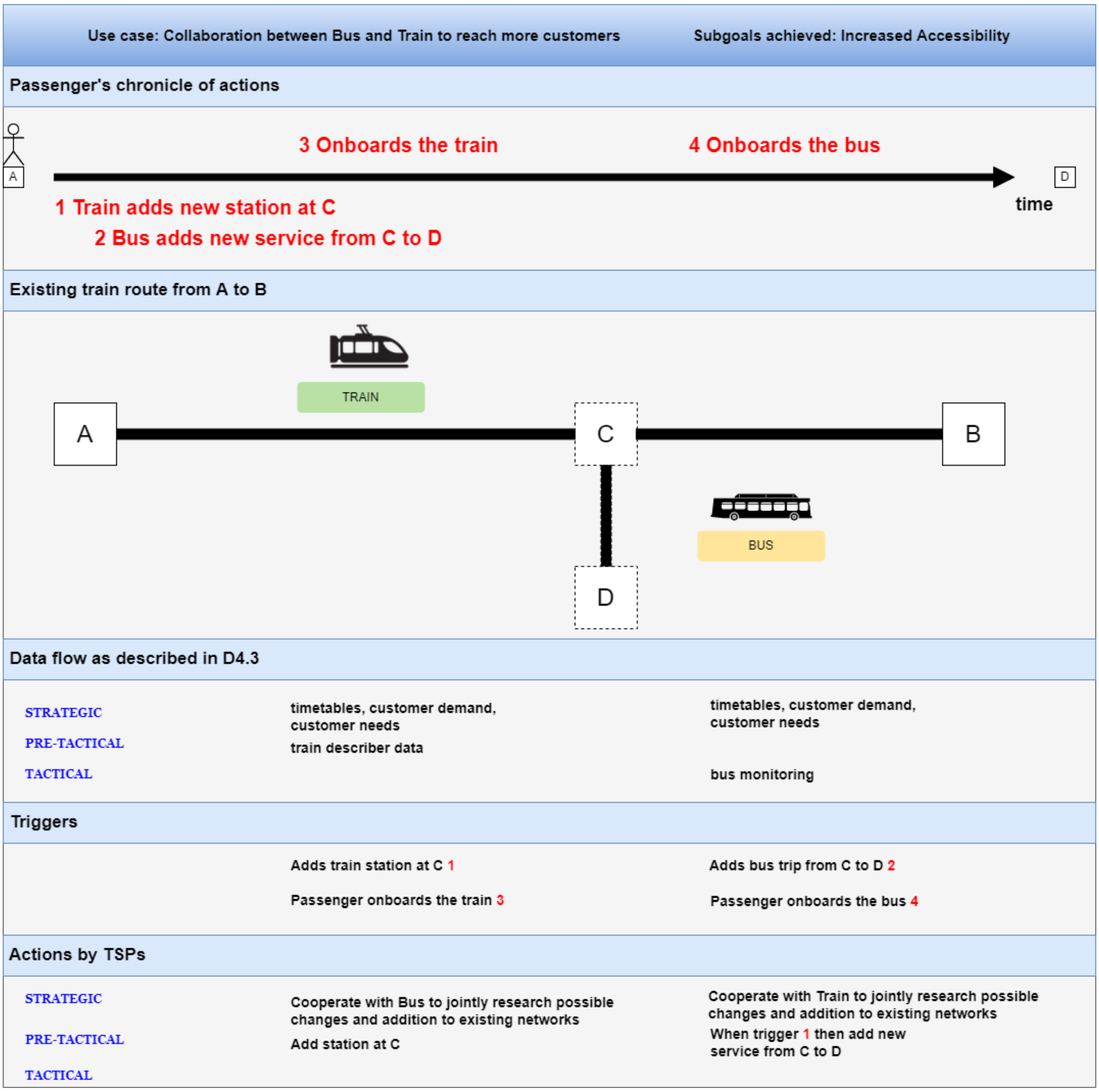

Figure 11 – Increased accessibility

4.10 Asset and personnel sharing

Two Bus TSPs initiate collaboration. They discover that Bus A has unused or underused vehicles in their fleet. At the same time, Bus B has the capacity to lend personnel if asked. Thus, they cooperate to lend each other those resources to increase their efficiency and flexibility at minimum extra costs.

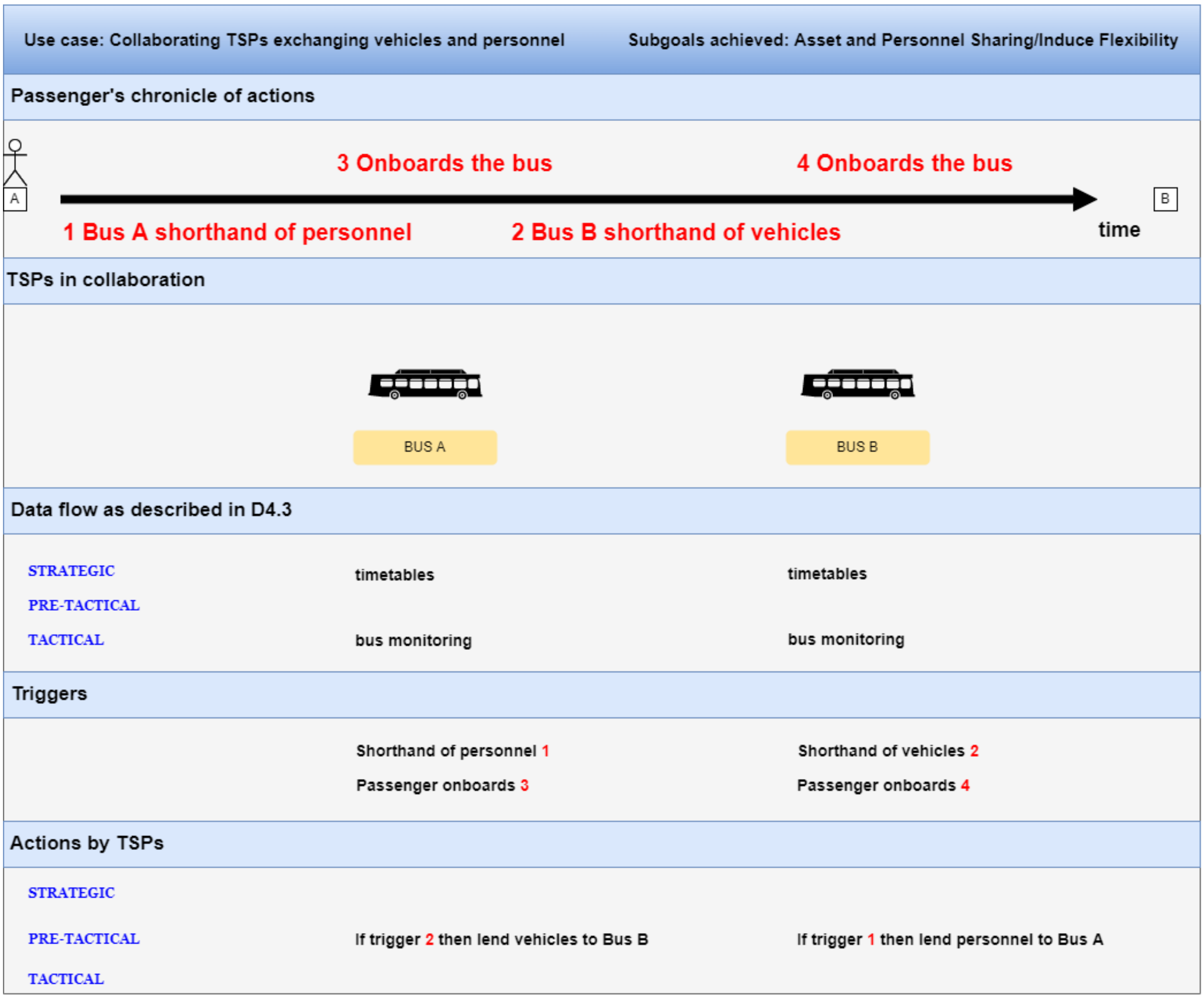

Figure 12 – Asset and personnel sharing

5 Conclusions

Collaborative transportation is the future of the industry and the only way to adapt to new challenges, solve incoming problems and to thrive. In particular, collaborations are paramount for the industry to provide the ideal D2D seamless travel from any two points in the EU, with all the economic, societal and environmental benefits it will bring along. Research shows that companies with collaborative relationships can survive even at times of severe economic stress. Citizens' access to public transportation has been linked to numerous measures of prosperity and life satisfaction, and TSPs in collaboration can improve that by taking common decisions informed by combining their individual information, perspectives, and data. A carbon neutral future absolutely needs the transportation and mobility sectors to take actions now, and collaborations of multiple TSPs towards this goal are crucial.

The UML examples presented few selected realistic use cases for potential collaboration of TSPs and depicted how data sharing can help TSPs achieve multiple objectives. As illustrated, TSPs need to exchange data and take actions in real-time, thus this deliverable sets the foundations for SYN+AIR's main technological breakthrough-proposal, the creation of a Smart Contract Framework, to automate and streamline these actions.

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