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Transportation Research Procedia 72 (2023) 2046–2053

Transportation Research Procedia

www.elsevier.com/locate/procedia

Transport Research Arena (TRA) Conference

Dividing Journeys in Milestones – A passenger (agent) trajectory reference

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Abstract

A journey is more than the connection between starting point and destination. Each person, each cargo passes through several stations until it reaches the desired destination. These stations can pass through similar processes despite the different transport modes and their dimensions (cf. Engler et al.). While the passenger waits at the airport security for the screening of the hand luggage, the cargo container at the port is also checked by customs officials. Both processes have the same objective, namely to investigate the traveling person and the container, for illicit items. It is evident that the start and end points of these processes should be given a similar designation. Dividing journeys in milestones frames a concept for research of interdependencies and interactions between planning and execution of travel chains from the infrastructure owner's and traveler's points of view.

Keywords: Traffic management; trajectory; travel chain; key performance indicators; milestones; intermodal transport.

1. Introduction

The travel process of a person or the transport of an object consists of any number of process points along the entire travel or transport chain until the destination is reached. As individual and diverse as each of the transport routes are, they have many things in common. Each journey can be divided into at least one section, in which various process points or stations are also passed through. Despite different modes of traffic and their dimensions, these process points have similar and therefore comparable images of the structure. For example, if the passenger is waiting at the airport security checkpoint for the carry-on baggage to be screened at the customs checkpoint, a comparable process takes place at a container port where a sea freight container is also checked by the customs authority. Ultimately, both processes have the same function, namely to check the travelling person as well as the transporting container for the

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2352-1465
10.1016/j.trpro.2023.11.687

possible import of illicit goods. It is obvious to give similar names to the start and end points of these process points. Similarly, there will be other comparable process points with a similar structure on the entire journey and the entire transport route. The aim of this paper is to provide and explain the milestones developed to comprehensively describe the start and end points of the entire travel chain in an intermodal manner for both transportation service providers and their customers, the travellers, while providing the service provider the interface for courses of action. It thus serves as a reference work for already recorded milestones and creates the prerequisite for the development of further reference points.

2. Current situation

Journeys made using different modes of transport require successful connections at the transfer points to reach the destination. Because of the manifold possibilities of combining modes of transport, there are already a number of definitions which provide a systematic classification. These include in particular the terms monomodality, multimodality and intermodality. Depending on the question, a further distinction is made between whether the transport offer or the usage behavior of the travelers is addressed.

Monomodally is characterized by the exclusive use of one mode of transport to cover all mobility needs (cf. Klinger). Transport modes are systemically differentiated from each other and reflect the vehicles and infrastructures used. Thus, typical modes of transport exist, such as the rail, the long-distance bus, the ship, the bicycle, etc. On the supply side, multimodality is characterized by the availability of different modes of transport to meet mobility needs. On the demand side, multimodality means that over a defined period of time (e.g., a week, a year, etc.) at least two modes of transport are used on different days to cope with the mobility task. The longer the observation interval is chosen, the more likely it is to encounter multimodal use, because also less frequent changes of transport modes contribute to this classification. On the other hand, intermodality constitutes a special case of multimodality, which does not rely on different modes of transport over a period of time, but uses more than one mode of transport to accomplish a single journey (cf. Gebhardt et al.). This means that there is a combination of partial sections where the transition takes place at transport nodes. The subject of connection protection addressed in this paper thus originates in particular in the intermodal context.

The literature classification of monomodality, multimodality and intermodality helps to classify the necessary case distinctions on the subject of connection protection, but is not sufficiently wide-ranging in all the aspects of mobility that occur. The differentiation on the concept of modes of transport is not automatically the only useful distinction for identifying mobility on offer and individual mobility behavior. Thus, a combination of two trains to cope with the mobility task can be monomodal according to the above definition. At least in the case of two different Rail transport companies (RTCs) whose trains are used in combination, classification is no longer so easy. If one of the train providers may not be a classic RTC, but for example an airline which operates trains with flight numbers as feeder to long-haul flights, the definition reaches its limits. At the latest, the transfer from such a train with flight number to an aircraft of the same airline constitutes a situation beyond the definitional limits.

Perhaps, at least from the traveler's point of view, it is less important that they are aware of the intermodality of their journey, but that the journey is as trouble-free as possible. In particular, the preservation of connections is divided into two different cases, which are entirely independent of the mode of transport behind them, but rather characterized by the diversity of companies behind them. Is it a change between two modes of transport of the same provider or at least of the same transport association or does the passenger also change his contractual partner in addition to the means of transport? Of course, even this structure is not sufficient to address all the needs of travelers during the connection process. The legislator, for example, has laid down different framework conditions depending on the mode of transport, which apply even if the change does not involve a change of provider. For example, air passenger rights under Regulation (EG) 261/2004 relate exclusively to air transport as a mode of transport and regulate, inter alia, cases of delays and compensation claims by travelers. In the case of rail as a mode of transport, comparable conflicts are regulated in the EU Rail Passenger Rights Regulation (EG 1371/2007). In local public transport, which has its own regulations, the change of modes of transport (e.g., tram, bus) is not always evident from the numbering of the lines. In some cases, both tram and bus services are operated from the same platform.

Intermodal long-distance passenger services suffer from the mode-specific nature of regulation because they are hardly offered as an integrated service. As Germany’s largest long-distance transport provider, Deutsche Bahn offers two intermodal interconnection products, "Rail&Fly” and “Lufthansa Express Rail”. The "Rail&Fly”-product is a discounted ticket, which can be booked in addition to purchases of flights to and from German airports. The advantage for travelers is, on the one hand, the fixed discount and, on the other hand, the immediate solution of the arrival or departure requirement on the website of the flight provider and the joint billing of all tickets. The risk of the connection protection remains entirely with the traveler. This is made clear by the fact that no specific train is booked, but only a specific route. Timely use and timely arrival at the gate are the sole responsibility of the passenger. The “Lufthansa Express Rail”-product is a product with an extended range of services, in particular including a transfer guarantee called connection guarantee clause. If the connection is actually missed and the passenger is not responsible for it, he or she will be automatically rebooked to a follow-on means of transport at no extra cost and subsequently transported. This offer is currently limited to 24 departure points in Germany and exclusively to Lufthansa flights at Frankfurt Airport.

From the traveler’s point of view, changing the means of transport at an interchange node always implies a connection risk. Whether the change is intermodal or intramodal often affects the routes to be travelled in between, when each mode of transport typically has its own platform area at a node. From the point of view of connection protection, however, it is important whether it simultaneously leads to a transition to another operator and, if necessary, to other regulations. Even if there is no need for intermodal integrated connection protection based on the current regulatory situation, the milestone-based traffic management approach presented here opens up a new perspective for transportation companies to specifically address customer needs and to offer individually adapted solutions. This approach requires a digital representation of a traveler's travel intention, which he or she shares with the stakeholders involved in the journey for the purpose of collaboration. In this way, each individual demand for transportation is automatically made available for the operational management of transport providers. The knowledge of such an individual demand through a standardized data interface (traveler API) allows and favors cooperative transportation management decisions instead of actions performed in-house, which without such knowledge can only coincidentally approximate the total needs.

3. Milestones´ information description

The linking of information in the context of a journey thus means for the traveler to know the chronology of the journey segments and to take into account temporal relationships. Transport operators provide planned timetable data, which can be updated by real-time applications. If a journey consists of the linking of several stages, it becomes increasingly difficult to maintain an overview. However, the management of the available data relating to the journey can be automated with technical aids. In this way, an overview can be offered to the traveler that clearly presents the current status of his or her entire trip. Automated data processing uses all available information relevant to the journey. For example, these can be arrival and departure times, but also expected operation times at process points that are to be used. Such self-disclosing services are not yet common, but are possible and desirable in the context of a system-wide exchange of information within the so-called Internet of Things (IoT). All important stages of an individual journey are mapped in so-called milestones, which are used to map the individual journey.

When collecting the available information, different data on different milestones are brought together in one data set for that one specific journey. Different data pertaining to the same milestones occur when different sources are used. As mentioned before, static timetable data are readily available, but they do not adapt to current traffic conditions and is therefore no longer a good basis for decision-making for connection assessments during the trip. Updated real-time information corrects these static timetable values. Therefore, different data fields should be kept for each milestone to record the essential information “SCEA”. These consist of schedule information (scheduled), calculated milestones (calculated), real-time based expected values (estimated), and documented sensor acquisitions (actual).

From an operator point of view, the data model is completed by management data fields “ROT”. Request, Offer and Target (ROT) values serve as fields of coordination between different stakeholders while finding a possible solution for traffic management.

All data fields together result in the SCEROTA data format with the claim to be able to assign at least one value to each milestone at any time. Another claim is that the most precise value available is the one that is actually assigned furthest to the right. This value is used as the "BEST" value for the majority of trajectory evaluations and provides the current best possible status of a travel chain at any time. The following table shows the description of the different values.

Table 1. SCEROTA data fields

Connection of the data fields
SCHEDULED-values are based exclusively on the timetable information of the selected means of travel.
CALCULATED-values represent milestones that are determined by calculating back from the next SCHEDULED-value in the future. The process durations required for back-calculating represent arbitrary assumptions.
ESTIMATED-values represent milestones that are determined by forward calculation. The previous BEST-value is always used to determine the next milestone value. As with the CALCULATED-value, an arbitrary assumption for the process duration is used. The BEST-values are also used for managed processes. If there is an update of the travel chain, for example due to individual decisions of the traveller or due to disruptions in the operational process, new estimated values are immediately calculated on the forecast based on this information.
ACTUAL-values are documented sensor values for milestones.
REQUESTED-values are management requests to influence the TARGET-values.
OFFERED-values are system owner responses to management requests to influence TARGET-values.
TARGET-values are the targets for milestones to be achieved by the milestone object.
BEST-values are those values from the SCEROTA data schema that are furthest to the right for each milestone.

The milestones follow a uniform notation to ensure the comparability of the corresponding stations. The notation is based on the Airport collaborative decision-making (A-CDM) of Eurocontrol (2017). The first letter results from the data quality described above. The second letter defines the mode of transport. The third letter can indicate the process status and the fourth letter the actual process. The last letter defines the value range. The table below illustrates the notation of the milestones.

Table 2. Milestone definitions

Data quality		Range marker		Ident 1		Ident 2	Data type	
S, C, E, R, O, T, A		O, I, A, L, S, U		A, P, C		A-Z	T, D, P, N, R	
S	scheduled	O	outbound	A, P	Agent reaches process point		T	time
C	calculated	I	inbound	C	Agent has completed process point		D	duration
E	estimated	A	airside				P	portion
R	requested	L	landside				N	number
O	offered	S	seaside				R	rate
T	target	U	unknown					
A	actual							

For a terrestrial transport node such as a train station or a bus stop, four milestones are sufficient to map the transport linking function of such an infrastructure, as shown on the following table.

Table 3. Milestones of a train station

Milestone	Milestone (long version)	Meaning
LPPT	Landside Passenger at Platform Time	Train stopped at the platform and the doors open.
LCPT	Landside Checked at Platform Time	Passenger has left the train and is standing at the arrival platform.
LPDT	Landside Passenger at Departure (Platform) Time	Passenger standing by at the departure platform.
LCDT	Landside Checked at Departure (Platform) Time	Passenger has entered the train.

However, when there is a modality change at a transport node the complexity of the linking function can increase significantly. In particular, the airport or seaport with its upstream processes of check-in and security as well as customs and passport control requires significantly more milestones to describe the conditions. Thus, only for the description of the departure process the following milestones are necessary at an international transport node.

Table 4. Example of Milestones at an international Transport node (e.g. airport and port)

Milestone	Milestone (long version)	Meaning
OPAT	Outbound Passenger at Airport Entrance Time	Passenger arrives at the airport.
OPCT	Outbound Passenger at Check-in Time	Passenger stands at the check-in.
OCCT	Outbound Checked at Check-in Time	Passenger is checked in.
SCCT	Seaside Checked at Check-in Time	Agent/Passenger is checked in (Port)
OPST	Outbound Passenger at Security Time	Passenger is at the security checkpoint.
OCST	Outbound Checked at Security Time	Passenger is security checked.
OPET	Outbound Passenger at Emigration Time	Passenger is at passport control.
OCET	Outbound Checked at Emigration Time	Passenger's identity has been verified.
OPGT	Outbound Passenger at Gate Time	Passenger is waiting at the gate.
SPPT	Seaside Passenger at Platform Time	Agent/Passenger is ready to board the ship (Port)
OCGT	Outbound Checked at Gate Time	Passenger is boarded. Boarding pass has been scanned (Airport)
SCPT	Seaside Checked at Platform Time	Agent/Passenger is boarded towards the ship (Port)

The number of milestones increases significantly, especially if certain processes at a transport node are mandatory for further progress. This is also the case at a seaport, for example (cf. Noyer et al. 2021).

Milestone definitions as listed above are intended to provide a standardized mapping for the different processes within the transport system. At the same time, they must be sufficiently precise and meaningful according to the context to avoid a multitude of required special solutions. The suggestions for naming and using the milestones addressed in this paper therefore attempt to realize a certain generality. They primarily address passenger-related processes within transport nodes, where travelers cover distances on their own. Within vehicles, travelers can be easily associated with their trajectories, as they can be collectively and securely tracked during transportation (cf. Rudolph et al. 2021).

4. Key performance indicators calculation

If milestones are set in relation to each other, key performance indicators (KPIs) can be derived from them to determine performance. Among other things, the duration of a process can be defined by the start and end points. If, for this purpose, the milestones OPGT (reaching the gate) and OCGT (as the time of the personal boarding start) are taken from the example in Chapter 3 in the best available data quality and set in difference to each other, the Usable Traffic Time can be determined from this as a KPI. In this case, this KPI represents the time that the passenger has at his or her disposal at the airport and is one of the essential evaluation criteria for the economic consideration of certain measures (cf. Scheelhaase et al. 2022).

The following table shows a selection of the KPIs to be collected and their calculation rule based on milestones. The KPIs can thus be determined for each individual agent from the overall simulation. By aggregating the KPIs of all agents, corresponding indicators can be created for the entire system or also for specific sub-areas as well as time-based dimensioning. If the first letter is not explicitly specified, either the qualitatively highest one always applies or the data quality is adopted.

Table 5. Description and calculation of the KPIs

Name	Description	Calculation
Turnaround Speed	Calculated by dividing the start and end of processes at a transport node by the number of agents or passengers. Results in an evaluation measure of the efficiency of a traffic node	
	Landside	$\frac{\max[LCPT]-\min[LPPT]}{count(Passengers)}$
	Seaside	$\frac{\max[SCCT]-\min[SCPT]}{count(Agents, Passengers)}$
	Airside	$\frac{\max[OCGT]-\min[OPAT]}{count(Passengers)}$
Agent Dwell Time (Lead Time)	How long does an agent stay at the traffic node?	Agent is registered for the first time at the transport node in relation to the entering and loading of the following vehicle
	Seaside (Freight)	$[SCPT - SCCT]$
	Landside	$[LCDT - LCCT]$
	Airside	$[OCGT - OCCT]$
Boarding Score (Passengers)	Do the agents reach the following mode at a transport node in time at the given point in time (1 = true; 0 = false).	x corresponds to the time factor for the arrival before the actual related event.
	Seaside	$OAPT < \left[(\mathrm{ATD}-x) \geq \mathrm{Cut}_{(of_{Date})}\right]$
	Landside	$LAPT < [Scheduled\ Departure\ Time - x]$
	Airside	$OPGT < [TOBT - x]$
Moves Count	Utilization of the transport node related to agents.	
	Seaside	*count (SCCT)*
	Landside	*count (LCPT)*
	Airside	*count (OCCT)*
Usable Traffic Time	Time for the agent, which cannot be used for the actual journey at the transport node and is thus at the agent's free disposal.	
	Seaside	$SCPT - SPPT$
	Landside	$LCPT - LPPT$
	Airside	$OCGT - OPGT$
Delay Time	Deviation of the time of the precalculated (calculated) milestones to the following updated milestones	
	Seaside	$(BEST(SCPT) - CALC(SCPT))$
	Landside	$(BEST(LCPT) - CALC(LCPT))$
	Airside	$(BEST(OCGT) - CALC(OCGT))$

5. Examples of use

The concepts of milestones and the arithmetic calculation of KPIs presented in chapters 3 and 4 provide the user (which can be both the transport operator and the passenger) with information about the passenger's connection protection. In addition, this provides information about the overall utilization of a transport operation up to the evaluation of the transport system under consideration. Information about one's own journey can be offered to the user, for example, via a mobile application that displays current information about the user's complete travel chain and derives certain service indicators from this, such as freely available buffer times. A first concept was presented in Milbredt et al. (2016) and further developed in Milbredt et al. (2018) to the current state in Grunewald et al. (2020). The following figures of the further development of this concept shows which milestones and KPIs can be applied to the individual user. On the other hand, the transport operator can use an aggregated representation of all users in relation to the vehicles operated as a feedback channel to make statements about the connection protection of individual transport users. Thus, a graphical representation of the $KPI_{(Boardingscore)}$ as a core element of this connection assurance can form conclusions about the status of individual elements of the transport system.

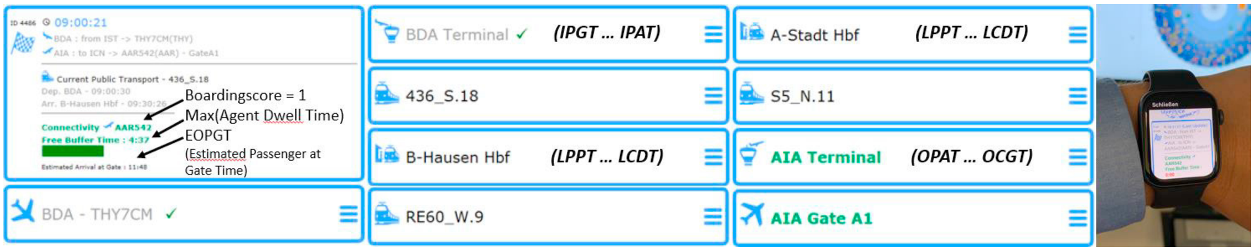

Fig 1. Concept of a traveler API and the milestones used (Grunewald et al., 2020)

The representation of the app shown in Fig 1 is roughly based on established mobility and traffic information services and provides the user with important information and updates about individual modes of transport of his journey, as well as the final arrival at the destination. However, the milestone concept presented goes far beyond a mere information display through the feedback channel, as it provides the service provider with conclusions about expected and possibly avoidable bottlenecks. In addition, it calculates the effects of regulatory measures to be implemented in the forecast (e.g. prioritization, cf. Grunewald et. al. 2014).

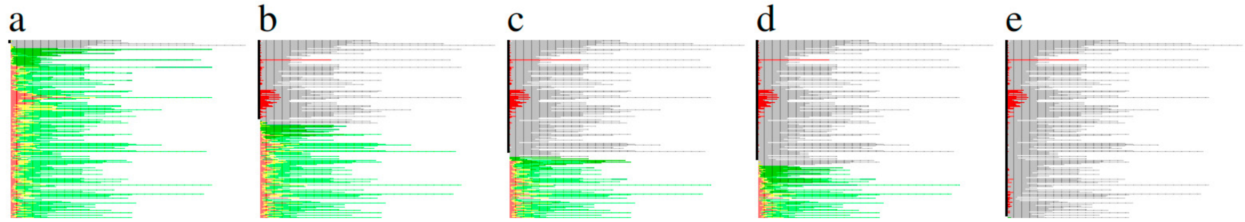

Fig 2. Visualization KPI(Boardingscore) (a) Time t = 360min; (b) Time t = 722min; (c) Time t = 935min; (d) Time t = 1001min; (e) Time t = 1230min (Milbredt, 2016)

Fig 2 shows a plot of the $KPI_{(Boardingscore)}$ over time, which complements the metrics proposed by Cook et al. (2013) and Laplace et al. (2014) on passenger-centric KPIs for delay times and additional wait times. The rows mark the individual vehicles in their temporal order. The length of the lines is proportional to the number of passengers assigned to the vehicle. Each pixel displayed in this way corresponds to a passenger. Pixels marked in red correspond to a boarding score of 0 (= failed) for that passenger, while green represents a boarding score of 1 (= for reaching the vehicle on time). This type of representation was performed five times during the period under consideration. Passengers that are no longer active in the transport system are represented with gray pixels, while passengers that have not yet been recorded in the transport system under consideration but are still expected in the forecast are given a lighter hue (cf. Milbredt et al. 2016). In the figure, red areas (failed boardingscore) can be seen, indicating a disruption in the system. In the temporal representation, it can be seen well that in (a) the disruption was detected early before it finally arrived ((b)-(e)). This conceptual example shows well how the KPIs are used to predict a disruption, and further, conclusions about dimensioning can be visualized. The minimization of the disruption can then be done by the management of the transport operator.

6. Conclusion and outlook

In the examples, it can be seen that the concept of milestones and the resulting KPIs created a tool to evaluate the performance of a transport system. A potential system has been presented that is able to visualize disruptions that affect KPIs and classify their impact. On the other hand, the traveler can find out the status of his own journey at any time on the basis of his own milestones. Furthermore, the milestone calculation provides a more detailed basis for calculating travel time savings (Subjective Value of Travel Time Savings; VTTS) as applied, among others, in studies on the value of time the "Value of Time Study" by Axhausen et al. (2015). The above discussion and the presented ideas of the concept should be reflected in the light of innovative projects, such as Flightpath 2050 (ACARE 2012), in particular the 4-hour door-to-door goal (Grimme et al. 2019) could be well represented by milestones and KPIs.

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