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Watching the Swiss: A network approach to rural and exurban public transport☆

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ABSTRACT

Public transport in rural and exurban areas faces major challenges, with low population densities making it difficult to provide high-quality, high-occupancy services. While demand-responsive transport is sometimes prescribed as an innovative strategy for service provision, the network planning approach to public transport suggests that integrated timed-transfer or pulse timetable networks should be explored first. This paper examines the rural network approach using examples from Switzerland, which has among the highest rates of public transport use in Western Europe, as well as nationally-coordinated *Taktfahrplan* scheduling that extends deep into rural areas. The basic Swiss pulse timetabling technique is reviewed, along with the application of the approach to a remote rural case study in Graubünden's Lower Engadine and Val Müstair. Characteristics of pulse timetable networks and the wider rural network approach are considered, drawing broad lessons for their potential application elsewhere.

1. Introduction

Despite widespread planning policies to contain urban sprawl and promote compact cities, settlements in rural and exurban areas continue to expand across the developed world. A European Environment Agency report suggests that this growth is led by desires for detached or semi-detached houses in "suburban/rural" settings or "rural areas outside the city", and finds that families with small children are most likely to move to these areas (EEA, 2006, p. 20). In countries where detached housing is the norm (such as Australia, the United States and Canada), scenic rural areas also attract young families, retirees and others seeking lifestyle changes and cheaper housing (Butt, 2014; Winterton and Warburton, 2012, p. 329; Ghose, 2004).

Public transport in these areas is often poor, with services characterized by low frequencies, limited hours of operation, indirect routes and inconsistent connections between modes (Petersen, 2012). Both residents and visitors arriving from nearby cities have little choice but to drive, which further entrenches car dependence and associated transport disadvantage, along with possible congestion, parking and other environmental problems (Cullinane and Stokes, 1998, pp. 7–8). A lack of alternatives to the car may, in particular, restrict older people's access to health services as well as to other activities necessary for social inclusion (Ward et al., 2014).

With even lower population densities than suburban areas, rural and exurban districts are considered some of the most challenging environments for public transport provision, with dispersed travel patterns and limited overall travel demand making it difficult to provide high-quality, high-occupancy public transport (White, 2009, p. 164). According to Hickman and Banister (2014, p. 141), even "classic good practice examples such as Freiburg, Strasbourg, Amsterdam and Zurich… are often surrounded by relatively car dependent suburban and rural areas." Nevertheless, in considering strategies to reduce carbon dioxide emissions from rural Oxfordshire, they propose upgrades for local rail and bus, including new bus rapid transit lines, although how these would address fundamental rural public transport problems remains unclear (Hickman and Banister, 2014, pp. 163, 171).

In the face of such difficulties, proponents of 'demand-responsive' services have mounted the most significant challenge to conventional public transport. A 2008 report by the UK's Commission for Integrated Transport ('CfIT') calls for *A New Approach to Rural Transport*, on the basis that the quality of public transport outside large towns and cities in the UK is "patchy" and that services are "infrequent, finish early in the evening and do not run at all at weekends"(CfIT, 2008, p. 7). The report argues that the UK's

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rural areas would be better served by the large scale roll-out of demand-responsive transport, citing its use in the Netherlands and Switzerland, and contends that this would provide better services and achieve higher cost recovery (CfIT, 2008, p. 9).

Demand-responsive services usually use smaller vehicles (including taxis) in place of conventional buses, while still charging fares for each passenger, but vary the fixed routes and/or timetables that define other forms of public transport (Davison et al., 2014, p. 47). Some demand-responsive services are designed to feed other public transport, while others operate entirely independently. They may offer cost reductions for operators when replacing poorly-patronised conventional services, and typically promise a flexible service that can be tailored to different users' needs.

However, some analysts of demand-responsive services advise that flexibility should be limited to avoid jeopardising operating economics: they explain that collective modes work most efficiently when demand is concentrated, and that too much flexibility can fragment this demand (Enoch et al., 2006, p. 13). Despite the success of some enduring examples, demand-responsive services have often proven to be operationally complex and expensive, achieving vehicle occupancies little higher than taxis, while being unable to guarantee access during peak times or make reliable connections to other public transport (Enoch et al., 2006; Davison et al., 2014; Mageean and Nelson, 2003). Potential users are often unfamiliar with procedures adopted by individual schemes, and booking requirements may hinder spontaneous travel. Although there are often other institutional, legislative, and funding-related barriers to the implementation or continued operation of demand-responsive services (see Mulley et al., 2012), these service-related issues help explain why so many rural demand-responsive services do not progress beyond trials or niche transport roles (such as serving people with mobility impairments).

A more recent challenge to the focus on demand-responsive services has come from the network planning approach (Mees, 2010; Nielsen et al., 2005; Thompson and Matoff, 2003). The emphasis is on concepts that are the opposites of flexibility: permanence, reliability and simplicity (Vuchic, 2005, p. 570). Carefully planned, fixed public transport routes are combined in a single, stable network, bound together by opportunities for quick and convenient transfers. In rural areas, high-frequency routes (enabling random, untimed transfers) are rarely an option, so services must instead be timed to connect at selected hubs.

Such timed-transfer or 'pulse' networks operate in the suburbs of some cities in the United States and Canada, as well as within regions of German-speaking Europe (Vuchic, 2005, p. 224). Switzerland, with Western Europe's highest number of public transport trips per capita (Pucher and Buehler, 2012, p. 543), provides an obvious case for investigation, and is of particular interest because it provides a nation-wide pulse system that extends into remote rural villages. While demand-responsive services still play a role in many Swiss cantons, research for the CfIT shows very high subsidies per passenger carried (Mott Macdonald Consultants, 2008, p. 23). Other preliminary work also suggests that cantons making less extensive use of demand-responsive 'PubliCar' services achieve higher canton-wide public transport mode shares (Petersen and Mees, 2010).

This paper examines the rural network approach, as applied in Switzerland, as a way of reducing car use and providing high-quality public transport in rural and exurban areas. The context in which it developed and the method by which it is planned are briefly explained, before its application to one of Switzerland's most remote rural regions, the Lower Engadine and Val Müstair in the Canton of Graubünden, is explored. Characteristics of the pulse timetable-based approach are also discussed, along with required policy and institutional settings.

2. The network planning approach

In identifying the poor quality of public transport in the UK's rural areas, and calling for more taxi-based services, the CfIT report (above) observes that "connections between buses and trains are erratic, and examples of integrated ticketing are the exception rather than the rule" (CfIT, 2008, p. 7). This suggests that planning and institutional deficiencies are at least partly responsible for rural public transport's poor performance in the UK, although they are not considered at any length in the report. Even Hickman and Banister (2014, p. 172), who propose packages for upgrading conventional bus and rail services in Oxfordshire, suggest better network planning and integration only as a "supporting measure".

Proponents of the network planning approach, in contrast, would start by exploring the prospects for public transport service coordination. The Australian transport academic Paul Mees described how an integrated network could make high-quality, high-occupancy public transport possible in low-density areas (Mees, 2000, 2010). When comparing Melbourne and Toronto, he found that throughout Toronto's inner and middle suburbs, a comprehensive grid of frequent public transport routes had been planned to allow quick and convenient transfers wherever routes intersected. This created a 'network effect', conveniently linking a far greater proportion of passengers' origins and destinations than isolated transport corridors, and overturned the typical assumption that the costs of increased service would, as a rule, outweigh the revenue from improved patronage.

The idea was also taken up by others (Nielsen et al., 2005; Stone and Beza, 2014), or independently identified to explain the better performance of 'multi-destinational' rather than traditional radial transit networks in US cities (Thompson and Matoff, 2003; Brown and Thompson, 2008). Nielsen et al. (2005, p. 35) also make a useful distinction between a "tailor-made" approach, where services are customised for particular market segments at different times (e.g., peak-only expresses for CBD commuters), and the "ready-made" approach favoured by network planning proponents, where a catch-all service is provided using stable network structures and services available all day. All authors recognise the importance of carefully-planned route networks and convenient transfers.

Beyond the suburbs, in low density rural or exurban areas, services are invariably low frequency and must be timed to connect to allow quick transfers between different routes. Nielsen et al. (2005, pp. 116–119) recommend timed-transfer pulse timetables for "weaker" public transport markets, citing small cities in Germany's Nordrhein-Westfalen that restructured their bus networks and increased patronage, improved cost recovery and cut subsidies per passenger. Mees (2000, p. 282; 2010, p. 179) also suggests pulse networks, similar to those covering Zurich's suburbs and parts of rural Switzerland, as a preferred approach for rural and exurban areas.

2.1. The pulse timetable concept

The 'pulse timetable' or 'timed-transfer system' concept is not new. Vuchic's public transport textbook (2005, p. 224; see also Vuchic et al., 1981) outlines the basic technique of timed-transfer planning, noting that pulsing is also used by airlines at hubs, where planes arrive at a central point simultaneously to allow passengers to transfer in all directions, and that similar strategies are often used by public transport systems that keep precise schedules. Pulse timetables are used to serve the automobile-oriented suburbs of North American cities like Edmonton, Sacramento and Portland, as well as providing some late-night services, where long headways (times between services) would otherwise discourage passengers from making trips involving a transfer.

Pulse timetabling is also used extensively within the intercity and regional rail systems of Germany, the Netherlands and Switzerland, with services that pulse at 15-, 30- or 60-minute intervals (Vuchic, 2005, p. 224). These 'integrated' pulse networks contain multiple pulse points across a wide region on which services simultaneously converge (one such pulse point is described by Apel and Pharoah (1995, p. 143) at Wetzikon in suburban Zurich). Pulse networks seem to allow high quality services in Swiss and German cities to be extended to surrounding suburbs and exurban areas (Pucher and Kurth, 1996; Mees, 2010, pp. 132–137), even if, as Hickman & Banister note, rural mode shares remain lower than in urban areas. Pucher and Buehler (2012, p. 558) describe the approach in many German regions as "state-wide coordination of schedules", backed by integrated fares and ticketing, and incorporating "full coordination of schedules and routes across modes and operators".

The concept behind railway pulse timetables is outlined in more detail by Clever (1997), who also refers to the idea's German name, the *Integraler* (integrated) *Taktfahrplan*. Taktfahrplan combines the words *Takt* (musical beat) and *Fahrplan* (timetable), but is without a direct equivalent in English, and so is often translated as a 'pulse timetable' or 'timed-transfer system'. Clever, while focussed on its application to rail, draws attention to the importance of integrated regional networks, claiming that "passengers do not get on board only a single line, but a whole system". He even proposes a sample bus stop sign that prominently displays a repeated hourly departure time.

Regional pulse networks in Europe are also the inspiration for Cullinane and Stokes's (1998, pp. 316–317) proposed "blueprint for rural transport", aimed at addressing the poor quality of the UK's rural public transport. In particular, they give the example of Switzerland's timetable synchronisation at the national and local level, with trains leaving major cities on the hour or half hour and reaching their destinations in 25 or 55 min (depending on distance), "thus enabling interchange to be made reliably without the use of timetables".

Cullinane and Stokes (1998, pp. 309–310) propose a national public transport network for the UK, which they say "does not need to reach every village, hamlet, or suburb, but… does need to allow travel between all centres of population of more than… say 5,000 people". Trains and buses would be "integrated through a common system of timetabling", and run at least every half hour between neighbouring towns of more than 20,000 people. Services would use direct routes and "would not deviate off major roads to serve minor settlements but would have feeder services to the major roads". However, Cullinane & Stokes provide little further information about the institutions or planning frameworks needed to bring about such a Swiss-style network; and the lack of movement in the UK towards such an outcome suggests that further investigation would be valuable.

3. Network planning in Switzerland

Switzerland is often considered an exemplar of public transport network planning. Although it is densely populated and wealthy, its population density is similar to that of the United Kingdom, and its high per capita income also permits higher car ownership rates (Petersen, 2014; Swiss Federal Statistical Office (SFSO) 2010, p. 529; Office for National Statistics (ONS), 2001; SFSO, 2013, p. 22). It is a particularly notable case because although much of continental Western Europe is associated with strong welfare states, Switzerland is economically liberal, low-taxing and cautious about state intervention, such that its economic approach is sometimes compared to 'Anglo-Saxon' nations (Leimgruber, 2008, pp. 4–10). However, it may be prepared to spend more on rural public transport due to the cultural importance of rural and mountain villages, and a tradition of using subsidies which are "justified as political acts of solidarity" to equalise service provision across cantons (Linder, 2004, p. 17, 1994, pp. 14–15). Switzerland's political climate is also shaped by citizen-initiated referendums disallowing (or proposing) major initiatives, which makes governments careful to cultivate broad support for new policy, and may have also dissuaded policymakers from closing much of the very dense network of Swiss railway lines.

It is in this context that the Swiss rural network approach developed. Its origins can be traced back to a crisis in the Swiss rail industry in the late 1960 s caused by competition from the car (Hürlimann, 2005). Three young officers in the Swiss Federal Railways ('SBB' in German) produced a report entitled 'Taktfahrplan Switzerland: A new passenger rail concept' (Berthouzoz et al., 1972; title translated from German). The report identified an inadequate level of service, especially inconvenient timetables, as one of the railways' main weaknesses. In response, it proposed a nation-wide, regular interval 'pulse' timetable: trains would depart every hour, serving every station at the same 'minutes-past-the-hour' (for example, departures might occur at a particular station at 7:42, 8:42, 9:42 etc.), with connections at major interchange or 'pulse' points. The idea slowly permeated the SBB bureaucracy and culminated in the implementation of the first national pulse timetable on routes between major cities in 1982.

Around the same time, another SBB proposal to make rail travel faster and more competitive with the car was foundering (Hürlimann, 2005). Released in 1977, and inspired by examples from Japan and Germany, the plan aimed to upgrade lines at the core of the network (between Bern, Basel and Zurich) for high speed trains. However, the first section of line between Bern and Olten was rejected by the federal parliament after being presented to the public in 1983. It faced strong opposition from rural landholders affected by new rail alignments, as well as from smaller towns that were concerned about being bypassed for larger cities. A shocked SBB regrouped and responded with a proposal to win over the general public and smaller settlements.

'Rail 2000′ promised half-hourly rail services between major cities, and hourly services on most other rail and regional bus lines throughout Switzerland, including rural areas. Rather than focusing on speed for its own sake, infrastructure upgrades were focused on speeding up trains to meet 'the pulse', which was reflected in the Rail 2000 slogan: "not as fast as possible, but as quick as necessary" (Hürlimann, 2005).

The Rail 2000 plan was approved by referendum in 1987 by 57 per cent of participating voters, and its success in winning public support seemed to energise Swiss public transport planning. While the policy has since undergone revisions—including the transfer of some decision-making responsibilities to the cantons—in rural areas, the widespread expectation of hourly services up to eighteen hours a day endures (Petersen, 2012). The system is supported by federal funding to the cantons for rural routes serving localities with no fewer than 100 permanent residents.

A year after Rail 2000 was approved, transport planners for the Canton of Zürich (which covers the City of Zürich and its surrounding suburban and rural commuter areas) used a similar service approach to gain the support of rural municipalities for a new Zürich Transport Federation (*Zürcher Verkehrsverbund* or 'ZVV') (Petersen, 2014). The ZVV was to bring together existing public operators, creating a new suburban and regional rail (*S-Bahn*) system, coordinating bus connections, and integrating fares by collecting and distributing revenue between operators

(Wiesendanger, n.d., pp. 18–21). It would also come with new subsidy arrangements dividing costs between the Canton and its constituent municipalities. As a result, the proposal included service standards to connect every main village within each of the Canton's 171 municipalities—a significant number of which were semi-rural or rural—to basic hourly bus or rail routes (R. Bergmaier, personal communication, September 8, 2008). This promised to significantly expand the transport network: not only did many municipalities have poor service levels, but as late as 1982, at least thirteen across the Canton were without any public transport at all.

With the ongoing commitment of a longstanding centre-right transport minister, a referendum to establish the ZVV was passed in 1988 with a 56.6 per cent majority (CZSO, n.d.). Within four years of the S-Bahn's opening, rail patronage had jumped to 129 per cent of the previous system's figure. A similar, service-standard based approach has also been applied in some other Swiss cantons, including largely rural Graubünden (see below).

4. Integrated pulse timetable planning technique

The integrated pulse timetable in Switzerland is planned around the national rail network. Hourly or half-hourly long distance trains come together (or 'pulse') on the hour and half-hour at the network's core stations of Zurich, Basel, and Bern. A similar approach is applied at designated pulse points on local and regional rail networks throughout the country: buses and trains arrive before the pulse time, wait a short time to allow passengers to change between services, and then depart. The pattern repeats every hour (or half hour), and as a result, trains also depart all intermediate stations at repeated times every hour.

The public transport planner responsible for redesigning the ZVV's regional bus network, Dr Rolf Bergmaier—also closely involved in Rail 2000 and the redesign of Graubünden's network (see below)—explains that the planning process for a Swiss style pulse network begins by setting a standard service headway based on expected patronage levels (R. Bergmaier, personal communication, September 8, 2008; Petersen, 2014). This echoes the advice of Vuchic et al. (1981, p. 43), who state that the choice of a headway is "the most important operational decision" in any pulse system, because schedules and network design are interdependent. For example, to make efficient use of vehicle and driver time, a bus serving a pulse point should be able to complete its route and return just in time for another pulse, whether this is each consecutive pulse, or every second pulse, etc. As passenger demand is only one factor in selecting a headway, Vuchic (2005, p. 232) suggests that a pulse headway of either 15 or 20 min be chosen, depending on which better fits the travel times of an existing system's routes.

But the Swiss generally choose standard headways of 15, 30 or 60 min, regardless of existing routes, as these offer the greatest flexibility to adjust service levels across a national network (R. Bergmaier, personal communication, September 8, 2008). Service levels can be doubled or halved whilst keeping the same network structure and maintaining easily memorable 'clock-face' departures (i.e. departures at regular intervals, repeating every hour). Twenty-minute headways are usually avoided: if service levels had to be reduced at quiet times of day, the next step to 40-minute headways would result in departures at non-clock-face times (e.g. 9:00, 9:40, 10:20 and 11:00). Alternatively, reducing service frequencies from every 20 to every 30 min would necessitate a complete network re-design.

In rural or exurban areas, passenger demand is usually low, so Bergmaier suggests that the only economically-supportable clock-face headways are usually 30 or 60 min (which also match the

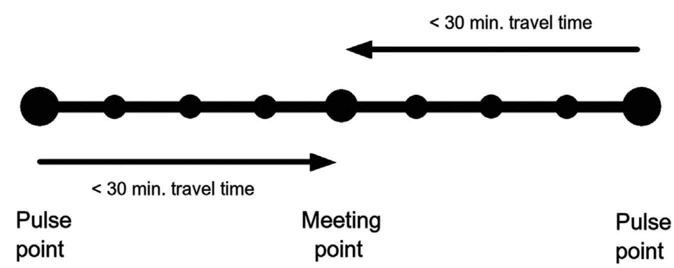

Fig. 1. Pulse and meeting points along an hourly pulse network's corridor. (Source: Author).

typical headways for trains between Swiss cities). Swiss rural pulse networks are therefore designed to operate at an hourly frequency. If required, extra services can then be added on the half hour (or even the quarter hour) without disturbing the base service patterns or network structure.

When planning the location of pulse points, the Swiss start by assuming a one-hour headway and identify major travel corridors radiating from a central pulse point (R. Bergmaier, personal communication, September 8, 2008). Zurich's main station is used as that point, although it need not always be a region's largest city (Foster and Stähli, 1982, p. 220). Each corridor extending from the central point is then examined to identify an important place that vehicles will reach in just under an hour's travel time (often around 55 min, allowing time for vehicles to converge and passengers to transfer). A major station or stop would make an ideal next pulse point, because hourly services travelling simultaneously in opposite directions to or from the central pulse point will always meet at that location. At the halfway point, just under 30 minutes' travel time from the central pulse point, services will also pass each other at a 'meeting point' (see Fig. 1). (If hourly services were ever doubled to half-hourly, there would be two additional meeting points at just under 15 and 45 minutes' travel time from the central pulse point).

Like pulse points, meeting points are ideal transfer points for local feeder services. These feeders, often buses, typically arrive at the meeting points before the main line corridor services arrive. The main line services stop just long enough to set down and pick up passengers, before departing again, and the feeders leave several minutes after. This allows efficient use of feeder bus and driver time, by taking passengers to and from main line services in both directions using only one return journey, and also minimising passengers' waiting time. Passengers can also change between different feeders where they converge on the main line.

The same feeder services can also cater for local trips, so it is best if the pulse or meeting points occur at the most important destinations along the corridor. It may be possible to speed up (or slow down) trains in order to align pulse or meeting points with major towns (R. Bergmaier, personal communication, September 8, 2008). Trains or buses might also use express or stopping service patterns, and buses might take an alternate route. Where interchange locations cannot be aligned with meeting or pulse points, feeders may only be able to provide quick, timed transfers in one travel direction. While often unavoidable, this is less desirable, as a feeder bus trying to serve travel in both directions would need to wait longer for the second main line service to arrive, meaning delays for some passengers, as well as reducing the time that would otherwise be available for the feeder to complete its own route.

Feeders are generally planned to match the frequency and operational hours of main line corridors so that connections continue to work throughout the day and evening, although this standard may be relaxed for remote rural feeder buses at the periphery of the network. A rural pulse network could also run basic services every two hours, resulting in departures from stops every odd or every even hour (depending on stop location). However, there would be fewer potential locations for efficient transfers between services, as each pulse and meeting point would be just under 60 (rather than 30) minutes' travel time apart. Perhaps more importantly, the Swiss experience was that two-hourly services were less likely to be used for short distance trips, or by occasional users, as the longer gaps between services were not as convenient for local travel (R. Bergmaier, personal communication, October 3, 2008).

5. Rural and exurban pulse networks in practice

The rural network approach, using an integrated pulse timetable as its central feature, is applied across rural and exurban Switzerland. The ZVV provides a model for exurban services in the Canton of Zurich's most extensive semi-rural district, the Zurich Weinland (Petersen, 2014). The Weinland, located between the small cities of Winterthur and Schaffhausen, is relatively flat (by Swiss standards), with multiple small villages interspersed through 175 square kilometres of otherwise rural land. It has a regional population density of 1.6 persons per hectare ("p/ha"), while the Weinland's villages themselves have an urban density of approximately 15.8 p/ha (SFSO, 1992/1997) similar to many North American or Australian suburbs. Although the region might be expected to be completely car dependent, its public transport is able to support a journey to work mode share of 21.7% (SFSO, 2000; note that this was Switzerland's last traditional census with detailed figures for particular rural regions). While this is lower than in nearby cities, it is more than double that of the UK's South Oxfordshire, part of the county considered by Hickman and Banister (2014). South Oxfordshire lies within a semi-rural commuter belt between Reading and Oxford, and has a population density of 1.9 p/ha, but only 8.1% of journeys to work by public transport (ONS, 2001).

A key reason for the Weinland's result is its high quality of public transport services: the region receives hourly (or twice-hourly) train and bus services between 6 am and midnight, with after-midnight services operating on weekends (see Petersen, 2014; Petersen and Mees, 2010). Trains run a basic all day service pattern—departing stations every hour at the same minutes-past-the-hour from first to last service—with additional peak trains slotted in-between. The simplicity of the service allows each timetable to be presented on a fraction of a page. Usage rates remain high even in villages that are not directly served by rail: short, direct feeder bus routes extend the rail catchment by making timed connections to trains, with many buses terminating at stations at both ends of their routes.

5.1. The Lower Engadine and Val Müstair

Much the same approach is used at the opposite end of the Swiss rural spectrum, in the remote and mountainous south-east of the country (Petersen, 2014; Petersen and Mees, 2010). The Lower Engadine valley and Val Müstair are two perpendicular mountain valleys at the eastern extremity of the Canton of Graubünden, bordering Austria and Italy. The valleys (henceforth both referred to as 'the Lower Engadine') are approximately 100 kilometres by road in total length, including a national park in between (see Fig. 2). Together, they have fewer than nine thousand residents (excluding tourists) and a gross regional population density of only 0.07 p/ha (SFSO, 2000 census). The surrounding mountains concentrate settlement in the middle of the valleys, of which the 'habitable area' population density can be estimated as 0.75 p/ha, while the average urban density of the villages is 8.5 p/ha (Petersen, 2012). Although the villages are typically compact and walkable, the region is one of the least densely populated parts of Graubünden, which is itself Switzerland's least densely populated canton.

Unlike the Weinland, the Lower Engadine has no large cities within commuting distance; residents' travel is predominantly local, between villages and the region's largest towns of Scuol (population 2000) and Zernez (population 1000). Nevertheless, 10.5 per cent of residents who travel to work do so by public transport, a figure still higher than South Oxfordshire and higher than many mid-sized American and Australian cities (Mees, 2010, pp. 60–61). The region's public transport system must also serve many visitors making longer journeys to the region from central Switzerland, as well as travelling locally within the region: for example, tourists account for the majority of rail passengers in the peak tourist seasons (M. Leuthold, personal communication, September 29, 2008). Services are particularly well used by those walking in the mountains in summer and skiing in winter, as they allow people to be dropped off at one point and picked up at another (extensive directional signage, with walking journey times included, also helps walkers plan their trips).

Despite these complex travel patterns, the usual pulse timetable concept is applied: a base network of hourly services departing at repeating times, with operating hours (largely) shared between routes. Short bus feeders are also designed to concentrate passengers on main line rail and bus services. The diverse travel patterns of visitors and local residents help to spread patronage across services.

The region is connected to the rail network, although the railway terminates at Scuol (see Fig. 3), leaving buses to serve a main line function in the eastern remainder of the Lower Engadine valley and through the Val Müstair. Two trains service the Scuol terminus, one from Graubünden's capital Chur, via Davos (also connecting to services from central Switzerland), and the other from near St. Moritz, each operating hourly until midnight. Operating hours for buses are typically shorter than in Canton Zürich, covering a 12–14-h span between 6am and 7–8 pm. Even though the valleys are linear, the villages are often higher up the sides of the valley than the main road or railway line, and attempts to serve them with one route would have made travel times uncompetitive with the journey by car (Petersen, 2014). Instead, passengers must transfer to village feeder services from the main valley lines. Where possible, feeders match the main lines' frequency and operating hours. Urban development is generally considered to be within the service coverage area where it is within a 300–400 m radius of bus stops or a 750 m radius of stations, although bus stops within villages may be as close as 200 m apart (K. Willi, personal communication, September 23, 2008).

The main valley lines run hourly, with half-hourly bus services operating at peak times in some of the villages immediately surrounding Scuol, and lower service levels for the most remote villages. The more remote ski resort of Samnaun also receives buses only every two hours, and in winter the villages of the Val Müstair have their services through the national park to Zernez reduced to running every one to two hours. Additional circuit buses run within Scuol and Samnaun, as often as every 15 min in winter, funded by the municipalities and tourist boards. Summer-only services funded by special tourist fares also run to the seasonally-inhabited village of S-charl, and to the Stelvio Pass.

Cantonal regulations relax Rail 2000′s effective standard of 18 return services per day, stipulating the minimum (and maximum) number of subsidised daily return services to connect groups of settlements to the public transport network, based on population densities (Canton of Graubünden, law nos. 872.100, 872.150). While not ideal from a network point of view, this does allow some very small villages to receive a service that they otherwise

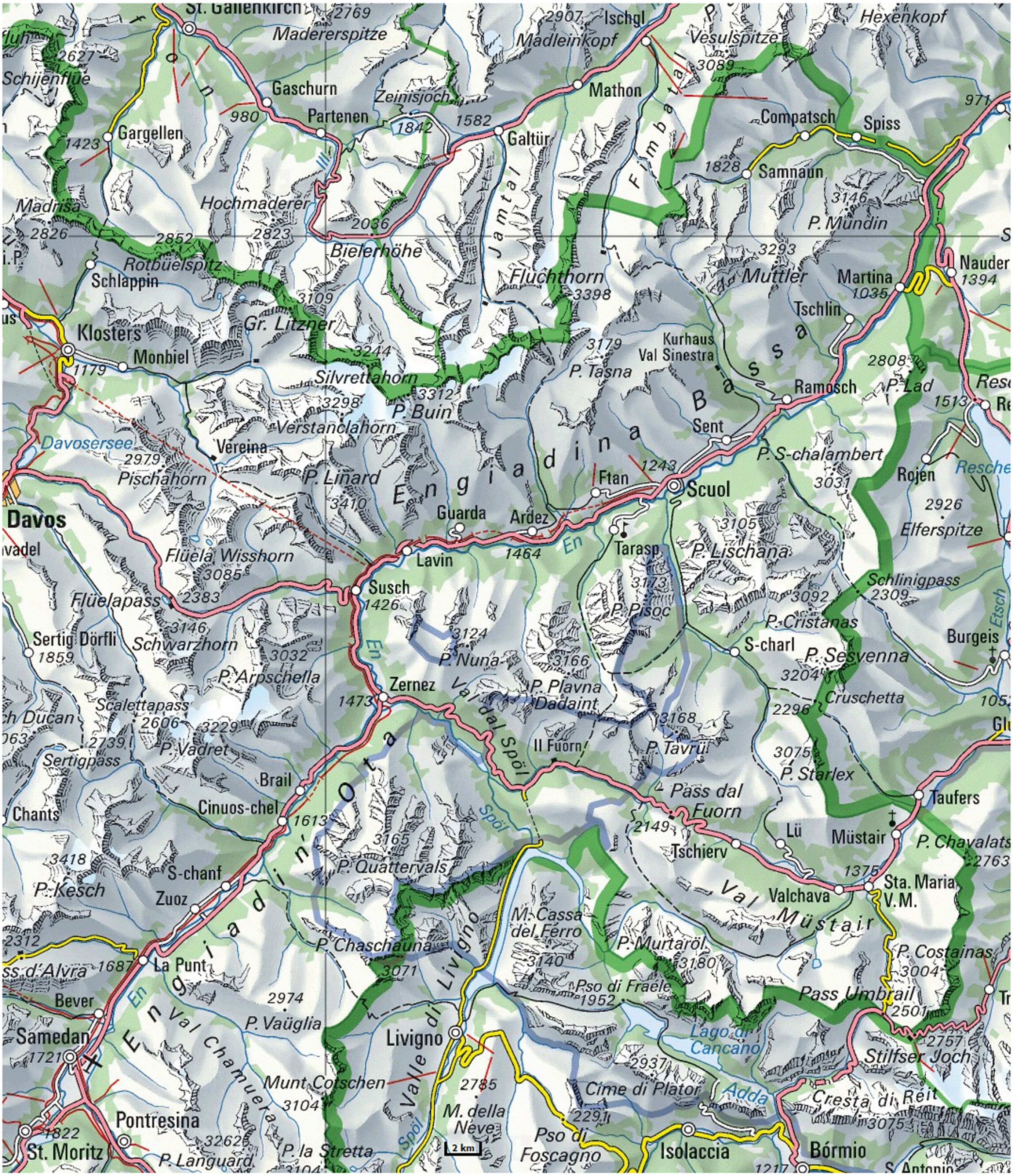

Fig. 2. The Lower Engadine (Engiadina Bassa) and Val Müstair and immediate surrounds. (Reproduced in *Transport Policy* by permission of Swisstopo (BA16064)).

could not support. For example, Lü (population 62) is provided with six return buses per day, plus two additional services in summer (Petersen, 2014). Wherever a route runs a reduced timetable, it will always run on the hour to connect with other trains or buses at a transfer point, but it may 'skip' some hours at the quietest times of day, usually the mid-morning and early afternoon. Breaks at these times may also allow services to be provided by a single bus and driver, as occurs for the short minibus route connecting the village of Guarda and its railway station.

Highly structured demand-responsive services also operate in the region, including bus-taxis to the villages around Scuol (Petersen, 2014). Private taxi businesses are contracted to run these

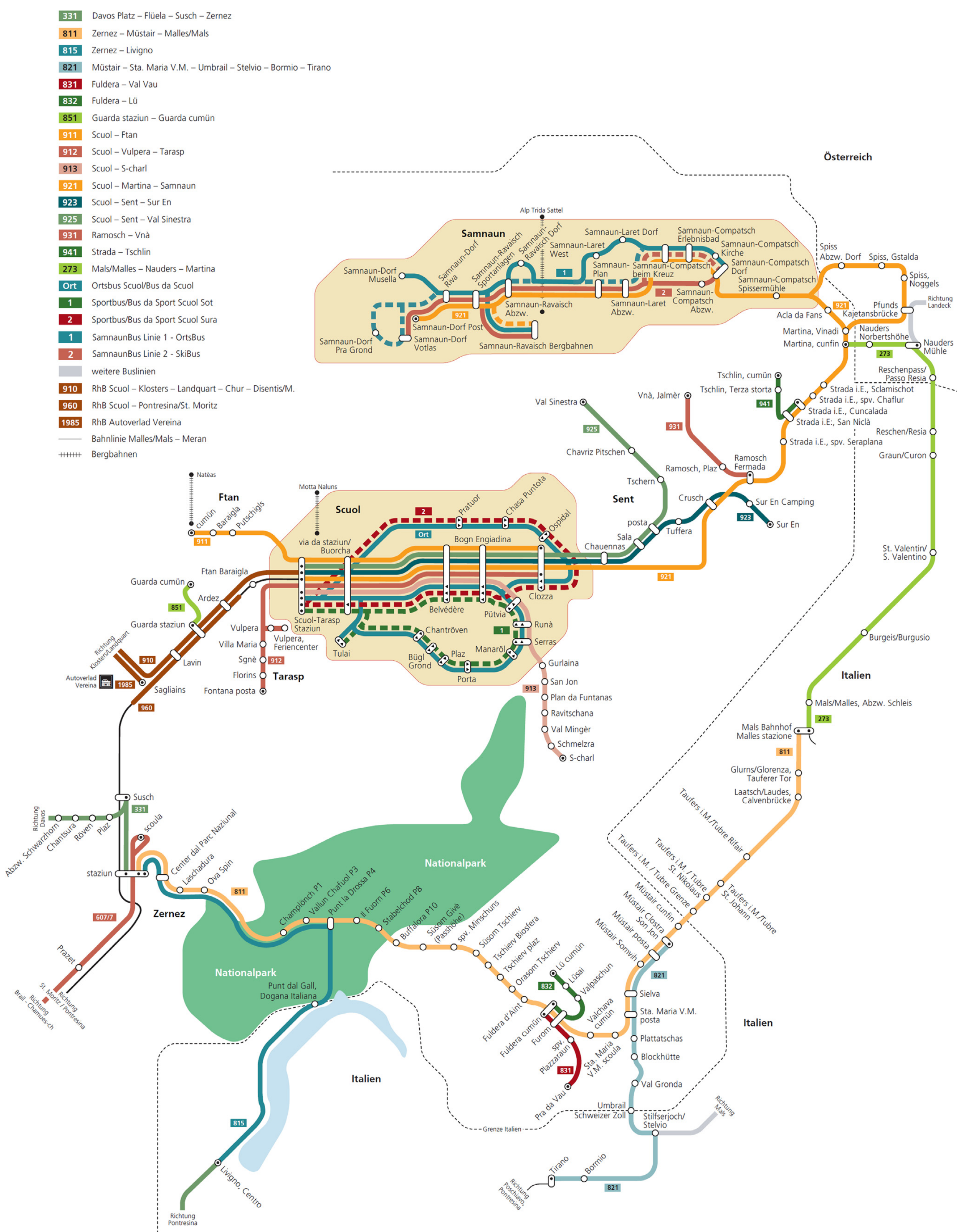

Fig. 3. Public transport network (bus and rail) in the Lower Engadine and Val Müstair, 2015 – not to scale. (Source: PostAuto; reproduced with permission).

smaller vehicles along the daytime bus routes from 9 pm to midnight when patronage is intermittent. They use the same bus stops, but charge a late evening fare surcharge. Bus-taxis always wait at the main station for any passengers that might be arriving by train, but anybody wanting to be picked up elsewhere must book by calling the driver's mobile phone at least 30 min before travel (or the bus-taxis may not leave the station at all). Subsidies are minimised by using smaller vehicles to save on fuel, applying a late-evening fare surcharge, and paying drivers a reduced rate in the expectation that they will spend a longer time standing by (K. Willi, personal communication, May 25, 2010). Until recently, there was only one all-day demand-responsive route in the region, running between the small village of Brail and its nearest administrative town, Zernez, which supplemented the village's conventional bus to towns in the opposite direction. It mainly served school children, but ran up to eight fixed-timetable return trips a day when booked an hour in advance, and had the lowest use of any route in the region (an average of 24 passengers per day in 2007) (PostAuto internal figures). In 2012, this was replaced with an extension of the conventional bus, demonstrating that structured demand-responsive transport can be used as a pilot for pulse-timetabled conventional services.

The overall effect of the Lower Engadine's coordinated network is that passengers can navigate the system's main lines throughout daylight hours without consulting a timetable. Users only need to know the 'minutes-past-the-hour' that a service departs from their local stop, and once having boarded are offered quick connections to almost any destination across the regional (and national) public transport network. Visitors arriving in the region by train will also typically find their local bus connection waiting at the station.

The network throughout Graubünden is planned through a small cantonal government office (Amt für Energie und Verkehr or 'AEV' in German), which works in close cooperation with majority government-owned rail (*Rhätische Bahn* or 'RhB') and bus (PostAuto) operators. The AEV has ultimate control over ensuring the provision of an interconnecting, canton-wide network with integrated fares (i.e., allowing a combined bus and rail journey on a single ticket). However, Graubünden's operators are more independent than those in a ZVV-style transport federation, retaining their own brands and marketing and customer information functions, including their own network maps and timetables. Nevertheless, each has a clearly defined role in the network, with buses generally acting as rail feeders, and timetable planning follows a hierarchical order from national rail, to regional rail and then local bus services. At yearly timetable conferences, RhB and PostAuto each make offers to run each of their lines at the service levels that the AEV specifies (giving forecast costs, along with predicted patronage and revenue), and the AEV then decides what services it can subsidise from its budget (M. Leuthold, personal communication, September 29, 2008).

The busiest main line bus routes have high average boardings, for example 989 trips per day between Scuol and one of its larger nearby villages, Sent (PostAuto internal figures, 2007; Petersen, 2014). This is approximately 23 boardings per scheduled service, although this may be overstated due to additional 'shadow buses' being run to add capacity at the busiest times (Petersen, 2012). Full size buses are generally used to allow services to cope with daily patronage fluctuations, although smaller vehicles are used on short feeder routes to the smallest villages where passenger numbers are consistently lower. Little information is publicly available on passenger transfers, partly reflecting the widespread use of travel passes rather than individual tickets, although passenger movement patterns can sometimes be inferred from general patronage figures. For example, total rail patronage to the region is only equivalent to one of the major bus routes, which appears to show mainly local travel on the transport network (RhB internal figures, 2007). Nevertheless, connections to rail routes are critical to provide links to other regions for tourists, and to serve residents making occasional longer trips.

Canton-wide, fares cover 35 per cent of operating costs for PostAuto, Graubünden's rural bus operator (W. Glünkin, personal communication, January 28, 2010), and 62 per cent for the canton's passenger rail operations (RhB, 2010). However, the total federal and cantonal subsidy per Graubünden resident for bus and rail operations is high: CHF 631 (Swiss francs) per person, 69 per cent of which is paid by the Swiss Federal Government (AEV internal figures 2009; Petersen, 2012). This is approximately double the subsidy per resident in more urban cantons (such as Zürich), indicating the Federal Government's willingness to subsidise rural transport services, and thereby give residents an equivalent level of access (much like health or telecommunications services), as well as support regional development and tourism. Nevertheless, the high usage means a relatively low subsidy per passenger (CHF 4.33), and it should be noted that there are no separate school bus systems or senior citizen travel concessions to be funded (see below).

The Lower Engadine demonstrates that a pulse timetable-based approach can deliver a viable, high-quality, fixed public transport network in a region with very low population densities. The convenience and ready legibility of repeating departures and planned connections are attractive to both tourists and a significant number of local residents, whose services benefit from tourist demand. The approach also shows sufficient flexibility to accommodate peak demands and seasonal routes, whilst also providing a structure for incorporating demand-responsive services.

6. Characteristics of integrated pulse networks

A central plank of the rural network approach applied in Graubünden and other Swiss regions is the integrated pulse timetable, and this section briefly outlines many of its technical characteristics, advantages and disadvantages (see also Clever, 1997, pp. 109–112).

As an integrated pulse system must connect to major destinations to be fully effective, passenger rail—often the fastest and highest-capacity form of public transport—will usually form the network's backbone. Railways should offer regular departures from stations at repeating 'minutes-past-the-hour', ideally across the entire rail network. At central city stations, the physical space required for all vehicles to simultaneously converge for the pulse may make implementing a system-wide pulse timetable difficult, at least in the short- to medium-term.

An integrated pulse timetable is ideal for situations where traffic flows are dispersed across a network 'without clear priorities', such as between the group of cities at the core of the Swiss rail network (Bern, Basel and Zurich) (U. Weidmann, personal communication, September 12, 2008). Even in decentralised Switzerland, however, there are dominant passenger flows to and from the larger cities. Where flows are uneven, an integrated pulse timetable will provide more services or capacity than strictly required in some travel directions at some times, but the benefit is an ability to serve all-day, multi-directional travel.

The pulse timetable's repetition is attractive to rail planners because it allows the same basic timetable to be applied every hour. Additional tracks or passing loops can be built on rural rail lines precisely where needed (F. Laube, personal communication, September 10, 2008). Planners can also use the stable timetable structure to prioritise investment in new infrastructure: for example, speeding up travel times to allow trains to arrive for an hourly pulse, and thereby reducing the number of vehicles and drivers required to operate the service. Local bus operations also benefit from being given consistent time windows between rail departures in which to complete their routes. As in most developed countries, where the largest transport running cost is labour, maximum use can be extracted from each vehicle and driver's time, even by extending routes to use up spare time (Ibid.).

Peaks are treated as anomalies from the norm, when capacity is added to cope with passenger numbers (Canton of Zürich, regulation no. 740.3, cl. 2). Sometimes this capacity is in the form of additional peak services inserted between regular services without disrupting their normal pattern; alternatively, additional train carriages or 'shadow' trains or buses may be run just before scheduled services. Trains and buses might therefore run less frequently at some times and on some routes than if headways were fine-tuned to travel demand. Off-peak services may also run slower than necessary, in order to keep timetables consistent across the day, although this can give planners added weight to pursue measures (like on-road priority) that reduce peak travel times.

Planners must be careful when setting basic service frequencies, as the interconnected network makes it difficult to cut back services if patronage is found to be 'too low' (U. Weidmann, personal communication, September 12, 2008). This is mainly an issue in the network core, as isolated peripheral services can be cut (or replaced by demand-responsive routes) with less effect on connectivity. Any network-wide service upgrades must also be done in large steps: for example, moving from 60- to 30-min headways doubles the quantity of services. This may cause large reductions in vehicle occupancy if planners are too optimistic about passengers responding to service improvements by travelling more (Clever, 1997).

Punctuality is crucial for pulse networks, as breakdowns in connections between services can cause major disruptions and a loss of passenger confidence in the system. While the Swiss are renowned for their timekeeping, they also employ practical strategies to make the outcome more likely. Due to the pulse timetable's repetition, detailed contingency and recovery plans can be prepared for a variety of possible problems in a single hour of rail operations, and then applied across the day (Tzieropoulos et al., 2010, pp. 8–10).

Additional time is also provided at the end of each route to allow late running services to get back on schedule. For trains, this recovery time ranges from about 4 per cent of travel time at the system's core to a maximum 12 per cent at the periphery (F. Laube, personal communication, October 13, 2008). Bus routes are generally kept short to act as feeders to rail, while on longer distance rural bus routes, buffer times at critical points also allow operators to recover from on-road congestion. Where trains are late, bus drivers are given clear instructions on how long they can wait for late trains, and if an operator fails to make the last connection for the day, they must compensate passengers by paying for a night's accommodation or a taxi to their destination (F. Laube, personal communication, September 10, 2008).

Overall, operators are placed under increased pressure, as strict clock-face timetabling requires that peak and off-peak schedules stay almost identical. This, for example, prevents operators from making adjustments to the running times of all-day services at peak times to allow for increased boardings or road (or rail network) congestion. While the concept of clock-face timetabling is well-known among transport planners, its less-than-systematic application in many rail systems suggests significant institutional resistance to its implementation. Tzieropoulos et al. (2010, p. 10) from the Federal Polytechnic University of Lausanne explain that for "less disciplined train operators, running according to regular-interval [let alone integrated pulse] timetables constitutes a real challenge. Success calls for dramatic changes in company mentality and culture."

7. Policy settings to support a rural network approach

The experience of the Swiss case studies discussed indicates that successful implementation of the rural network approach requires particular institutional and policy settings.

Strong service standards are crucial to support the hourly service frequencies that structure the Swiss integrated pulse network and allow passengers to navigate much of the rural network without consulting timetables. In Switzerland, these standards were attained through the interaction of planners, politicians and the public, and their simplicity gives them the advantage of being readily understood by both citizens and policymakers. (Minimum service standards may also form a stable basis for the provision of demand-responsive services, allowing them to substitute for fixed routes when patronage is low). The use of standards-based, regular-interval services is also a form of 'supply-oriented' planning, the proactive raising of public transport supply to levels "higher than technically needed" to develop public transport demand (Tzieropoulos et al., 2010, p. 11). This means that service levels "remain relatively high, even in off-peak periods… [the] idea is to send the message to transport users that public transport is 'there and available' at any time, much like the private car". Tzieropoulos et al., (2010) argue that the approach works best when combined with policies to manage demand for car travel.

Increases in operational funding are likely to be needed to run comprehensive, all-day pulse services compared to pre-existing irregular service patterns, even if, as in Switzerland, operators are often able to provide pulse services using the same number of vehicles (Petersen, 2012; F. Laube, personal communication, September 20, 2008). As in Graubünden, recognition of a high-quality public transport system's benefits for rural tourism, and high cost recovery and usage levels, are also likely to assist the funding case. School transport functions should also be integrated into the regular public transport system, rather than providing school-only services, to maximise its use and reduce duplication. An accessible fixed network can also be used to serve many people with special mobility needs, including older people and people with disabilities, in conjunction with taxis for parts of journeys (as in the ZVV service region).

A multi-modal fare system (which allows transfers without penalties) is required to support a network that relies on transfers. A large pool of passengers with long-term (heavily discounted) travel passes is also an advantage: Swiss rural services carry significant numbers of pass holders, including many retirees who take leisure or tourist trips to the countryside, and thereby help to fill middle-of-the-day services. Further travel pass discounts are available to senior citizens and young people. Children pay half price single fares, and regular users of any age can purchase a 'half fare' card for an upfront fee (CHF 185 in 2016) to entitle them to the same discount. The focus on travel passes and half-fare cards is intended to encourage customer loyalty and mirror the greater upfront costs of car ownership and use.

Providing multi-modal fares and an integrated pulse timetable requires differential subsidies between services that are typically run by different operators (bus and rail, or different routes of the same mode); therefore, a strong central agency with the ability to direct operators and control resource allocation is needed. The agency must have the powers to direct timetable planning in the interests of the wider network (where a particular action may not be in the interest of the operator) and to distribute resources from a central subsidy pool to ensure consistent levels of service across routes of varying patronage. State ownership of operators and close oversight of operating costs and revenue (as in Switzerland) may also reduce concerns about potentially over-compensating operators.

The Swiss case seems to demonstrate the "multi-modal regional planning" that Mulley et al. (2012, p. 5) associate with mainland Europe, in contrast to the deregulated, "on-the-road competition between transport operators" practiced in the UK. One notable UK attempt at coordinating fixed route buses run by various operators, along with more highly-subsidised demand-responsive services, is organised by the Lincolnshire County Council under the brand names 'InterConnect' and 'Call Connect'. However, outside the core routes between towns (whose populations are many times larger than those in the Lower Engadine), service levels are highly variable and seven-day-a-week operation rare. Passengers continue to report frustration with mobility options (see e.g., Ward et al., 2014), and Mees (2010, p. 178) criticises poor connections between services, as well as the deregulation policy that makes formal network planning "illegal". As such, UK-style deregulation, and probably also rail franchising, would directly conflict with the central timetable planning and cross-subsidies required for a Swiss-style network. This may be one reason why pulse timetable systems are yet to be implemented in the UK, despite its dense rural settlement and often highly tourist-oriented rural areas.

8. Conclusion

The pulse timetable-based rural network approach allows conventional public transport to provide a high-quality alternative to car travel, capable of attracting a significant share of travellers in an affluent society. Its regular, fixed-route services provide a stable basis for transport service planning, as well as for any transit-oriented land-use planning measures that might be adopted by rural settlements. It also seems likely to provide an efficient model of general transport service for ageing populations, and one that could be easily scaled-up to deal with greater passenger numbers, if ever required for environmental or other reasons.

Graubünden's Lower Engadine demonstrates that even in rural regions with very low population densities—especially where settlements are concentrated along corridors—pulse timetable-based networks can operate with more than adequate levels of cost recovery and vehicle occupancy. In particular, tourist-oriented rural regions can use pulse networks to take advantage of independent tourist travel and provide higher quality services to their own residents. When (or where) there are fewer travellers, fixed-route demand-responsive services, like the Lower Engadine's taxi-buses, can be used to save on fuel and pay drivers a lower stand-by rate.

Rural pulse networks can also work in regions with flatter topography, such as between the scattered villages of the Zurich Weinland, although routes will often need to be structured to favour timed connections to a predominant travel corridor (usually between the two nearest towns or cities). Networks are likely to be most efficient where rural development is compact (but not necessarily high density) and clustered within walking distance of potential stops on direct routes. In cases where dispersed housing cannot be brought within walking distance of a single direct fixed route, and planners judge that two or more fixed routes cannot be justified, corridor-based demand-responsive services should be considered. However, these may also bring some disadvantages, such as an inability to guarantee passengers a service at peak times.

Overall, there are likely to be opportunities to apply the rural network approach more widely across the rural areas of other densely-populated developed countries, especially in Europe. The model could even be used in the more densely-populated rural or exurban regions of North America and Australasia, although it is unlikely to be able to serve large, isolated rural housing lots, and rural usage rates may reflect generally lower levels of urban public transport use (Petersen, 2012). As elsewhere, patronage is likely to be higher when rural systems are effectively connected to high-quality metropolitan public transport.

The Swiss example shows that delivering services through an integrated pulse network requires central planning through public agencies, incorporating hierarchical timetabling processes and cross-subsidies for routes with lower levels of cost recovery. Total subsidies per resident may be high, but low subsidies per passenger and high cost recovery (for a rural network) suggest good value-for-money. To make similar rural transport networks possible elsewhere, these features may require a re-think of transport policy goals, institutional arrangements and funding levels; and notably in the UK, the overturn of deregulation policy.

While the rural network approach makes space for structured demand-responsive transport, its focus is squarely on providing fixed-route, pulse-timetabled services, which it seems to be able to push deep into rural areas. While there will often be important roles for more flexible demand-responsive services, the rural pulse network and widespread demand-responsive models represent opposite approaches to transport planning: the 'inflexible' routes and timetables of the network approach are not tailored to individual travellers' needs, but planned as a standardised, 'catch-all' service. The rural network approach therefore challenges proponents of extensive demand-responsive transport, as well as conventional public transport planners, who have often overlooked a model of service delivery that in many cases offers clear advantages.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.tranpol.2016.07.012.

References

Apel, D., Pharoah, T., 1995. Transport Concepts in European Cities. Avebury, Aldershot, England.

Berthouzoz, J.-P., Meiner, H., Stähli, S., 1972. Taktfahrplan Schweiz: Ein neues Reisezugkonzept [Taktfahrplan Switzerland: A new passenger rail concept]. Choindez, Switzerland.

Brown, J.R., Thompson, G.L., 2008. Service orientation, bus–rail service integration, and transit performance. Transp. Res. Rec. 2042, 82–89.

Butt, A., 2014. Developing a typology of changing multi-functional regions. Australasia J. Reg. Stud. 20 (2), 233–257.

Canton of Graubünden, law nos. 872.100 Gesetz über den Öffentlichen Verkehr im Kanton Graubünden [Public Transport Law] 1993, and 872.150 Verordnung über den Öffentlichen Verkehr [Public Transport Regulations] 1994.

Canton of Zürich, regulation no. 740.3, Verordnung über das Angebot im öffentlichen Personenverkehr [Regulations on public transport supply] 1988, 2009 version, cl. 8.

CZSO (Canton of Zürich Statistical Office), n.d.. Abstimmungsresultate kantonale Vorlagen 1934–1996 [Canton Zürich referendum results 1934–1996] [webpage]. Retrieved June 6, 2009 from: 〈http://www.wahlen.zh.ch/abstimmungen/zhresultate.php〉.

Clever, R., 1997. Integrated timed transfer: a European perspective. Transp. Res. Rec. 1571, 107–115.

Commission for Integrated Transport, 2008. A New Approach to Rural Public Transport. HMSO, London.

Cullinane, S., Stokes, G., 1998. Rural Transport Policy. Elsevier Science, Oxford.

Davison, L., Enoch, M., Ryley, T., Quddus, M., Wang, C., 2014. A Survey of Demand Responsive Transport in Great Britain. Transp. Policy 31, 47–54.

Enoch, M., Potter, S., Parkhurst, G., Smith, M., 2006, January. Why do Demand Responsive Transport Systems Fail? Paper presented at Transportation Research Board 85th Annual Meeting, Washington DC.

European Environment Agency (EEA) (2006). Urban Sprawl in Europe: The Ignored Challenge. Copenhagen.

Foster, R., Stähli, S., 1982. Taktfahrplan Schweiz- 1: Background and principles, Modern Railways (May). Ian Allan, Shepperton, England, pp. 218–221.

Ghose, R., 2004. Big sky or big sprawl? Rural gentrification and the changing cultural landscape of Missoula, Montana. Urban Geogr. 25 (6), 528–549.

Hickman, R., Banister, D., 2014. Affluent rurality and car dependence (Oxfordshire), Transport, Climate Change and the City. Routledge, Abingdon, pp. 141–175.

Hürlimann, G., 2005. The Swiss Path to the 'Railway of the Future (1960s to 2000): Contributions towards a History of Technology for the Swiss Federal Railways. Paper presented at the Swiss Transport Research Conference, Monte Verità/ Ascona.
Leimgruber, M., 2008. . Solidarity Without the State? Business and the Shaping of the Swiss Welfare State. Cambridge University Press, Cambridge, pp. 1890–2000.
Linder, W., 1994. Swiss democracy: possible solutions to conflict in multicultural societies. St. Martin's Press, New York.
Linder, W., 2004. Political Culture. In: Klöti, U., Knoepfel, P., Kriesi, H., Linder, W., Papadopoulos, Y. (Eds.), Handbook of Swiss Politics. Neue Zürcher Zeitung Publishing, Zurich, pp. 13–31.
Mageean, J., Nelson, J., 2003. The Evaluation of Demand Responsive Transport Services in Europe. J. Transp. Geogr. 11, 255–270.
Mees, P., 2000. A Very Public Solution: Transport in the Dispersed City. Melbourne University Press, Melbourne.
Mees, P., 2010. Transport for suburbia: beyond the automobile age. Earthscan, London.
Mott Macdonald Consultants, 2008. Appendix Case Study F– PubliCar (In: The Role of Taxis in Rural Public Transport: Final Report). Commission for Integrated Transport, London.
Mulley, C., Nelson, J., Teal, R., Wright, S., Daniels, R., 2012. Barriers to implementing flexible transport services: An international comparison of the experiences in Australia, Europe and USA. Res. Transp. Bus. Manag., 3–11.
Nielsen, G., Nelson, J., Mulley, C., Tegnér, G., Lind, G., Lange, T., 2005. HiTrans Best Practice Guide 2: Public Transport: Planning the Networks. HiTrans, Oslo.
Office for National Statistics (ONS UK), 2001. Key Figures for 2001 Census [dataset]. Retrieved December 11, 2010. From: ⟨http://neighbourhood.statistics.gov.uk/⟩.
Petersen, T., Mees, P., 2010, July. A Case of Good Practice: The Swiss 'Network' Approach to Semi-rural Public Transport. Paper presented at the 12th World Conference on Transport Research (WCTR), Lisbon.
Petersen, T., 2012. Public Transport for Exurban Settlements (Unpublished doctoral thesis). The University of Melbourne.
Petersen, T., 2014. Public transport beyond the fringe. In: Gleeson, B., Beza, B. (Eds.), The Public City: Essays in Honour of Paul Mees. Melbourne University Press, Melbourne, pp. 149–165.
Pucher, J., Buehler, R., 2012. Demand for Public Transport in Germany and the USA: An Analysis of Rider Characteristics. Transp. Rev. 32, 541–567.
Pucher, J., Kurth, S., 1996. Verkehrsverbund: the success of regional public transport in Germany, Austria and Switzerland. Transp. Policy 2, 279–291.
RhB (Rhätische Bahn) (2010). Geschäftsbericht 2009 [Annual Report 2009]. Chur, Switzerland.
Stone, J., Beza, B., 2014. Public transport: elements for success in a car-oriented city. In: Gleeson, B., Beza, B. (Eds.), The Public City: Essays in Honour of Paul Mees. Melbourne University Press, Melbourne, pp. 90–105.
Swiss Federal Statistical Office (SFSO), 1992/1997, Arealstatistik 1992/1997 [Area Statistics, dataset]. SFSO Nomenclature NOAS92_15. Retrieved May 10, 2010, from: ⟨http://www.bfs.admin.ch⟩.
Swiss Federal Statistical Office (SFSO), 2013. Mobilität und Verkehr 2013 [Mobility and Transport 2013]. SFSO Publication No. 1130–1300, from: ⟨http://www.bfs.admin.ch/bfs/portal/de/index/news/publikationen.html?publicationID=5294⟩ (Retrieved 1.06.13).
Swiss Federal Statistical Office (SFSO), 2000. Räumliches Informationssystem zu den Pendlern und Verkehrsmitteln, 1990 und 2000 [Spatial Information System on Commuters and Travel Modes, 1990 and 2000; online dataset]. Data aggregated from Tables C1A and C2A for each commune within the Lower Engadine and Val Müstair or Weinland regions, based on 2000 census data. From: ⟨http://www.media-stat.admin.ch/stat/pendler/pop.php?qmode=ch&q=1&lang=de⟩ (Retrieved 10.12.09).
Swiss Federal Statistical Office (SFSO), 2010. Statistical Yearbook 2010. Neuchâtel. From: ⟨http://www.bfs.admin.ch⟩ (Retrieved 01.11.10).
Tzieropoulos, P., Emery, D., Buri, J.-D., 2010, July. Regular-interval Timetables: Theoretical Foundations and Policy Implications. Paper presented at the 12th World Conference on Transport Research (WCTR), Lisbon.
Thompson, G., Matoff, T., 2003. Keeping up with the Joneses– radial vs. multi-destinational transit in decentralizing regions. Am. Plan. Assoc. J. 69, 296–312.
Vuchic, V., Clarke, R., Molinero, A., 1981. Timed Transfer System Planning, Design and Operation. US Department of Transportation, Washington D.C..
Vuchic, V., 2005. Urban Transit: Operations, Planning and Economics. John Wiley & Sons, Hoboken, New Jersey.
Ward, M., Somerville, P., Bosworth, G., 2014. 'Now without my car I don't know what I'd do': the transportation needs of older people in rural Lincolnshire. Local Econ. 28 (6), 553–566.
White, P., 2009. Public Transport: Its Planning, Management and Operation, 5th ed. Routledge, London.
Wiesendanger, W., n.d. Vernetzt sind wir stark: 10 Jahre Zürcher Verkehrsverbund [Networked we are strong: 10 years of the ZVV]. Zurich: ZVV.
Winterton, R., Warburton, J., 2012. Ageing in the bush: the role of rural places in maintaining identity for long term rural residents and retirement migrants in north-east Victoria, Australia. J. Rural Stud. 28, 329–337.