Towards a functional, transport-market-oriented definition of regional traffic

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Abstract

In literature, many authors address issues related to regional traffic. However, there is no clear and agreed definition of what regional traffic actually is, especially regarding its delimitation from long-distance traffic, but also from city & agglomeration traffic. Practice in different countries across Europe uses many different approaches to set the boundary between long-distance traffic and regional traffic. Most of them are dominated by regulatory and financial aspects rather than transport-system-based considerations.

First of all, this paper will provide an overview of definitions currently used in practice and literature across Europe in general and Switzerland in particular, including their respective advantages and disadvantages. Afterwards, it will propose a generic transport-market-oriented definition, which allows assigning a given line of public transportation with a given demand pattern to either regional traffic, long-distance traffic or city & agglomeration traffic.

Keywords

regional traffic, long-distance traffic, agglomeration traffic, functional role, definitions

1 Introduction

The question of what regional traffic actually is has been debated for a long time by researchers and practitioners. Most current definitions in Europe, especially when delimiting regional traffic from long-distance traffic, are more dominated by regulatory and financial considerations, rather than taking into account the transport system's perspective. This paper seeks to fill this gap by investigating the following hypothesis:

It is possible to give a functional definition of regional traffic based on the service characteristics distance, travel times and demand on the one hand, and the respective performance limits of buses and trains as laid down by Sinner and Weidmann (2017) on the other hand.

2 Review of practice and literature

This section provides an overview of how the definition of regional traffic has been handled in practice in different countries and how scientific literature over the past decades has been approaching this issue.

2.1 Terminology

In the German-speaking countries, the term *"Nahverkehr"* is frequently used to describe all forms of short-distance traffic (including local, city and agglomeration traffic) with the deliberate exclusion of long-distance traffic (Höhnscheid, 2000). The abbreviation ÖPNV is used as a synonym.

2.2 The definition of regional traffic in practice

2.2.1 Switzerland

In Switzerland, the definition of regional traffic has been debated in policy documents for almost 50 years. Already in the 1970s, *Gesamtverkehrskonzeption Schweiz* [1] aimed to address this issue

[1] The conclusions of this report became part of the constitutional article on the *Koordinierte Verkehrspolitik* which was rejected in a popular vote in June 1988 (Güller, 1988).

(Eidgenössische Kommission für die schweizerische Gesamtverkehrskonzeption, 1977). While stating that short-distance traffic can be understood as inner-regional traffic below 30 km distance and 45 min travel time, it does not further elaborate to what extent it is identical to or different from regional traffic, neither how the latter is to be defined. It only defines national traffic competences (on the level of the Swiss Confederation) to include national and international long-distance traffic as well as the connection of regions and country parts among each other (Kaspar, 1987). Regional traffic competences could only be read as the complement to the national ones (Güller, 1988).

Furthermore, the term *"Gemeinwirtschaftliche Leistungen"* (to be translated as *'services on public accounts'*) is used to describe public transport lines not being able cover their costs through fare revenues. They are thus subsidized under public service contracts by cantonal and federal government(s), as their operation is considered as a contribution to achieve certain policy goals (e.g. environmental protection, social welfare, etc.). It is explicitly stated that short-distance traffic is the principal segment of application of services on public accounts and that the latter are excluded in long-distance traffic. Although the term regional traffic is used throughout the report to refer to short-distance traffic with the deliberate exclusion of local and city traffic, it is never explicitly defined as such.

The concept of delimiting short and long-distance traffic by the criterion of the presence - or absence - of a public service contract is still in place as of now. However, it shall be noted that not all long-distance train lines can cover their costs through fare revenues. Inside the basket of long-distance train lines (defined in the concession granted by the Swiss Federal Office for Transportation (Bundesamt für Verkehr, BAV) to SBB), profit-making lines cross-subsidize loss-making lines (Schweizer Eisenbahn-Revue, 2017). In the sum, the entire basket of long-distance lines is profitable.[2] While there are both profitable and non-profitable long-distance lines, the same is also true for lines under public service contracts. Although the majority of lines in regional, city or agglomeration traffic rely on subsidies, there are a few lines in the agglomeration traffic around Zurich (e.g. eastern branch of S12 between Zurich and Winterthur) that have a cost-coverage-ratio of more than 100 % (Kanton Zürich, 2016).

In a preparatory study for the elaboration of guidelines on the design and funding of regional (public) transport, Güller (1988) shows that different Swiss laws and concepts apply a multitude of different definitions for regional transport. Among them, the mandate of SBB (Leistungsauftrag 1982, respectively 1987) assigns regional traffic to 'services on public accounts', while long-distance traffic is considered as market service on own accounts ("marktwirtschaftliche

[2] It is important to note that in this context 'profitable' always is to be understood under the assumption of current infrastructure tolls according to Swiss law. They do not cover the full costs of the infrastructure, but are explicitly defined as only covering the short-term marginal costs.

Leistung"). Güller (1988) calls this distinction the *upper segmentation* of regional traffic. At the same time, he also introduces a *lower segmentation* which separates regional traffic from local and city traffic ("Ortsverkehr").

The current Swiss ordinance on the funding of regional passenger transport (Schweizerische Eidgenossenschaft (2015), Verordnung über die Abgeltung des regionalen Personenverkehrs (ARPV)) upholds this distinction of regional versus local traffic. While the Confederation and the canton jointly finance regional transport, local and city transport is explicitly excluded from financial contributions by the Confederation. However, this ordinance does not further elaborate on the upper segmentation of regional traffic. It only states that it is traffic within a region, without further defining the term 'region'.

Only in 2017, in the perspective of the reallocation of the long-distance concession, Bundesamt für Verkehr proposed a guideline on how the distinction between short-distance traffic, including regional traffic, and long-distance traffic shall be handled (Bundesamt für Verkehr (BAV), 2017). It is based on "Raumkonzept Schweiz" (spatial concept of Switzerland) by the Swiss Federal Office for Spatial Development (Bundesamt für Raumentwicklung (ARE), 2016). This concept divides Switzerland in 12 so-called action areas ("Handlungsräume", FIGURE 1). According to the guidelines by BAV, a train line is considered long-distance traffic, if it provides the fastest

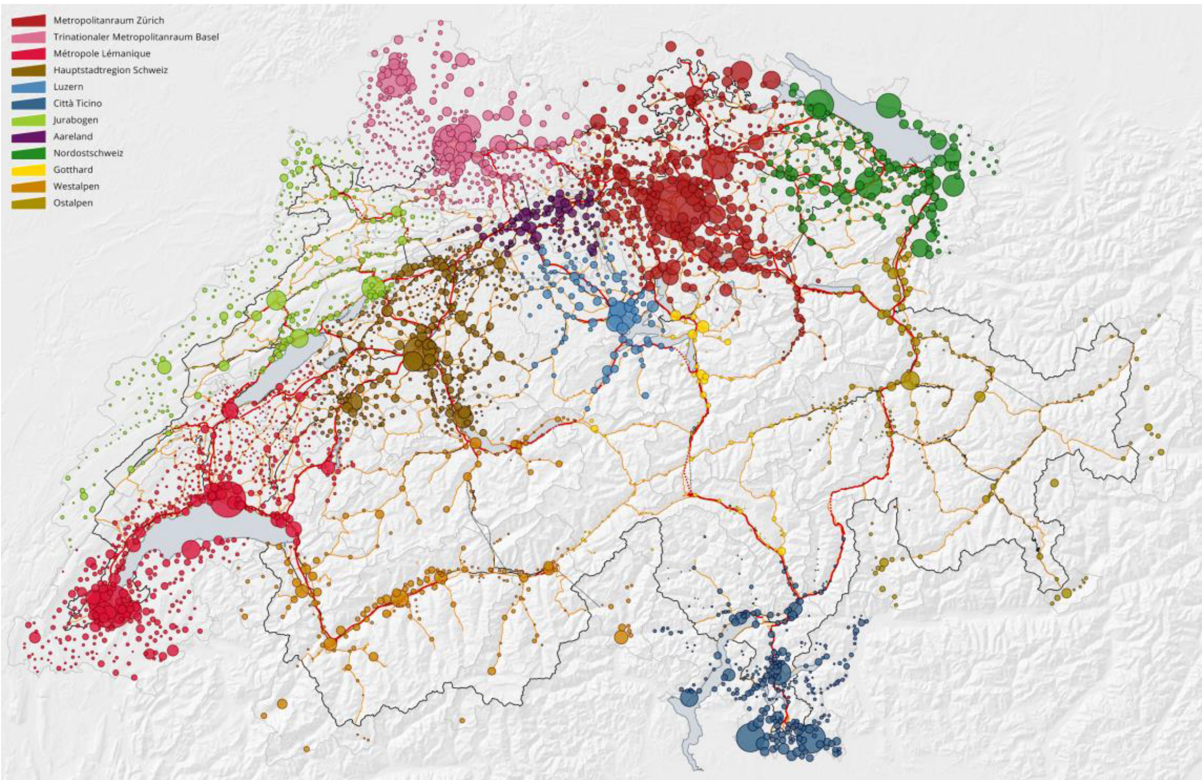


FIGURE 1: Action areas of "Raumkonzept Schweiz"
Source: Bundesamt für Raumentwicklung (ARE) (2016)

connection between middle-size-cities (or larger) in at least two different action areas. With this concept, some lines will be newly integrated into the long-distance basket, while other fall out of it. The set of long-distance lines is thus not static over time.

2.2.2 Germany

The so-called 'regionalization law' (Bundesrepublik Deutschland (2016), "Gesetz zur Regionalisierung des öffentlichen Personennahverkehrs", in short form "Regionalisierungsgesetz", original version passed in 1993), which delegates the power to organize and fund short-distance public transport to the German states (Bundesländer), defines the latter as line-based passenger transport which satisfies demand in city, local or regional transport (Schnieders, 2010). As a guideline, it states that in case of doubt, a line is to be considered satisfying regional demand if - for the majority of its passengers - travel distance does not exceed 50 km or travel time is below one hour. Following this definition, it is very well possible that the total line length of a regional train line can be more than 50 km, under the condition that most passengers' journey remains below the aforementioned thresholds.

Meyer (1994) further elaborated this concept by introducing another category in-between regional traffic and long-distance traffic: the one of regional express traffic (Table 1). The transport market he characterizes as regional traffic corresponds almost exactly to the definition given by the 'regionialization law'. However, the market of regional express traffic is without any doubt situated beyond the limits set by the latter. With that, Meyer (1994) in fact anticipates a trend one could observe over the last years: the trend towards longer (and faster) 'regional' services satisfying transport demands of significantly more than 50 km or one hour of travel time (Weidmann, 2007). Two main patterns can be identified in this context:

Table 1: Delimitation of transport markets according to Meyer (1994)

	City traffic	**Regional traffic**	**Regional express traffic**	**Long-distance traffic**
Route length	< 20 km	< 60 km	< 150 km	> 150 km
Top speed of rolling stock	80 km/h	100 km/h	120 - 140 km/h	> 160 km/h
Average speed	30 km/h	40 km/h	60 km/h	> 80 km/h
Average journey time	0,5 h	1 h	2 h	> 2 h

- With the withdrawal of long-distance traffic (operated under the sole commercial responsibility of DB Fernverkehr) from several more peripheral regions over the previous years, the German states were forced to step in by tendering the corresponding replacement services. In these cases, the main function of these long and fast 'regional' lines is to connect areas not served by long-distance-traffic to the major centers and to the subsisting long-distance network.

- Other states tender services running parallel to existing long-distance services and providing almost as fast connections as the latter do. The most prominent example is the Munich-Nuremberg-Express, which runs via the high-speed line connecting the two cities. Among other reasons, the State of Bavaria aimed to create an affordable connection between its two largest cities, which accepts regional tickets and passes sold at lower fares than the competing ICE tickets.

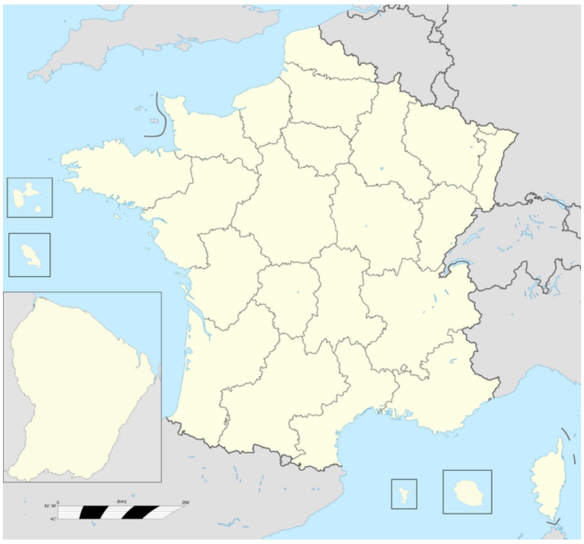
According to Barth (2000), one could argue in both cases that these lines satisfy regional demands, if the region is considered equal to the entire state. She further points out that a margin of interpretation exists in this matter and that the law does not specify which institutional level is entitled to make use of it.

2.2.3 France

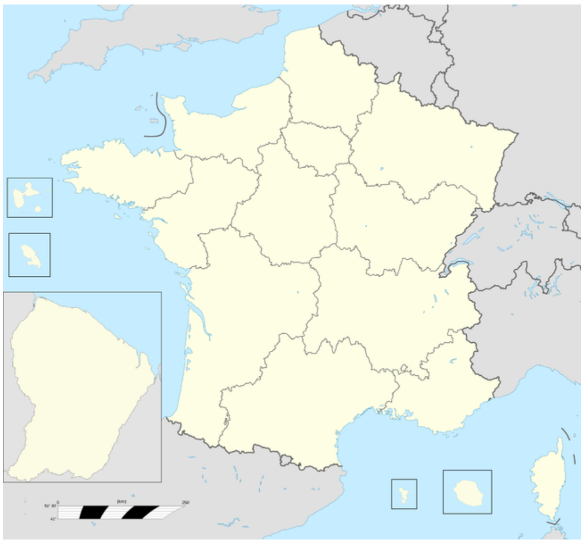
The French orientation law on domestic transport (République Française (2000), "loi d'orientation des transports intérieurs", abbreviated LOTI) provides a very fuzzy definition of what shall be understood by 'regional railway transport' to be organized by the then 22 regions[3] of (metropolitan) France. The latter is defined as all traffic happening on the national railway network with the exception of services of national interest or international services (Schnieders, 2010).

In practice, however, this fuzzy definition had several shortcomings. Regions were mostly taking care of traffic within their own jurisdiction, while cross-regional traffic that could not be qualified of national interest was somehow neglected, since there was no defined responsibility for inter-regional traffic. In areas where two administrative regions border, this sometimes resulted in gaps in the public transport coverage, as no through-services were offered. As part of traffic of national interest, the central government took care of a number of secondary, inter-regional, long-distance services outside the TGV high-speed network. Most of these services covered

[3] Here the term 'region' refers to the administrative division of the French territory in contrast to functional spaces according to spatial planning. Most administrative regions include more than only one functional region within their jurisdiction.



(a) before territorial reorganization
Image source: Wikimedia Commons [4]



(b) after territorial reorganization
Image source: Wikimedia Commons [5]

Figure 2: French regions

tangential relations (opposite to radial lines emerging from Paris) and were also referred to as "trains d'équilibre du territoire" (abbreviated TET, trains for territorial balance).

After the French territorial reform of 2015, which brought the number of regions in metropolitan France from 22 down to 13 (Figure 2), several relations that were before inter-regional became intra-regional. In this context, the government was also keen to pull out of its function of organizing authority of most TET-trains and passed the responsibility to the respective regions in exchange for funding new rolling stock. Some of the new French regions (Figure 2(b)) now cover areas that are larger than some neighboring countries like Belgium or Switzerland. In the future, there might thus be 'regional' trains covering distances of 200 - 300 km. This shows to what extent the notion of regional is on the one hand dependent on administrative divisions, which can be subject to change, and on the other hand, mirrors the spatial structure of the respective country (Keller, 2017, Weidmann, 2007).

[4] Image Credit: Blank map of France's 27 regions at the same geographical scale, by Rosss [licensed under CC BY-SA 3.0, *https://creativecommons.org/licenses/by-sa/3.0*], accessed on 2017-09-26 via Wikimedia Commons, *https://commons.wikimedia.org/wiki/File:France_fond_de_carte_27_r%C3%A9gions.png*.

[5] Image Credit: Base map of France with 18 regions, by Chessrat at English Wikipedia [licensed under CC BY-SA 3.0 *https://creativecommons.org/licenses/by-sa/3.0*], accessed on 2017-09-26 via Wikimedia Commons, *https://commons.wikimedia.org/wiki/File:France_base_map_18_regions.png*.

2.2.4 European law

European law does not provide a definition a regional traffic. Directive 91/440/EEC (European Communities, 1991), which is the very first legal text establishing open-access to railway infrastructure, explicitly exempts city, agglomeration and regional traffic from its scope of application. However, regional traffic is only defined as the transport services satisfying the needs of a region without going further into detail on the definition of a region.

Regulation (EC) 1370/2007 (European Union, 2007), which outlines the rules governing the tendering process of public service contracts, is not limited to regional services. The frequent division between commercial market-financed long-distance traffic and publicly procured short-distance and regional services is a mere consequence of the inability of most short distance services to generate sufficient yield at affordable fare prices. Legally speaking, public tendering of long-distance services is perfectly possible, same as there could be commercial short-distance services (with certain restrictions to protect existing tendered services). In the UK for instance, the franchise system does not make any distinction between agglomeration, regional or long-distance services. While there are some franchises that include only short-distance or only long-distances services, others are mixed.

2.3 The definition of regional traffic in literature

The issue of regional traffic has been part of scientific debate for more than 50 years. This section provides an excerpt of the corresponding literature published in Switzerland and Germany. As one of the first publications devoted to public transportation subsidized by governments, Wagner (1965) defined short-distance traffic (referred to by Öffentlicher Personennahverkehr) as the one occurring either inside towns or between neighboring towns. According to his definition, train services would be part of long-distance traffic. In that respect, the definition by Wagner (1965) differs from the current one given by Höhnscheid (2000).

In the 1980s, the issue of regionalization of public transport became a prominent issue in literature. Here, the term 'regionalization' describes the process of decentralization of certain competences in public transportation to lower levels of government (Rieder, 2005). The main idea is the concentration of policy competences, financial and planning responsibility for public transport services on the level of government (municipality, canton, Confederation) most affected by it. This concept has to be seen in the light of the normative principles of federalism and subsidiarity (Rieder, 2005, Berger et al., 2009). Subsequently, financial contributions to so-called 'services on public accounts' shall be borne by the level of government in whose interest the concerned services are (Brändli and Kobi, 1978, Kaspar, 1984).

At this time, Boos (1983) and Kaspar (1984) were the first ones discussing the segmentation of the public transport in order to assign its lines to the different levels of governments as laid down in the principles of regionalization. Boos (1983) proposes to base the definition of regional traffic on three criteria (FIGURE 3):

1. travel time or distance,
2. the functional role in the transport system (access versus connection),
3. the spatial structure of the area under consideration (urban versus rural).

This concept is to a certain extent comparable to the one used by Güller (1988): the first two criteria act as the upper segmentation to divide regional traffic from long-distance traffic. The third can be seen as a form of lower segmentation with the purpose of the exclusion of agglomeration traffic. In this respect, it slightly differs from the concept proposed by Güller (1988). While the latter separates regional traffic from local and city traffic, Boos (1983) does likewise for agglomeration traffic. In one aspect, the definition of regional traffic by Boos (1983) is wider than the one by Güller (1988), as the former also includes local traffic in small rural

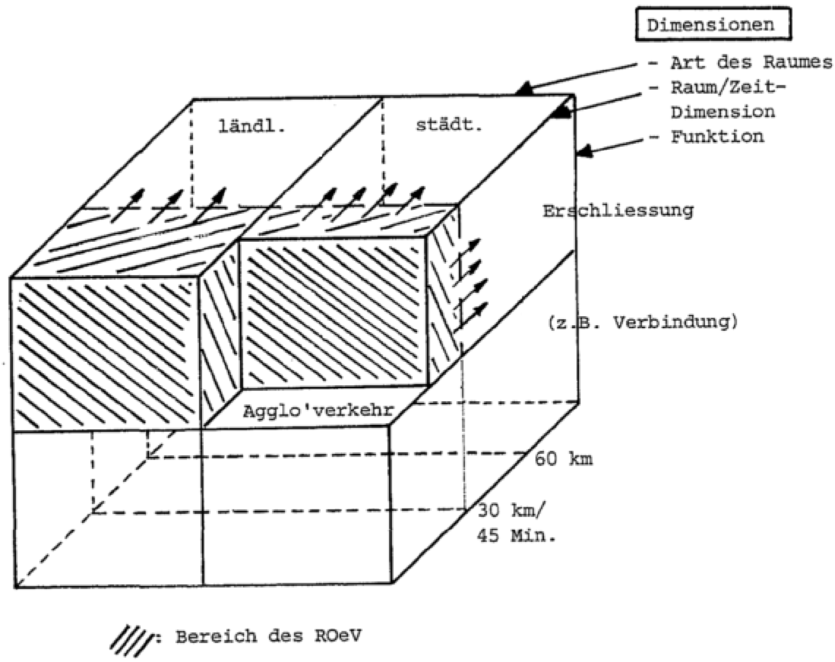


FIGURE 3: Definition of regional traffic according to Boos (1983)
Source: Boos (1983)

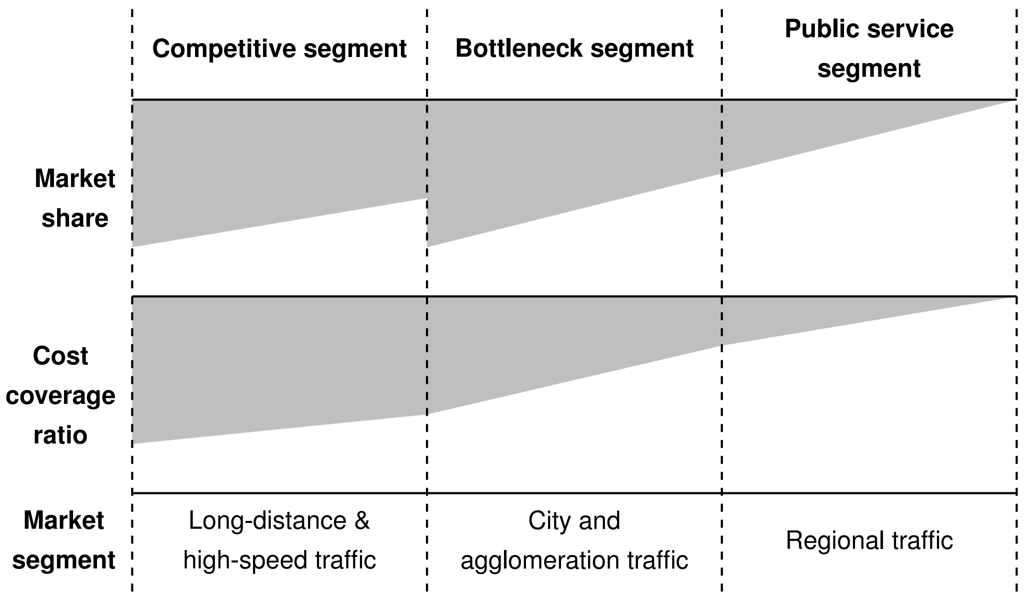


FIGURE 4: Market segments of public transport
Representation after Weidmann (2013)

towns; in another aspect, the former is narrower, as it excludes in agglomerations traffic beyond the core city. Strictly speaking, the definition by Boos (1983) is not only a lower segmentation but also a lateral one, as FIGURE 3 illustrates very well. Kaspar (1984) goes in the same direction by adding the aspect of the bottlenecks on the road network as an argument for the separation of regional traffic on the one hand, and agglomeration traffic on the other hand. The concept of bottlenecks on the road network is relevant in the sense that these bottleneck are the foundation for a comparable advantage of public transport: the one travel time reliability. This idea is later on reiterated by Weidmann (2007, 2013) who divides the public transportation market into three strategic segments as shown in FIGURE 4 [6]:

- In the *competitive segment*, public transport can benefit of comparative advantages such as higher speed, high traffic volumes, etc. It corresponds to long-distance and high-speed traffic between larger cities. In this market segment, public transport can generate sufficient yield through fare revenues to cover its costs.

- In the *bottleneck segment*, which corresponds to city and agglomeration traffic, the bundling of demand on collective means of transportation is required in order to evacuate

[6] A slightly different development of the ideas by Boos (1983) and Kaspar (1984) can be found in Brändli (1988) who further splits up agglomeration traffic into two segments depending on the main driver behind its promotion: 'only' relief of individual traffic for the sake of preventing the system from collapse or more comprehensive substitution of individual traffic driven by higher considerations such as but not limited to environmental protection in various aspects, spatial planning, etc.

the given transport demand on a limited traffic surface. Given the wider public interest, operation is generally subsidized by public authorities.

- Finally the *public service segment* is the market segment where public transport cannot take profit of strong comparative advantages. It is provided and subsidized by public authorities in order to allow everyone basic mobility. This is typically the case outside urban areas. This market segment corresponds to what is generally referred to as regional traffic.

In the context of regionalization, the question of how to define a region was also addressed. Brändli and Kobi (1978) state that a region can be seen as defined area in-between the municipality and the Confederation. They also state that limits between regions do not necessarily need to follow cantonal borders. This argumentation is reiterated by Giger (1991) who further acknowledges that in some cases, like Basel, regions can even stretch beyond international borders (see also Barth (2014)). He furthermore follows the argumentation that the administrative boundaries between cantons are historically grown and hence they do not necessarily correspond to limits between regions in the sense of modern transportation. Furthermore, he states that the latter is an issue in Switzerland more than in other (European) countries whose administrative division is not historically grown to the same extent[7].

Giger (1991) furthermore proposes an innovative idea to overcome the necessity for differentiation between local, agglomeration, regional and long-distance traffic in respect to the provision of public funds by different levels of government: instead of contributing financially to the operation of single lines, municipalities, cantons or the Confederation should rather subsidize tickets. On the level of the individual ticket, the purpose of a trip and its assignment to local, agglomeration, regional or long-distance traffic can be made more easily. In practice, however, this proposal would collide with the wide-spread use of yearly or monthly passes; although the technical possibilities of digital ticketing systems (e.g. Check-In-Check-Out (CICO) or Be-In-Be-Out (BIBO)) would make such a funding model more feasible today than at the beginning of the 1990s.

After the 2000s, several authors were looking at the process of regionalization in retrospective. The questions of interest were the comparison between different countries or administrative entities within the same country as well as cost-benefit analyzes over time. In this context, Genoud (2000) and Rieder (2005) shall be mentioned. While the former looks at the process of

[7] German Bundesländer in their current boundaries have been formed after World War II. In France, departments have been made by Napoléon at beginning of the 19th century. Their aggregation into regions only happened in the second half of the 20th century with a major reform in 2015 (FIGURE 2).

regionalization in different regions of Switzerland, the latter provides a more comprehensive overview with the inclusion of France and Belgium.

Weidmann (2007, 2013) further develops the concept proposed by Boos (1983) and Kaspar (1984) by stressing the aspect of functional role of a public transport line within the transport system. Four product levels (each with possible sub-levels) can be discerned: A: transit, B: connection, C: collection and D: access. The functional role of a given public transportation line is obviously dependent on the perimeter of consideration. According to Weidmann (2007), the usual perimeter of reference is a country. In a second step, he assigns those product levels to one of the three market segments long-distance, agglomeration or regional traffic:

- **A-lines:** long-distance traffic,
- **B-lines:** mostly long-distance traffic, in some cases also regional traffic,
- **C-lines:** agglomeration or regional traffic (depending on their service area),
- **D-lines:** agglomeration or regional traffic (idem).

Whereas the consideration of the product level can be an indicator when discerning long-distance traffic from the two other market segments, it also has its limitations. One needs to bear in mind that cross-comparison between countries of significantly different size and population (e.g. Switzerland versus Germany) leads to certain distortions. For instance, the comparison of Switzerland with single German states (e.g. Bavaria) might be the more accurate choice.

While the question of the 'upper segmentation' from long-distance traffic has been widely debated in literature (because of its greater practical relevance in transport policy), the 'lower segmentation' from agglomeration traffic is far less. Whereas Weidmann (2013) and Kaspar (1984) propose to apply the criterion of the bottleneck factor, Boos (1983) does not further elaborate on it. Although the spatial definition of an agglomeration area is possible (Barth, 2014, Bundesamt für Statistik (BfS), 2012), its application to the individual line of public transportation raises the fundamental question how to handle lines crossing the presumed boundary: are they to be considered agglomeration traffic, as their demand is oriented over there, or are they considered regional traffic, because in most cases the major part of their route is located outside the agglomeration area?

Instead, Weidmann (2007, 2013) further differentiates among the C and D-lines (defined as described above). Inside the C-lines, he makes a difference between C1 and C2 products in agglomeration traffic (suburban and underground railway lines) on the one hand, as well as

C3 and C4 products in regional traffic (regional railway and bus lines) on the other other hand. Similarly, D-lines can further be differentiated into D1, D2 and D3 products in agglomeration traffic (underground, light rail, tram or bus lines) and D4 products in regional traffic (local bus lines). Whereas in agglomeration traffic C-products generally have a lower-level D-product that connects to them, in regional traffic C and D functions often happen to be concentrated on the same line. Distinct D-products only exist in bigger towns.

2.4 Conclusions

The explanations in this section have shown that a large number of possible criteria has been put forward in practice and literature to define regional traffic. TABLE 2 summarizes them regarding their usability for a generic definition.

Table 2: Usability of criteria for definition of regional traffic

Criterion	Usability for segmentation from long-distance traffic	Usability for segmentation from agglomeration traffic
Average travel time and/or distance of passengers	Usable under conditions [1]	Not usable
Functional role in the transport system	Usable under conditions [2]	Usable
Funding	Not usable [3]	Not usable
Administrative divisions	Not usable	Not usable
National interest	Not usable [4]	Not applicable
Train route length	Not usable [5]	Not usable
Bottleneck factor	Usable	Usable
Perimeter of the agglomeration	Not applicable	Not usable

Explanations:

[1] This aspect needs to be seen in relation to the spatial structure of the respective area. While travel distances of 50 - 100 km could be considered long-distance in countries with a large number of medium-sized centers (e.g. Germany, Switzerland), the same travel distance can have a clearly regional character in more sparsely populated areas (e.g. central France, northern Sweden). Even within the same country, different perceptions are possible.

[2] The perimeter of consideration needs to be specified. Furthermore, it can happen that a train/bus line concentrates several functions at the same time or that it changes its function in the course of its route.

[3] The financial balance of a line is legislation-dependent, as some countries have higher infrastructure tolls than others. In some cases, this can make a line shift from one side of the financial break-even-point to the other.

[4] National interest is a very fuzzy concept which can be subject to diverging political interpretations.

[5] Consideration of this aspect potentially produces strong discontinuities. Let us assume two different lines, whose lengths are below a supposed threshold, and terminating at a common station. If one connects those two lines, their added route length might end up above the supposed threshold without the slightest change in their function, demand, etc.

3 Development of a functional definition

3.1 General approach

In this section, we will develop a functional definition of regional traffic along the concepts laid down by Boos (1983), Kaspar (1984) and Weidmann (2007, 2013). Based on the finding of 2, we will propose quantitative and qualitative criteria which allow us to decide whether a given train or bus line has to be considered long-distance traffic, respectively city & agglomeration traffic. If neither of them applies, the line belongs to the market segment of regional traffic.

3.2 Definition of long-distance traffic

Generic definition According to TABLE 2, the following criteria are suitable - under certain conditions - to decide whether a given train or bus line is part of long-distance traffic:

1. average travel time and/or distance of the effective passengers,
2. functional role in the transport system,
3. bottleneck factor.

Of the three above, only the first criterion can be quantified numerically; the two others are qualitative. However, the functional role of a train or bus line in the transport system is also materialized by the travel distances/times of its *effective passengers*, which serve as a strong quantitative indicator. This consideration is also the basic idea behind the definition provided by the German 'regionalization law' (Bundesrepublik Deutschland, 2016). Furthermore, the existence of the bottleneck factor can be seen in the volume of passengers, too. Hence, the consideration of transport performance in passenger-km and/or passenger-h allows the combination of both aspects.

We thus propose to use the distribution of travel distances and times of the effective passengers as the criterion for long-distance traffic. Therefore, let us assume a distribution of travel distances as shown by FIGURE 5 (the shape of the function does not have a specific meaning). Travel distances vary between d_{inf} and d_{sup}. d_{limit} is a yet-to-be-defined threshold: beyond that, passengers are considered to be part of the long-distance traffic market. This threshold can be defined on a

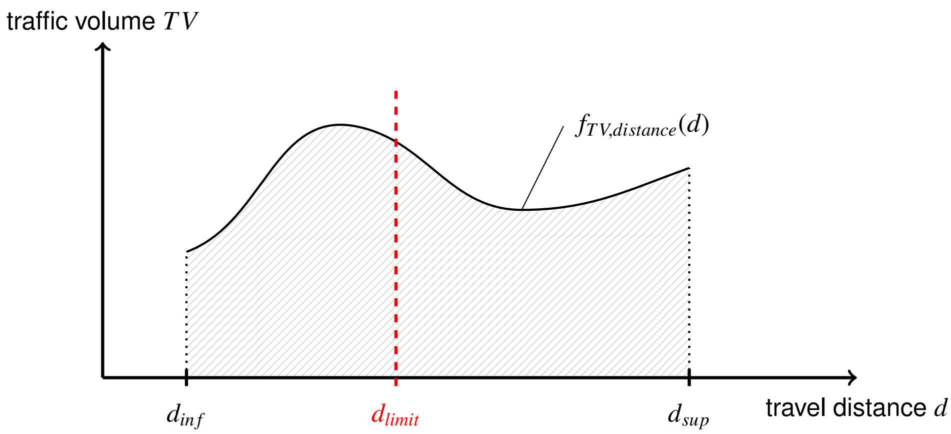


FIGURE 5: Distribution of traffic volume over travel distance for a bus or train line

country-by-country (or even region-by-region) basis and allows to account for differences in their spatial structures (see TABLE 2).

Henceforth, we define:

$$\Psi_{distance} = \frac{\sum\limits_{d_{limit} \leq d \leq d_{sup}} d \cdot f_{TV,distance}(d)}{\sum\limits_{d_{inf} \leq d \leq d_{sup}} d \cdot f_{TV,distance}(d)} \tag{1}$$

$\Psi_{distance}$ thus represents the ratio of passenger-km produced in long-distance-traffic over the total number of passenger-km. This definition allows to account for train or bus lines which serve multiple functions on the same route.

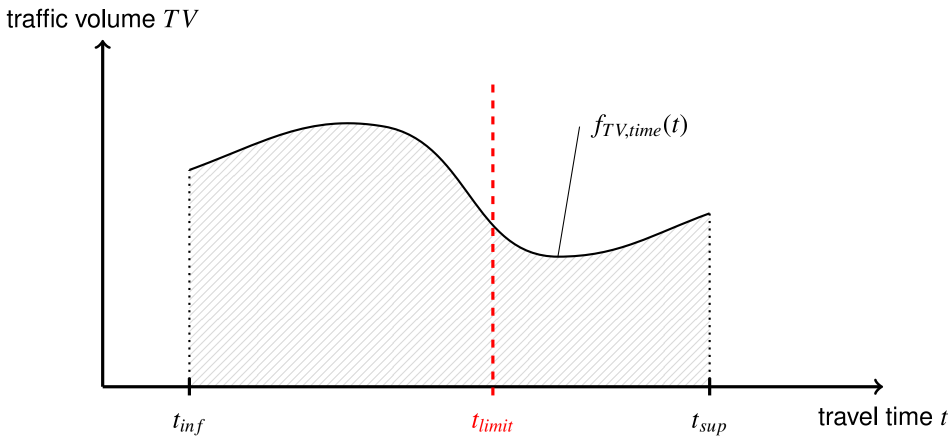


FIGURE 6: Distribution of traffic volume over travel time for a bus or train line

Similarly, we can define Ψ_{time} based on FIGURE 6 as the ratio of passenger-h produced in long-distance-traffic over the total number of passenger-h:

$$\Psi_{time} = \frac{\sum_{t_{limit} \leq t \leq t_{sup}} t \cdot f_{TV,time}(t)}{\sum_{t_{inf} \leq t \leq t_{sup}} t \cdot f_{TV,time}(t)} \quad (2)$$

t_{limit} is again a yet-to-be-defined threshold, which can be chosen according to spatial conditions or the population's travel behavior in the considered country or region.

Based on the values of $\Psi_{distance}$ and Ψ_{time}, it is possible to define under which exact conditions a train or bus line is to be considered long-distance traffic. We propose the following approach: **a line is long-distance traffic, if a combined, significant majority of its transport performance in terms of passenger-km *and* passenger-h - as shown by FIGURE 7 - is produced in the long-distance market**.

The required threshold-value of 67 % (point B in FIGURE 7) is motivated by the following consideration: if we assume the special case with a constant distribution of travel distances

$$f_{TV,distance}(d) = constant = \rho \quad (3)$$

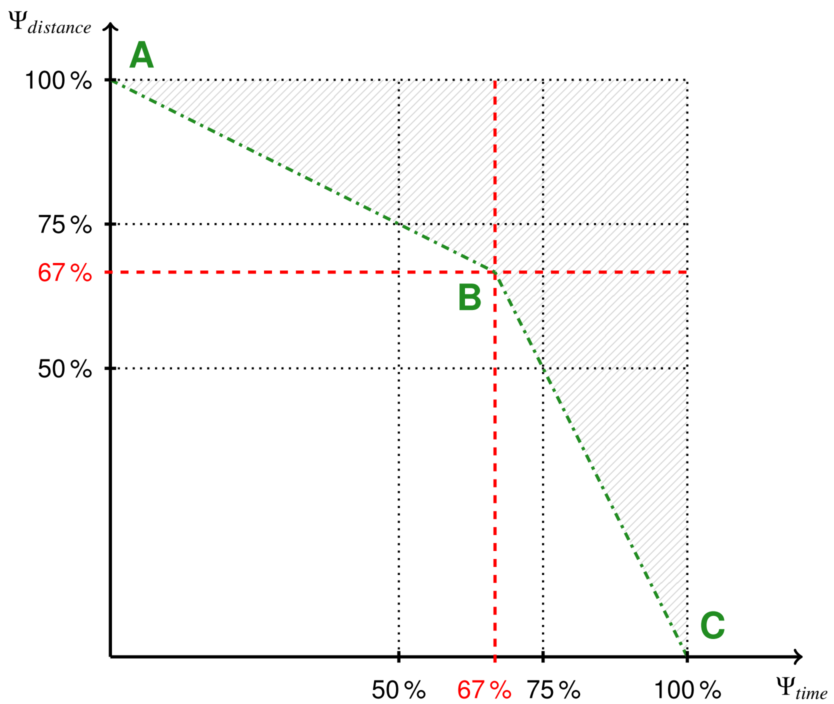


FIGURE 7: Definition of long-distance traffic using $\Psi_{distance}$ and Ψ_{time}

over an interval from $d_{inf} = d_{limit} - \Delta d$ to $d_{sup} = d_{limit} + \Delta d$ (exactly one half of travelers above the threshold and the other half below the threshold), we obtain for $\Psi_{distance}$:

$$\Psi_{distance} = \frac{\left(d_{limit} + \frac{\Delta d}{2}\right) \cdot \Delta d \cdot \rho}{d_{limit} \cdot 2 \cdot \Delta d \cdot \rho} = \frac{1}{2} \cdot \frac{d_{limit} + \frac{\Delta d}{2}}{d_{limit}} > \frac{1}{2} \quad (4)$$

Hence, a constant distribution of passengers' travel distances around d_{limit} always leads to a ratio $\Psi_{distance}$ strictly greater than one half (the same result holds analogously for t_{limit} and Ψ_{time}). In order to fulfill the previously mentioned requirement of a 'significant majority', a higher threshold-value than $\frac{1}{2}$ is required. Hence, we propose to set this threshold to $\frac{2}{3}$.

The linear interpolation between points A and B, respectively B and C in Figure 7, shall allow compensation between $\Psi_{distance}$ and Ψ_{time}. On the one hand, fast services which do not fulfill the time-based conditions (e.g. short high-speed trains like Paris Est - Reims (ca. 150 km, 46 min)), but do transport passengers exclusively over distances larger than d_{limit} can be included in long-distance traffic. On the other hand, slower services which do not fulfill the distance-based conditions, but whose passengers' travel times are exclusively larger than t_{limit} can also be taken into account appropriately.

Special case: sectioned train or bus routes In some cases, train or bus lines change their functional role in the course of their route. Hence, it can happen that on one section they serve long-distance traffic, while on another section they have a primarily regional function. The above generic definition could handle such cases by simply splitting the route into two sections

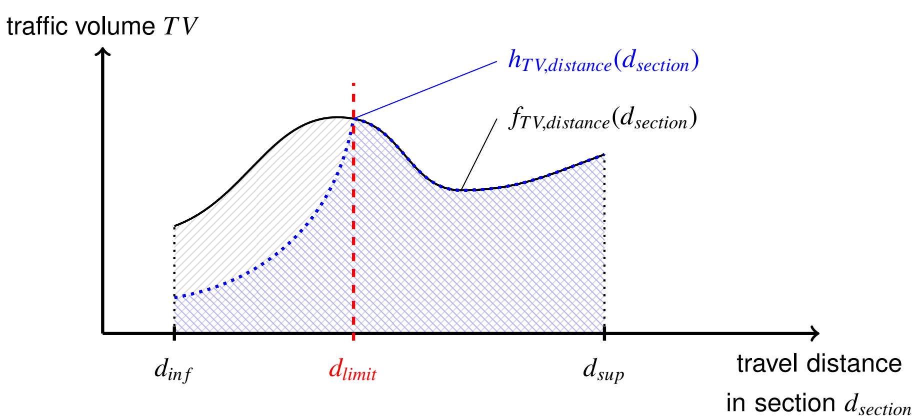


Figure 8: Distribution of traffic volume over distance for a sectioned bus or train line

being treated as independent train or bus routes. However, such a procedure would not account for through-travelers. A slight add-on to the methodology can fill this gap. At this place, we show its principles through the example of the travel distance. The procedure applies fully analogously to the travel time.

Firstly, we need to make a difference between $d_{section}$ and d_{route}: while the former describes the distance traveled by passengers in the section currently under consideration, the latter refers to the distance they travel on the entire train/bus route (all sections combined). Thus:

$$\forall \, passengers: \; d_{route} \geq d_{section} \tag{5}$$

In FIGURE 8, the blue curve (function h) shows the traffic volume of passengers whose d_{route} is larger than d_{limit} as a function of their travel distance in the current section only ($d_{section}$). It is defined as follows:

$$h_{TV,distance}(d_{section}) = f_{TV,distance,d_{route} \geq d_{limit}}(d_{section}) \tag{6}$$

Beyond d_{limit}, function h is identical to function f (black curve in FIGURE 8), as $d_{section} \geq d_{limit}$ necessarily implies that also $d_{route} \geq d_{limit}$.

Thus, $\Psi_{distance,section}$ can be defined as follows:

$$\Psi_{distance,section} = \frac{\sum\limits_{d_{inf} \leq d_{section} \leq d_{sup}} d_{section} \cdot h_{TV,distance}(d_{section})}{\sum\limits_{d_{inf} \leq d_{section} \leq d_{sup}} d_{section} \cdot f_{TV,distance}(d_{section})} \tag{7}$$

Having determined the values of $\Psi_{distance,section}$ and $\Psi_{time,section}$, continuation goes on ordinarily according to FIGURE 7.

Advantages and limitations of the proposed approach The methodology presented above has several *advantages* which make it different from other definitions of long-distance traffic used in practice (see section 2):

- The decision 'long-distance traffic yes or no' is based on how the customers use the offer. It thus reflects the competitive position of the offer on the transport market: the more people use the offer over longer distances, the more passenger-km and passenger-h produced in this market segment.

- Hybrid products which combine several functional roles on the same route portion can easily be handled. The proposed methodology allows to determine which market segment is the primary one and which one is only secondary.

- The described add-on for sectioned routes allows handling of public transport products which change their functional role in the course of the route: on the one hand a differentiation between sections is possible, while on the other hand through-passengers can appropriately be accounted for.

- The threshold-values d_{limit} and t_{limit} can be chosen by taking into account the specific conditions of a country or region. The methodology thus keeps a generic character while at the same time being able to accommodate regional or national specificities.

In return, the methodology also has some *disadvantages*:

- It has the inherent shortcoming which all methodologies aiming at taking a binary decision (yes or no) in a continuous space suffer from: the fixation of a threshold, which is inevitable in presence of such a binary question, potentially leads to inadequate outcomes in the vicinity of the former.

- The application of the presented methodology in practice presupposes a large amount of data which might not always be (publicly) available in the required scope or level of detail. Hence the practicability of the methodology could be impaired. This situation can be expected to improve in tendency in the future, as more and more data is collected and/or made publicly available.

Implementation in the present thesis The generic definition presented above leaves open the fixation of the threshold-values d_{limit} and t_{limit}. The present paragraph addresses this issue.

Fixation of t_{limit} In literature, several authors, such as but not limited to Zahavi (1979) as well as Schafer and Victor (2000), proposed the concept of the travel time budget: in average, people have a limited 'budget' of travel time per day. Consequently, the acceleration of transport services would not lead to shorter travel times, but rather to longer travel distances. Banerjee et al. (2007) further developed this concept of the travel time budget by making a difference between travel time expenditure (corresponding to the effective times traveled) and travel time frontier (being the maximum time people are willing to travel). Travel time expenditures for the Swiss population by age cohorts have been determined by Ciari et al. (2013) and - in an updated version - by Smith (2018). Among the active population, the average trips' duration per day is around 100 minutes. As people normally have the outbound and inbound trip on the same day, we can state that a trip duration of over 50 minutes can be considered above-average.

As long-distance traffic is a market segment where travel distances are above-average compared to the entire population, we propose to use $t_{limit} = 50\,min$ for the case of Switzerland. It shall be noted that this threshold is below the actual travel time between the major Swiss metropolitan regions, such Zurich, Bern, Basel, Geneva, Lugano, etc. Hence, one can expect the methodology not to produce any fully counter-intuitive results.

Fixation of d_{limit} While the previously proposed value of t_{limit} is based on the mobility behavior of the population, we propose to use a transport-system-based approach to fix d_{limit}: it shall be the distance above which rail transport can - given its generic properties of higher maximum speed - gain an advantage in terms of travel time over road transport and more specifically private car. FIGURE 9 shows a time-space-diagram for private car, train (at different mainline average cruising speeds) and airplane (included for the sake of completeness). It is constructed along the following assumptions:

- **Airplane:** cruising speed of 800 km/h, distance-independent minimum travel time of 3 h for access and egress to/from airport (30 min each), check-in and boarding (1 h), taxiing at departure and arrival airport (15 min each) and unboarding and baggage claim (30 min). The airplane travel time TT_{plane} as a function of the distance d thus becomes:

$$TT_{plane}(d) = 3\,h + \frac{d}{800\,km/h} \tag{8}$$

- **Car:** for the first 10 km, an average speed of 30 km/h is assumed (non-conservative assumption for city traffic according to Loder et al. (2017)). It covers the access and egress to/from a motorway. On the latter, an average cruising speed of 100 km/h is assumed. Congestion is not taken into account for these considerations. The car travel time TT_{car} - from parking-spot to parking-spot - as a function of the distance d can thus be expressed

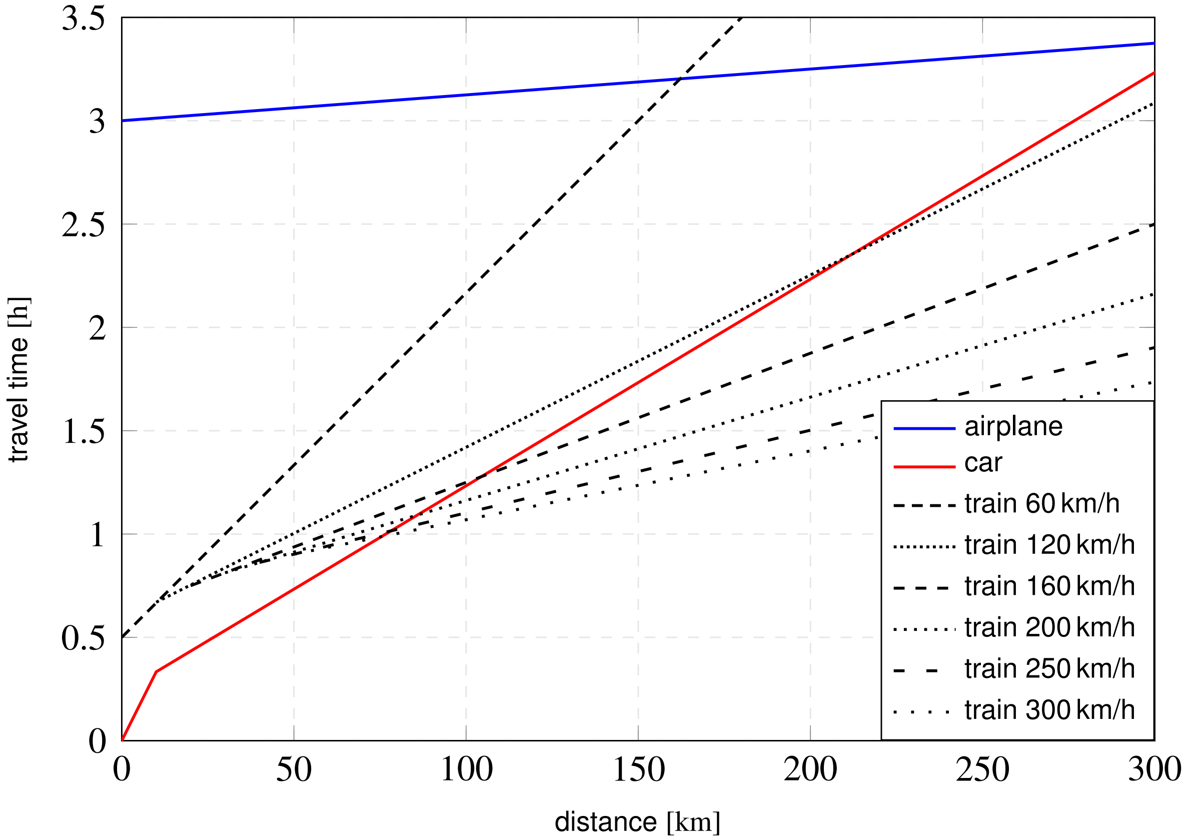


Figure 9: Time-space-diagram of train vs private car

as follows:

$$TT_{car}(d) = \begin{cases} \dfrac{d}{30\,km/h} & \text{if } d \leq 10\,km \\ 20\,min + \dfrac{d - 10\,km}{100\,km/h} & \text{if } d > 10\,km \end{cases} \tag{9}$$

- **Train:** a set of curves is given depending on the *average cruising speed on the mainline*. Furthermore, we assume that also for faster trains (e.g. high-speed trains), there are line portions at lower speed at the beginning and the end of the trip. In total, there are 6 speed levels (60 km/h, 120 km/h, 160 km/h, 200 km/h, 250 km/h, 300 km/h). For each speed level, the minimum distance to be run with the respective speed is 5 km at the beginning and the end each (i.e. in total 10 km per speed level).

Finally, we assume access and egress times of 15 min each at the beginning and the end of the trip. This is a non-conservative assumption. Figure 9 thus underestimates the train travel times. The analytical formulations of the corresponding travel time functions can be constructed analogously to equation (9).

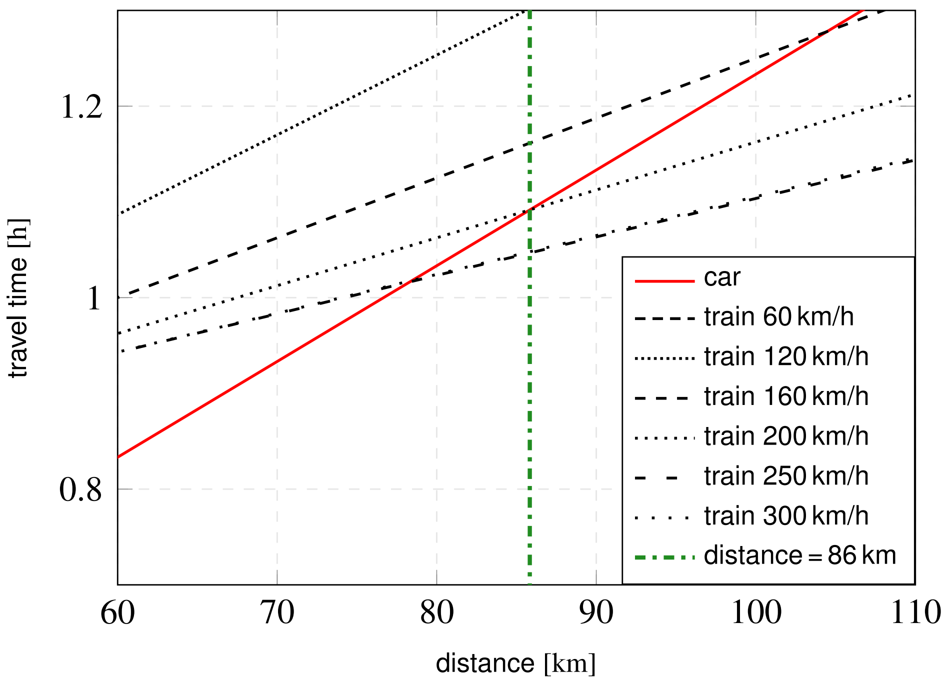


Figure 10: Zoom into time-space-diagram of train vs private car

Figure 10 shows a zoom into the area of the time-space diagram where the car and train functions intersect. In Switzerland, where the highest speed practiced in commercial service is 200 km/h, the distance beyond which train can outperform car travel-time-wise is found at $d = 86\,km/h$ (see green dashed line): it is the horizontal axis coordinate of the intersection between the car travel time function and the one of the train at 200 km/h.

As long-distance traffic is the market segment where train can gain a comparative advantages thanks to higher speeds, we propose to use $d_{limit} = 86\,km$. Again, it is worth noting that this distance-threshold roughly corresponds to the actual distance between Switzerland's major metropolitan centers.

Summary We could develop a functional definition of long-distance traffic which allows the assignment of given bus or train lines based on the *a-posteriori analysis* of the travel times and distances of their effective passengers. The threshold-values t_{limit} and d_{limit} can be determined using actual travel behavior data as well as the performance limits of rail and road transport respectively. **Regarding the definition of long-distance traffic and its delimitation from regional traffic, the initial hypothesis could be verified.**

3.3 Definition of city & agglomeration traffic

The main distinctive feature between regional and city & agglomeration traffic is the much higher traffic volume (in combination with most of the time also a higher revenue level). In this context, the initial hypothesis postulates that the respective performance limits of buses and trains can serve as a criterion for distinction. However, as Sinner and Weidmann (2017) have shown, the system limit in terms of passenger capacity of a bus line with fully segregated right-of-way is around 14'000 passengers/h. In Switzerland, there is not a single public transport line whose demand exceeds this capacity. Beyond in Europe, only very few lines in big cities like Paris or London are susceptible to come close to this order of magnitude.

Regarding the delimitation of city & agglomeration traffic from regional traffic, the system limits of buses and trains do not allow any distinction:

- The distances of both traffic kinds are so similar, that the maximum respective speeds cannot allow for a distinction.
- The system limits in terms of capacity do not allow a separation, as both buses and trains are potentially technically capable of serving the respective demands if the necessary infrastructure conditions are fulfilled.

Hence, the initial hypothesis cannot be verified when it comes delimiting city & agglomeration traffic from regional traffic.

Alternative generic definition Even though the initial hypothesis could not be verified in respect to the delimitation between regional and agglomeration traffic, a methodology for distinction shall be proposed. According to Table 2, the functional role of a line inside the transport system as well as the bottleneck factor are suitable criteria to determine whether the line belongs to city & agglomeration traffic on the one hand or regional traffic on the other hand. Both of these criteria being qualitative, Table 3 lists possible indicators which materialize the two previously mentioned top-level criteria.

The market share of public transportation on a given relation is the most suitable criterion, as it is - similar to the proposed definition of long-distance traffic - based on the effective usage of the considered public transport product by the population. It also includes the other two indicators of the average speed on the road network and the parking space availability: the market share of public transportation is the mere consequence of the two last named. It reflects best the notion

TABLE 3: Possible indicators for separation of agglomeration and regional traffic

Top-level criteria	Possible indicators
Functional role in the transport system	• *Superposition of C- and D-products:* as laid down by Weidmann (2007, 2013), C1 and C2 products in agglomerations generally have a lower-level D-product that connects to them and takes over service provision on the last mile. In regional traffic, in return, C3 and C4 products also cover D-functions. Separate D-lines (e.g. local buses) only exist in bigger towns. The *non-existence of a separate D-product* is thus a strong indicator of regional traffic.
Bottleneck factor	• *Average speed on the road network:* indication of the level of congestion and thus of the encountered bottlenecks on the road network; can be determined through the macroscopic fundamental diagram (Ambühl and Menendez, 2016, Loder et al., 2017); low average speeds are also an indicator of unreliable travel times. • *Parking space availability:* another direct indicator of the congestion level on the road network in agglomerations, which generally have insufficient parking space available to cover the full demand; can be expressed through the average occupancy time of parking places or more generally by taking into account cruising traffic as shown by Cao (2016). • *Market share of public transportation:* information to what extent the population is willing to choose public transportation as an alternative to private car due to persistent congestion on the road network or parking space scarcity: the higher market-share is an indicator of the existence of bottlenecks; it can be determined through a national or regional general transport model (e.g. Gesamtverkehrsmodell Schweiz).

of the bottleneck factor in all its facets by taking into account the variety of reasons for the existence of such a bottleneck.

Henceforth, we propose a similar approach to the one adopted for the definition of long-distance traffic. Let $f_{TV,distance}(d)$ be the traffic volume of a given train or bus line as a function of the travel distance d, ρ the market-share of public transport on the considered OD-relation and ρ_{limit} the yet-to-be-defined threshold-market-share above which traffic is considered agglomeration traffic. With that, we can define as shown in FIGURE 11:

$$h_{TV,distance}(d) = f_{TV,distance,\rho \geq \rho_{limit}}(d) \qquad (10)$$

On a public transport product where agglomeration traffic and regional traffic coexist, the OD-relations which are part of agglomeration traffic (inner circle around a city) tend to be shorter than the those that are part of regional traffic (outer circle). In order to limit the weight of the longer trips, we propose to use $\sqrt{d}$ instead of d as the weighting factor.

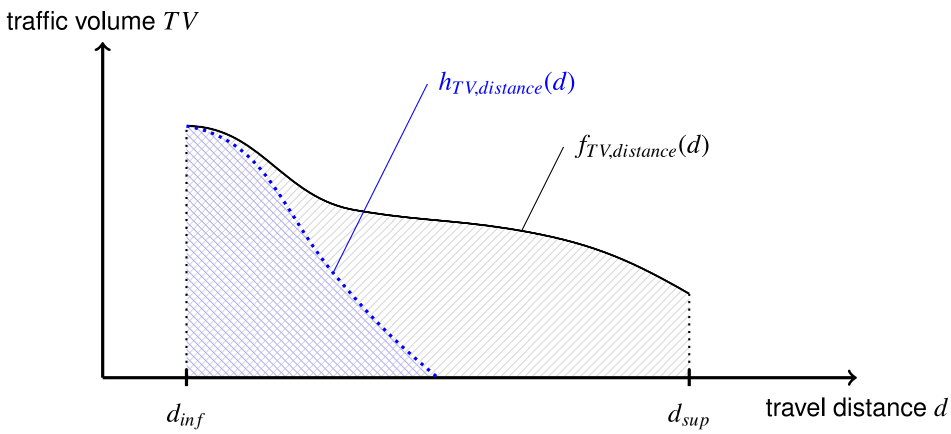


Figure 11: Traffic volume as function of passengers' travel distance

The 'adjusted' average ratio Φ of agglomeration traffic among total traffic of the respective bus or train line can thus be defined as follows:

$$\Phi = \frac{\sum_{d_{inf} \leq d \leq d_{sup}} \sqrt{d} \cdot h_{TV,distance}(d)}{\sum_{d_{inf} \leq d \leq d_{sup}} \sqrt{d} \cdot f_{TV,distance}(d)} \tag{11}$$

We thus propose to qualify a given bus or train line as being part of agglomeration traffic, if $\Phi \geq 0.5$. Consequently, $\Phi < 0.5$ means that the line is part of regional traffic.

Implementation in the present thesis The threshold market-share ρ_{limit} remains to be defined for the specific conditions of Switzerland. According to the micro-census 2015 (Bundesamt für Statistik (BfS) and Bundesamt für Raumentwicklung (ARE), 2017), the distance-weighted modal-split in Switzerland overall is as follows:

- Human-powered mobility: 8 %
- Private motorized traffic: 66 %
- Public transportation: 24 %
- Others: 2 %

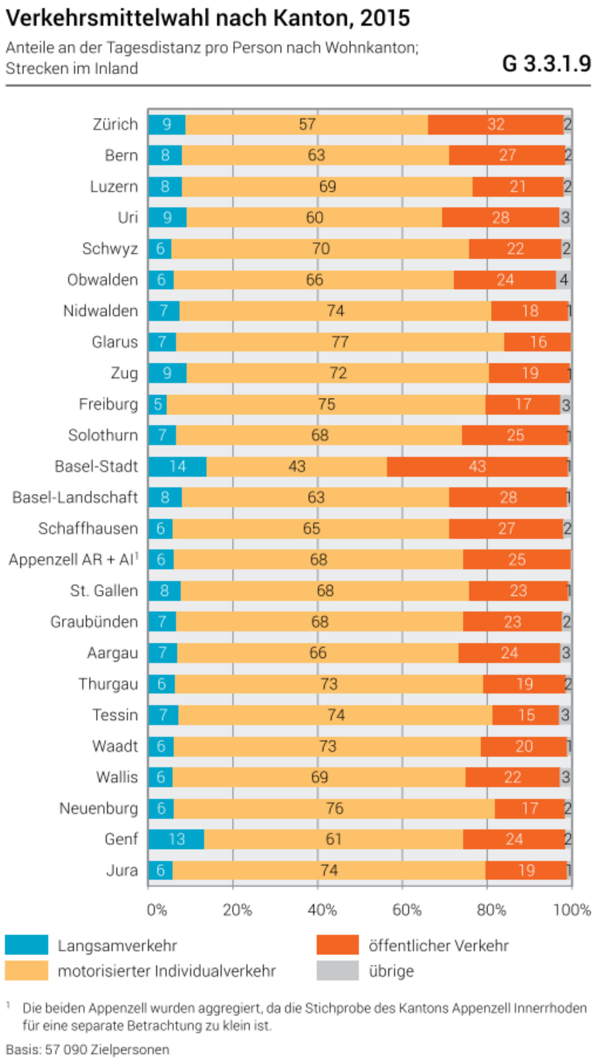


FIGURE 12: Modal-split by canton
Source: Bundesamt für Statistik (BfS) and Bundesamt für Raumentwicklung (ARE) (2017)

When excluding Human-powered mobility and Others, the market-share of public transport is 27 % against 73 % for private motorized traffic. As previously stated in TABLE 3, agglomeration traffic is characterized by an above-average market-share of public transport. **We thus propose to fix $\rho_{limit} = 35\,\%$.**

FIGURE 12 shows the modal-split differentiated by canton. We can see that a modal-split of 35 % (when excluding Human-powered mobility and Others) is not unrealistically high. For instance, the canton of Zurich reaches this modal-split even canton-wide: in agglomeration traffic the modal-split of public transport can thus be expected to be even higher. The city-only canton Basel Stadt has a modal-split of 50 % - 50 % public transport vs individual motorized traffic.

4 Conclusion

This paper showed the variety of approaches used in practice and literature to define the public transport market segment of regional traffic, including their respective strengths and weaknesses. Afterwards, a methodology for a functional, transport-market-oriented definition was proposed. It is based on the a-posteriori analysis of passengers' travel behavior. This way, the assignment of a bus or train line to a market segment does not depend on regulatory considerations, neither financial interests, but on the effective use of the considered product by passengers.

The initial hypothesis claiming that the performance limits of trains and buses can serve as a criterion for the delimitation of regional traffic could only be verified in respect to the 'upper segmentation' from long-distance traffic where speed limits have an influence. In contrast, the capacity limits cannot serve as an element to distinguish regional traffic from city & agglomeration traffic.

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