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Sonia Strube Martins
Matthias Finger
Andreas Haller
Urs Trinkner

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Swiss Economics SE AG
Stampfenbachstrasse 142
CH-8006 Zürich

T: +41 (0)44 500 56 20
F: +41 (0)44 500 56 21

office@swiss-economics.ch
www.swiss-economics.ch

Integrated timetables for railway passenger transport services

Dr. Sonia Strube Martins, Swiss Economics[1]
Prof. Dr. Matthias Finger, EPFL Lausanne and Swiss Economics
Andreas Haller, Swiss Economics
Dr. Urs Trinkner, Swiss Economics and University of Zurich

Abstract

Rail passenger transport services with integrated regular interval timetables (IRIT), offer passengers a regular interval timetable for services on the railway network. IRIT have the potential to increase the quality and attractiveness of railway passenger services in comparison to other transport modes. This paper summarizes the advantages and challenges of an implementation of IRIT for railway passenger services and derives the main requirements for the successful introduction of IRIT.

The comparison of the regulatory framework, the role of IRIT and the development of passenger railway services in CH, the NL and the UK, shows that in those countries, where either IRIT has been introduced (CH) or the high frequency of trains between cities provides for a system comparable to IRIT (NL), railway services play a more important role in the modal split. The successful introduction of IRIT requires a long-run implementation schedule which identifies the necessary investment in the railway infrastructure and points out the financial resources available to make those investments. Further, IRIT requires a high level of punctuality of railway passenger services, the coordination between railway companies when designing the timetable and a priority rule for passenger railway services within IRIT when there are capacity restrictions on the railway network.

[1] Sonia.strubemartins@swiss-economics.ch, Stampfenbachstrasse 142, CH – 8006 Zürich

1. Introduction

IRIT have the potential to increase the quality and attractiveness of railway passenger services (in comparison to other transport modes). This paper aims at showing the role IRIT can play to strengthen the competitiveness of rail passenger transport in the modal split. Further, the requirements for a successful introduction of IRIT will be discussed including the regulatory framework for the introduction of IRIT.

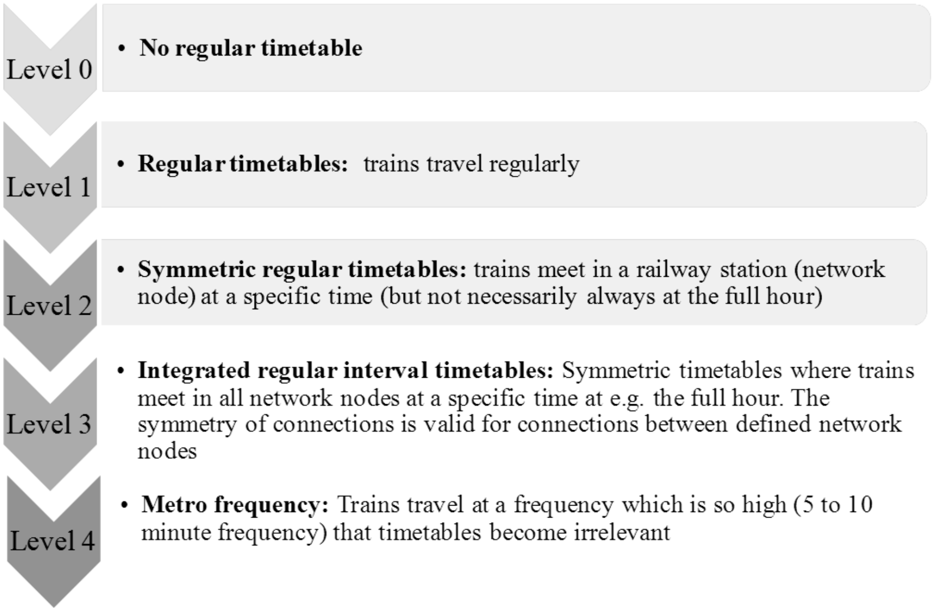
Regular timetables can be introduced in different variations (see Figure 1). In a railway system without regular timetables the trains run at irregular intervals, e.g. only at rush hour times or when they are completely booked (level 0). Simple regular timetables are the most reduced form to introduce regular timetables and refer to time schedules with regular trains (level 1). The next step would be the introduction of symmetrical regular timetables. In this case, the train connections cross at network nodes at some specific time but without coordinating the crossing time at all network nodes (level 2). Integrated regular timetables refer to symmetric regular timetables with train connections meeting at all network nodes at a specific time (e.g. at the full hour, level 3). The symmetric frequency is introduced for all network nodes which have been defined in advance. Integrated regular timetables which are designed to be attractive for customers also take into account aspects like the frequency of connections during the day and/or the tariff system (one tariff system for national rail and cooperation with/between regional rail networks as well as across transport systems).[2] In the last level of integrated regular interval timetables trains run at very high frequency similar to a Metro-System every 10 or 5 minutes. The train frequency is so high that time schedules become irrelevant (level 4).

In this paper we perform case studies on the introduction of IRIT in Switzerland, the Netherlands and the UK which are characterized by a different level of introduction of IRIT. For each country information was gathered on the introduction of regular timetables, the legal framework and the development of passenger rail transport. The results of the case studies and desk research were the basis for the discussion of pros and cons as well as the requirements for a successful introduction of IRIT.

The paper begins with the results of the case studies in chapter 2. Based on the information from the case studies, chapter 3 discusses the advantages as well as the challenges of IRIT. The requirements for a successful introduction of IRIT are described in chapter 4. The conclusions are presented in chapter 5.

[2] See Engel, R. (2012), p. 262 und Leister, H. (2010), p. 3.

Figure 1: Definition of integrated timetables



2. Regular timetables in selected countries

The role of IRIT for passenger transport is reflected in the development of selected indicators. Experience in Switzerland and in the Netherlands helps assessing the requirements for a successful introduction of IRIT or of high frequency timetables respectively.

2.1 UK: Low level of integration in (national) timetables

The development of passenger transport in the UK is characterized by the early liberalization and the franchising of regional networks. Serious problems with the (safety of) rail infrastructure after the liberalization in the 90’s called for regulatory measures which aimed at improving the infrastructure and at solving problems with scarcity of capacity as well as with the quality of rail services.[3] The focus was on punctuality, safety and other performance indicators but not on the introduction of IRIT.

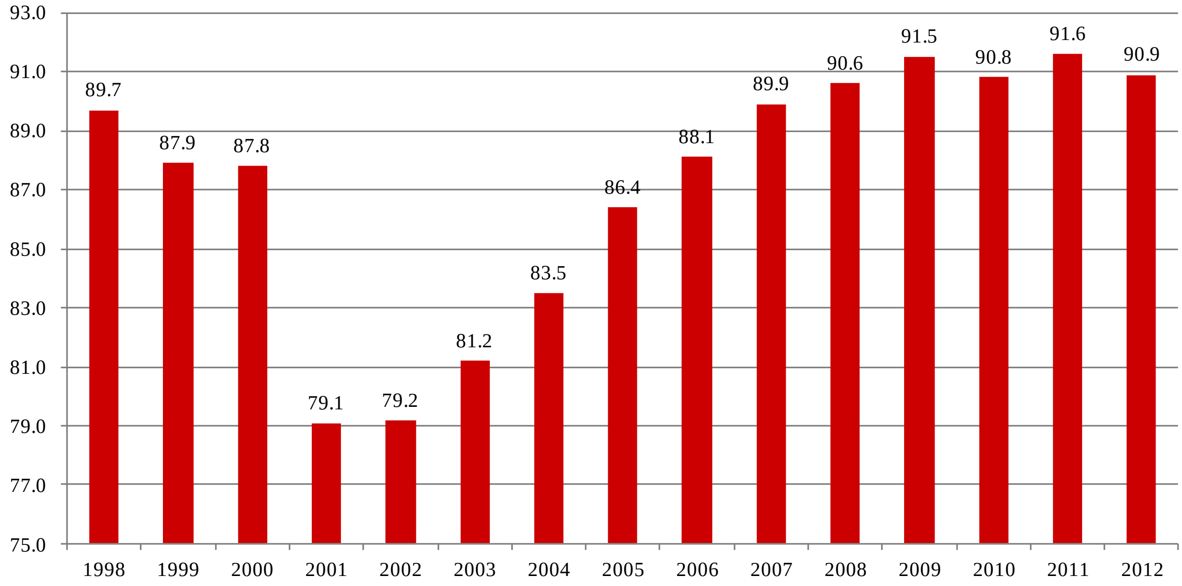
Due to the high frequency of connections the service of the time schedules in big agglomerations is comparable with IRIT (in many regional franchises IRIT has been introduced at level 3 or 4). With respect to national rail services – due to the focus on licensing regional networks through tenders – the tariff system and the design of time schedules are very fragmented with a low level of coordination between the franchises. The operators of the franchised networks target at optimizing the network usage in their franchise area without having to coordinate their activities with other operators.

Experience in the UK showed that the separation of network and rail services and the tendering of licenses for the franchise regions can be of disadvantage. Shortly after the liberalization policy in the 90’s the performance in punctuality of trains decreased significantly (see Figure 2) and the quality of

[3] See Tyler (2003), p. 2 ff.

the infrastructure suffered. As a consequence, high investment was necessary to improve the infrastructure.

Figure 2: Development of punctuality in the UK (trains with maximum 5 minutes delay in %)



Source: ORR (2014), Public performance measure (PPM) by sector. Great Britain annual and quarterly data from 1997-98 quarter 1 up to 2013-14 quarter 2 - percentage of trains arriving on time; http://dataportal.orr.gov.uk/displayreport/report/html/be8ce46b-ba99-41c5-8a22-48b8759a16cb

As a result, the punctuality has improved. However, the coordination of the time schedule process is very costly and in comparison with other European countries the infrastructure cost in the UK are significantly higher. Eventually, the liberalization did not bring the expected improvement in efficiency. On the contrary, an international benchmark of the UK with the Netherlands, Switzerland and Sweden showed that there is an efficiency gap of 40%. One of the reasons for the higher cost in the UK is seen in the inefficient cooperation between the rail operators and Network Rail.[4] In several countries there is a trend to reintegrate rail infrastructure and transport services to profit from synergies and for a better coordination of the priorities between the infrastructure operator and the rail services providers so that the cost of rail services are reduced.[5]

The advantages of an integration of infrastructure and passenger transport services are strongest when there is a high capacity usage and a high frequency of trains, as the need for continuous coordination between infrastructure and rail services is strongest in this case and becomes more difficult when rail infrastructure and services are operated separately.[6]

2.2 Switzerland: Introduction of IRIT step by step

[4] See ORR (2010), S. 21 ff.

[5] See DB (2012), S. 42 f.

[6] See DB (2012), S. 45 und Mizutani, F.; Uranishi, S. (2010), S. 3.

In Switzerland regular timetables have been introduced in 1982 on an hourly basis. This was the starting point of the ambitious project **Bahn 2000**.[7] The project aimed at introducing half-hour IRIT in an expanded network with network nodes. One condition for the introduction of IRIT was the investment in rail infrastructure to implement the network nodes. The project was realized from 1997 on in several steps. The main milestone of the project was achieved in December 2004 when the new connection between Zurich and Bern was inaugurated. 58% of all connections between 40 of the railway stations were accelerated by 5%. In some cases connections had to be slowed up to be able to realize IRIT.[8]

The development of passenger services in Switzerland from 1990 until 2010 shows that the realization of the first step of Bahn 2000 (including of the introduction of half-hour IRIT) was followed by a significant increase in usage of passenger rail services. According to the final report of the Bahn 2000 project, passenger trains of SBB travelled 127.6 million train kilometers in 2006, 16.7% more compared to 2004. The number of passengers increased by 14.4% which corresponds with 14.3 billion passenger kilometers. The transport services of SBB in national connections increased by 16.3% to reach 10.7 billion passenger kilometers. This increase in demand led to a share of rail transport in the overall mobility growth which lied above average. Regional rail transport also benefited from this increase in demand. The traffic volume in 2006 increased by 9.1% compared to 2004 and reached 3.6 billion passenger kilometers. Most transport undertakings in public transport observed a significant increase in demand due to the expanded offer achieved with Bahn 2000. The success of Bahn 2000 also depended on factors which were not directly linked with IRIT but which play an important role in the acceptance of rail passenger transport. Among others, these factors include the tariff system. In Switzerland new tariff networks as well as the Halbtax-, General- and network subscriptions were introduced which were well accepted by the customers. The same tariff applies to international trains and SBB. In Switzerland there are about 20 tariff and transport networks. In these networks special network tariffs are sold and in most cities or agglomerations it is possible to buy tickets which are valid 24h for the different modes of transport. The Halbtax subscription can be bought for one, two or three years and reduces the tariffs for most modes of transport by 50%.

Figure 3 shows that with the completion of the first steps of Bahn 2000, the trend in the development of rail transport turned to a growth of train kilometers which lied over the growth of private automobile transport. In 2004, when Bahn 2000 was completed, there is a clear break in favour of public passenger transport which reaches a share in overall passenger transport which lies over the share of private automobiles.

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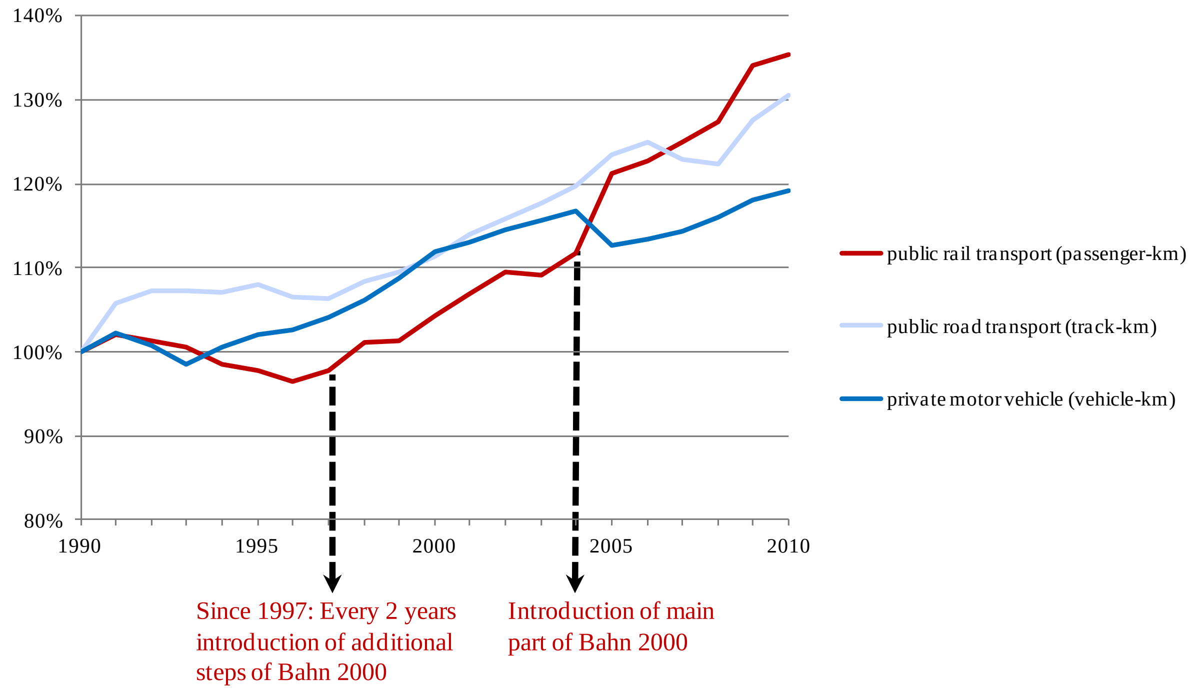
7 Bundesgesetz betreffend das Konzept BAHN 2000 vom 19. Dezember 1986 (SR 742.100).

8 See Bundesamt für Verkehr (2007), S. 18 ff.

Figure 3: Successful introduction of Bahn 2000



Source: Swiss Economics, based on Bundesamt für Statistik (2012).

In 2005 work started for the project «**Zukünftige Entwicklung der Bahninfrastruktur» (ZEB)**. Among others, ZEB completes the network nodes concept of Bahn 2000 by intending to complete the steps which were not realized in Bahn 2000 because the financial resources did not cover those steps. Further, in February 2014 the Swiss population approved a constitutional revision concerning the financing and expansion of rail infrastructure. As a result, in the future all costs of rail infrastructure will be financed by a new unlimited rail infrastructure fund (BIF). Together with the constitutional revision the population approved the so called STEP (strategic development program) which deals with the rail demand and expansion in the long-run perspective.

STEP is based on the plans of "Bahn 2030". It covers the timeframe until 2050 and investments of about 42.5 billion CHF. The implementation of STEP will take place in several steps. One of the first steps refers to investments of 6.4 billion CHF to be realized until 2025. The step 2025 will be coordinated with ZEB as the steps of both projects overlay in their timeframe. Another step which refers to higher investments to be performed until 2030 is to be presented to parliament in 2017.[9]

2.3 Netherlands: On the way to 10-minutes-frequency

Regular timetables have been introduced in the Netherlands as early as 1938. In 1970/71 network nodes were introduced and connections met at those nodes every hour. Currently, the high frequency

[9] See Botschaft zur Volksinitiative „Für den öffentlichen Verkehr" und zum direkten Gegenentwurf (Bundesbeschluss über die Finanzierung und den Ausbau der Eisenbahninfrastruktur, FABI) vom 18. Januar 2012 (BBl 2012 1577), S. 1581 and Volksabstimmung vom 9. Februar 2014, Erläuterungen des Bundesrates.

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makes it possible to change trains and use connections without waiting long, even though IRIT with more than one train per hour have not been introduced officially. On some routes the traffic is so frequent that there is thought of giving up timetables.[10] The high frequency of national connections leads to a transport density in rail passenger transport which is comparable to transport services with IRIT. In June 2010 the Dutch government decided on the High-Frequency-Rail-Program (HFP). The decision was based on a proposal of the Ministry of Transport, which was developed in cooperation with Prorail and NS. Target of the program is to increase the frequency of national connections on the most used routes until 2020 to 10 minutes so that timetables become irrelevant.[11] To achieve the high frequency for those routes and at the same time be able to reserve minimum capacities for freight transport, freight corridors are planned which optimize the usage of the Betuweroute. Further, investment in rail infrastructure for freight transport is planned to reach the Betuweroute and to connect the Betuweroute with the border.

In the Netherlands one chip-card is valid for all public transports. The tariff is based on km and differentiated by mode of transport. The total route is covered by a check-in and check-out system.

2.4 Regulatory implementation of IRIT in Switzerland and the Netherlands

As mentioned above, IRIT in Switzerland and in the Netherlands are rather advanced. The implementation of IRIT or of high frequency connections respectively has been accompanied by regulatory measures which will be discussed below with reference to the priority of IRIT, an obligation to coordinate timetables according to IRIT and the licensing regime.

2.4.1 Priority for IRIT

The implementation of IRIT in Switzerland went hand in hand with introducing a priority for IRIT in the legal framework. Art. 9a Nr. 2 railway act rules that in network access management the passenger transport in the context of IRIT has priority access. Connections in the transport chain of public transport are not allowed to be interrupted. The Eisenbahn-Netzzugangsverordnung (NZV) rules in Art. 11 Nr. 1 that network access and the allocation of rail track capacity has to be coordinated with the timetable process. The NZV also refers to Art. 9a of the railway act, i.e. to the priority of regular passenger transport.

Similarly, there is a priority of national rail passenger transport in the allocation of rail network capacity in the Netherlands. It is however combined with the obligation to reserve track capacity for freight transport. The decision on capacity allocation (Besluit capaciteitsverdeling) contains minimal frequency obligations for specific national routes (connections between cities). These have priority in case there are conflicting requests for rail track capacity, under the condition that there is minimum

10 See Engel (2012), S. 263.

11 See Ministerie von Verkeer en Wasterstaat (2010), Priority Decision High-Frequency Rail Transport Programme, http://www.rijksoverheid.nl.

capacity for freight transport. Art. 10 of this decision includes a priority list which is to be considered in the case of scarce capacity and if the minimal frequencies mentioned above do not solve the conflict.[12]

2.4.2 Coordination obligation

In Switzerland Trasse Schweiz AG is responsible for the allocation of capacity and for the timetable process close cooperation with the rail undertakings and the infrastructure operators. Trasse Schweiz AG accompanies the rail undertakings and network operators in the preparation of the timetable and is responsible for a non-discriminatory and correct preparation of the timetable. Trasse Schweiz AG was founded 2006 by the main incumbent operators SBB, BLS and SOB together with the association for public transport (Verband Öffentlicher Verkehr VöV).[13]

The timetable process according to Art. 3 Fahrplanverordnung (FPV) of November, 4 2009 comprises the following phases:[14]

1. Preparation of the concept for national transport;
2. Preparation of timetables for each connection;
3. Provisional capacity allocation according to NZV of 25 November 1998;
4. Preparation of the draft timetable;
5. Final capacity allocation according to NZV;
6. Preparation of the final timetable.

The rail undertakings involved in the process prepare a concept for national rail as a basis for the planning of paid transport services and for the draft timetable.

The concept is presented to the Bundesamt for Verkehr (BAV), the customs direction and the cantonal administrations. The national rail concept includes the Swiss and the international transport. The customs direction takes position to the cross-border traffic. The BAV and the cantonal administration are allowed to require justified changes in the concept. The rail undertakings give a statement to these required changes and if they ignore the required changes, they have to explain it.[15]

After the decision of the entities ordering regional transport services on the services to be included in the timetable and after the provisional capacity allocation by Trasse Schweiz AG, the rail undertakings prepare a draft timetable for the national and regional transport. After the final allocation of capacity the rail operators prepare the final timetable. The rail undertakings coordinate their timetables continuously and give special attention to connections between trains.

In the Netherlands the network operator Nederlands Spoorwegen (NS) is obliged to publish a transport plan in which they specify the frequency planned for trains on certain routes between specified cities.

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12 See Besluit capaciteitsverdeling hoofdspoorweginfrastructuur in der Version 12.02.2011.

13 See Internetseite der Trasse Schweiz AG, www.trasse.ch.

14 See Fahrplanverordnung vom 4. November 2009, 745.13 (FPV 2009).

15 See Art. 4 FPV.

The license of NS contains minimal frequencies for specified connections with which NS has to comply. The transport plan is presented to the Ministry of transport.[16] NS' license also rules that NS has to exchange opinions about the transport services offered by NS (also about changes to the offer in the year before and the compliance with performance targets e.g. as specified in chapter 2 and 3 of the transport plan) with consumer associations, with Prorail as well as with regional organizations before preparing the transport plan.[17]

The timetable procedure is explained in the Prorail Network Statement. Prorail coordinates the process, starting with preparing a draft together with the rail undertakings at a round table (basic hour pattern). In this draft train frequencies are coordinated and the obligatory tracks for freight transport are planned.

The daily plans (updated versions of the yearly timetable) are prepared by NS and Prorail and since October 2010 there is a cooperation platform (the OCCR) between Prorail and other rail undertakings to deal with network closures and interruptions.[18]

2.4.3 Licensing/market regime

In Switzerland SBB holds an exclusive concession to provide passenger transport services on national routes. Freight transport was liberalized in 1999. Regional passenger transport services are ordered at national and cantonal level by the administration and concessions are granted to the operators chosen to provide the services. The undertakings providing services at regional level only provide services if they are able to cover their cost or if they are ordered by public administrations. The national law on the second step of rail reform 2 of 16 March 2012 contains rules for tendering procedures for ordering transport services at regional level.[19] Network access of foreign rail undertakings is ruled by bilateral agreements. For passenger transport, network access for foreign rail undertakings is restricted to transit and charter traffic. The concessions in regional and national rail transport comprise a protection from competitive offers on the road (e.g. from buses or cars providing similar connections).

In the Netherlands rail undertakings are to be provided non-discriminatory network access. The national market for freight transport has been liberalized so that foreign rail undertakings are entitled to provide cross-border transport in an open-access regime. For the public national rail passenger transport the concession has been given to NS in 2005 and includes an exclusive right to provide national rail passenger services. The concession expires in 2015. The Dutch rail network is regarded as a

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16 See Vervoerconcessie voor het hoofdrailnet.

17 See Vervoerconcessie voor het hoofdrailnet und NS Vervoerplan 2012.

18 See Netherlands Competition Authority (2009), S 20.

19 Bundesgesetz über den zweiten Schritt der Bahnreform 2 vom 16. März 2012 (Gesetz Bahnreform 2.2 2012). See also for more background information on the implementation of IRIT Botschaft zur Gesamtschau FinÖV vom 17. Oktober 2007, Botschaft zum zweiten Schritt der Bahnreform 2 vom 20. Okktober 2010, Bundesbeschluss über den Gesamtkredit für die zukünftige Entwicklung der Bahninfrastruktur vom 17. Dezember 2008, Bundesgesetz über die zukünftige Entwicklung der bahninfrastruktur (ZEBG) and Faktenblatt FABI: Bahnausbau STEP 18. Januar 2012.

big regional network so that the national rail offered by NS covers 90% of the total rail passenger transport services.

The following table gives an overview of the regulatory measures and compares them to the British regulatory framework.

Table 1: Overview of regulatory implementation of IRIT

	Switzerland	Netherlands	UK
Priority of IRIT in capacity allocation	✓	✓ (indirect)	-
Obligatory coordination according to IRIT	✓	✓	-
Licensing regime	Exclusive license for national passenger rail services for SBB. Tendering of regional transport services is possible but not obligatory.	Exclusive license for national public transport for NS Direct licensing of private transport services, tendering is possible. Open access in cross-border rail transport	Franchising by tendering licenses for regional rail networks

3. Advantages and challenges of an introduction of IRIT

Based on the results of the case studies and on desk research the advantages and challenges of an introduction of IRIT are discussed in the following.

3.1 Advantages

Quality of Service

The introduction of IRIT has a direct impact on the QoS of rail passenger services. The following advantages are to be expected from IRIT:[20]

- High geographical network coverage with optimal connections including connections requiring to switch the trains at network nodes

[20] Busche, H.; Buyken, H.; Kemnitz, J. (2000), S. 36 f.

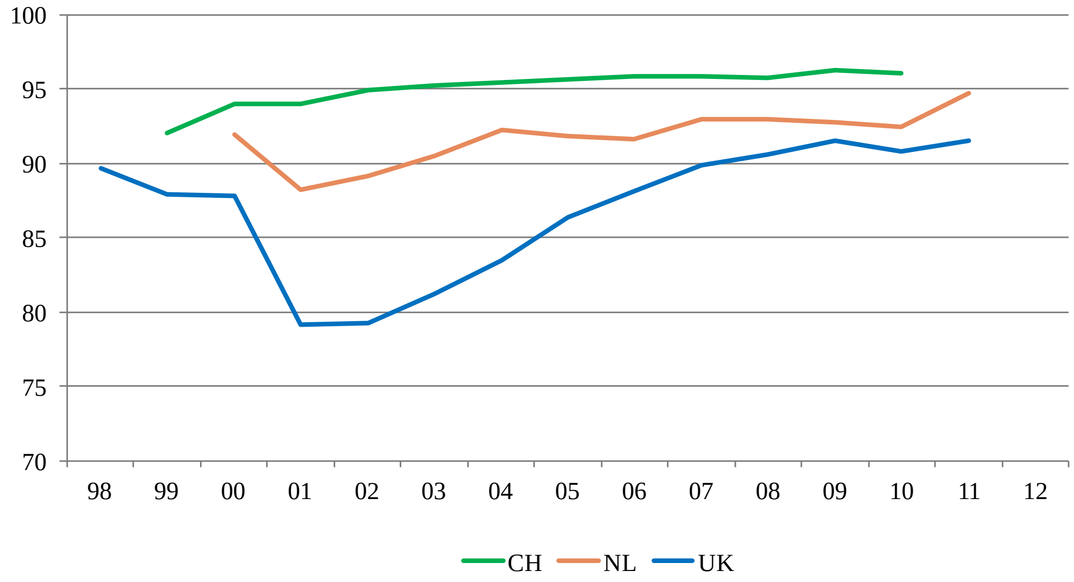
- Faster connections (not only of direct routes but especially of routes with transfers at network nodes; see also the results from the quantitative model)
- More direct connections
- Punctuality (because it is a requirement for a successful introduction)
- Easy to memorize timetable

Punctuality is not a result of but a requirement for the successful introduction of IRIT. This is shown in the Appendix and supported bythe results of a quantitative model that shows that delays have a stronger effect in an a system with IRIT than in a railway system without integrated timetables. Figure 9 illustrates that not only countries with IRIT achieve a high level of punctuality. In the UK the efforts in the last years to improve performance of rail services after the decrease in punctuality until 2001 have shown results so that punctuality has been increasing in the last years. However, IRIT have the advantage to require a high punctuality (see also the quantitative model) but not only for direct connections but also to optimize transfers between trains. Rail systems with IRIT go hand in hand with strong incentives to achieve and sustain high punctuality. Apart from that, punctuality alone does not ensure that the rail services are customer oriented while IRIT (ideally) is planned according to customer needs.

The combination of the different performance indicators, i.e. regular train connections, reliable connections for train transfers and punctuality in total provide a service level for rail passenger transport which together with the coverage, adds up to a rail system which enables the customer to use rail passenger transport or public transport respectively in a very flexible way.[21]

[21] See Clever, R. (1996), S. 140 ff.

Figure 4: Development of punctuality (trains with maximum 5 minutes delay in %)

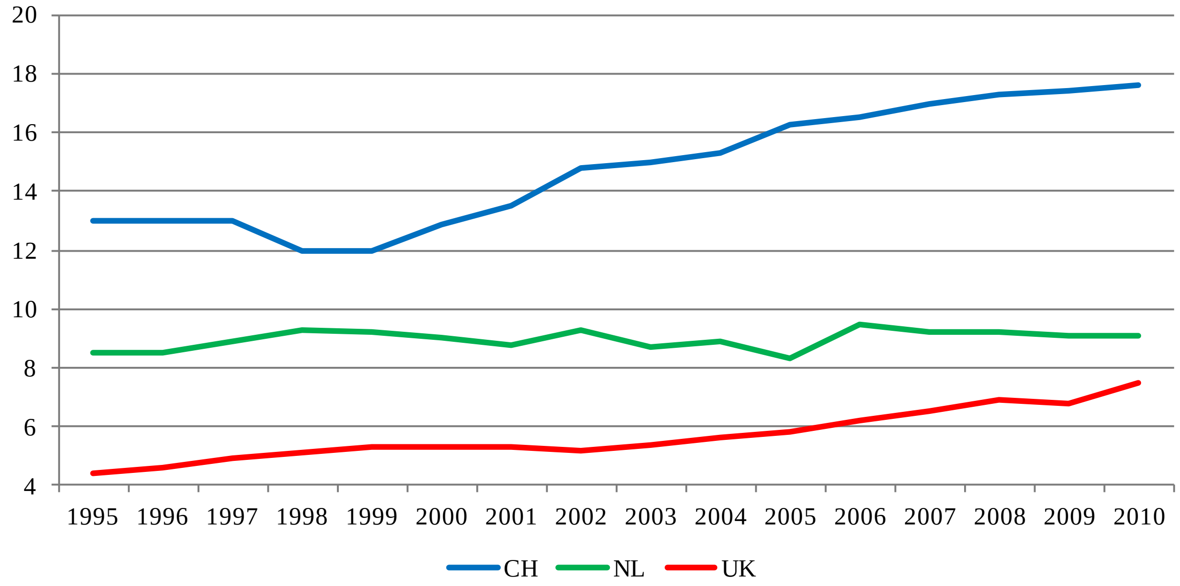


Source: Praxis des Bundes bei der Steuerung von Post, SBB und Swisscom, Expertenbericht zuhanden der Parlamentarischen Verwaltungskontrolle vom 30. August 2011; Prorail (2011), International Benchmark; http://www.prorailjaarverslag.nl/jaarverslag-2011/Kerncijfer.Kerncijfer1/aDU1001_Kerncijfers.aspx; ORR (2012), National Rail Trends Quarterly Summary 2011-12 Q3.

Strengthen rail passenger transport in the modal split

In the studied countries rail passenger kilometers have increased in the last years. As the development of demand depends on a number of factors it would have been difficult if not impossible to prove that the increase in demand results from the introduction of IRIT. The development of transport services in Switzerland however, illustrates that the implementation of Bahn 2000 is followed by a significant increase in demand for rail passenger transport services and a decrease of private automobile transport. The modal split (Figure 5) shows that in countries with IRIT or high frequencies of trains respectively rail transport holds a higher share of total transport which suggests that IRIT can strengthen demand for rail passenger transport services.

Figure 5: Development of Modal Split



Source: Eurostat, Personenbeförderung nach Verkehrszweig, % am Personentransport-km.

In addition to that, consumer research performed by Gallup (2011) showed that a high share of car users indicated that they do not switch to public transport because the number of connections is too little, frequency of trains too low and the services are not reliable.[22]

These results together with the experiences in Switzerland and the fact that countries with IRIT have a higher share of rail in the modal split seem to indicate that IRIT strengthens the role of rail passenger transport in the competition with other modes of transport.

Efficient infrastructure investment and better capacity usage of infrastructure

With IRIT the investment in infrastructure takes place on the basis of an overall concept which aims at optimizing the offer of rail services.[23] Ideally, when introducing IRIT, the infrastructure operator prepares a usage plan - based on a democratically based assignment and demand forecasts – which should ensure that the demand for capacity in the long-run can be satisfied. Further, IRIT support infrastructure operators to fulfill the EU requirements with respect to routes with scarce capacity. In this context it is important to recognize scarcity in time and to ensure that the development of rail capacity is based on the expected development of demand.

IRIT also have the advantage of ensuring an efficient usage of routes and train capacity.[24] A comparison of the capacity usage indicates that countries with IRIT have a better capacity usage of their infrastructure (see Figure 6).

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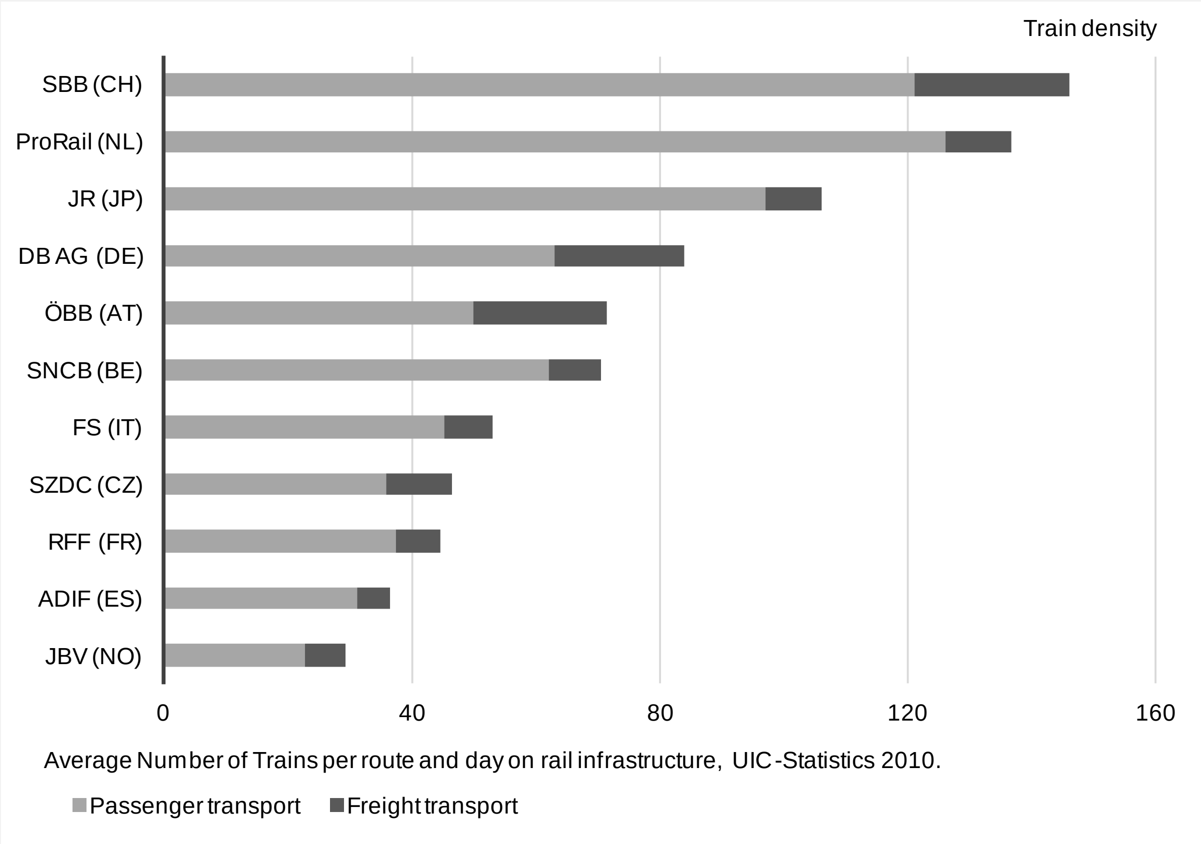
[22] See Gallup (2011), S. 18 ff.

[23] See Stalder (2010).

[24] See Leister, H. (2010), S. 5.

Figure 6: International comparison of capacity usage of rail infrastructure in 2009



Source: SBB in Zahlen und Fakten 2011.

3.2 Challenges

3.2.1 List of priorities for project plan

The introduction of IRIT requires planning the infrastructure investment and its financing in the long-term perspective. This represents a challenge which should not be underestimated, particularly taking into consideration the current level of public debt in many countries and the critical development of financial markets. In addition to that, the long-term perspective of the project plan increases the probability that the implementation will be confronted with unexpected developments which call for re-adjustments. Here, the challenge consists in avoiding wrong decisions concerning the list of priorities for investments or project steps.

3.2.2 Intramodal effects on competition

The regulatory implementation of IRIT in Switzerland and in the Netherlands is not compliant with a fully opened market for rail passenger transport. IRIT impose two major limitations for a fully opened, intra-modal market. First, IRIT lines require priority over all other lines, hence restricting the slots available for competing services. In turn and as shown in the case studies, railways are strengthend in the inter-modal competition with road-services. Second, likely market entries during peak hours may impede the cross-subsidisation of off-peak IRIT lines.

The relevant issues with respect to market mechanisms and competition hence refer to the question whether the provision of transport services outside the scope of IRIT by third parties should be allowed. If those offers are excluded from the market this implies restricting competition. But if third parties are allowed to offer services in the geographic footprint and within the timetable of IRIT, this offer would compete with the services provided with IRIT and would reduce the efficiency of IRIT. Problems like cherry-picking would become an issue (see also Figure 7).

In this context there also remains the question of the market conditions for the provision of rail services within the IRIT. There is a spectrum of possible designs for the framework to be applied (while complying with the non-discrimination rule) with reference to the providers as well as the licensing regime. With respect to the providers of services within the IRIT, the IRIT lines can be provided by one rail undertaking or by several rail undertakings (the overall offer can be split in regional networks, in connections or bundle of connections). The licensing regime can include direct concessions or tendering procedures. International experience is diverse[25].

On one hand, there may be the need to restrict intramodal competition to ensure a successful introduction of IRIT. On the other hand IRIT strengthens rail passenger transport in the modal split and as a result competition between different transport modes. Apart from that, experience in the UK has shown that liberalization with the separation of infrastructure and rail services can be counterproductive. The coordination of the timetable process in the UK (which has to take place independently of IRIT) is linked with very high cost and compared with other European countries, the infrastructure cost in the UK is considerably higher[26] so that instead of achieving efficiency gains, liberalization seems to have had the opposite effect.

3.2.3 Capacity constraints

As already mentioned IRIT have the advantage that they usually achieve a better capacity usage. At the same time it is thinkable that – as currently observed in Switzerland – the capacity usage represents another challenge which has to be dealt with. The rail network in Switzerland has a high capacity usage due to the increase in demand (which was stronger than expected) in the last years. If capacity usage increases even more, the stability of the system (with reference to punctuality) will be reduced. During rush hour measures to ensure system stability and quality are only possible at very high cost and require new infrastructure investment (e.g. new tracks or longer platforms).[27]

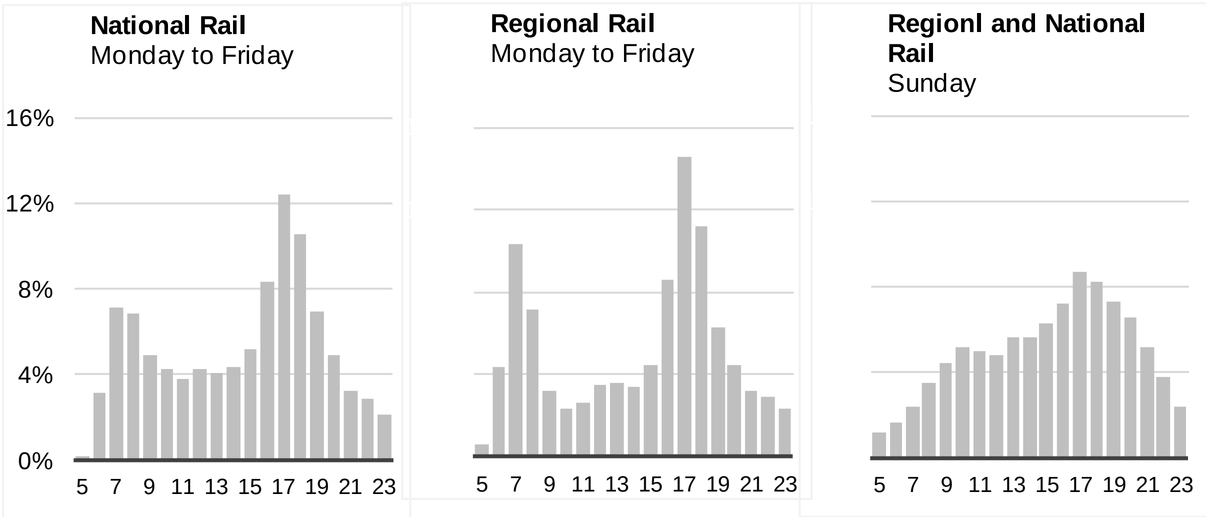
Figure 7 shows the capacity usage at rush hour. The differences in demand are balanced by measures in the tariff system and also through longer and additional trains.

[25] See Jaag, C. and Trinkner, U. (2010).

[26] Vgl. ORR (2010), S. 21 ff.

[27] See Wildener (2010), S. 20 und 37.

Figure 7: Traffic volume at rush hour at Zurich railway station



Source: SBB in Zahlen und Fakten 2011.

The capacity constraints do not only affect rail passenger transport but also freight transport. Due to the priority of passenger transport in IRIT, freight transport uses the remaining capacity. This does not always lead to the most efficient use of capacity. The more the frequency is increased and the capacity is allocated according to strict rules the more there is a danger of using capacity inefficiently. Efficiency gains are realized by bundling customers with similar usage profiles. The more the traffic density increases and the train regularity decreases at certain intervals, the more it becomes difficult to bundle customers and the capacity constraints slow up the freight transport. If slowing up freight transport is to be avoided it is necessary to find a balance in the capacity usage without endangering the success of IRIT.[28]

3.2.4 Costs

In the context of the challenges of IRIT it is important to address that both the benefits and the costs have to be considered in order to analyze the overall economic impact of introducing an IRIT. Not only are there differences in what is considered to be important when it comes to the benefits of railway services (e.g. diverging goals and targets of railway policy etc.[29]). But also the cost structure and the implications of introducing IRIT differ considerably depending on a number of factors such as density of population, topology, quality standards etc.[30] The challenge of an introduction of IRIT will be to insure that the benefits overweigh the costs of an introduction so that overall there is a positive economic impact.

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[28] See Weidmann, U.; Frank, P. (2012), p. 13.

[29] See Beck, A. et al (2013), pp. 11 ff.

[30] See Hansen, I. et al (2013) also with an overview of several studies on efficiency benachmarks p. 3ff.

3.3 Conclusion

The discussion of advantages and challenges of IRIT has shown that IRIT can play an important role in strengthening rail passenger transport in the modal split. The introduction of IRIT is linked with the challenge of setting the right priorities. In the long-run, the challenge lies in dealing with capacity constraints which can reduce punctuality and can have a negative impact on freight transport.

The implementation of IRIT goes hand in hand with the challenge to reconcile the regulatory implementation of IRIT with the requirements of non-discrimination and effective competition. There are various designs which combine intra-modal competition with intermodal competition focusing more or less on one or the other. If the aim is to achieve a higher share of rail passenger transport in the modal split, it is more likely that rail passenger services are strengthened by the implementation of IRIT. This is supported by the experience from the UK where the liberalization did not bring the expected efficiency gains but rather a significant decrease in QoS and QoS could only be restored under high costs. In contrast, countries with IRIT have achieved a better capacity usage, more efficient infrastructure investment and persistent high punctuality.

4. Conditions/requirements for the introduction of IRIT

4.1 Infrastructure investment and financial resources

The introduction of IRIT in Switzerland and the High Frequency project in the Netherlands show that the implementation of IRIT requires long-term planning. Starting point should be the planning of future transport services based on the estimation of future demand. Based on these results it is possible to plan the necessary infrastructure and equipment for the trains. IRIT can only succeed when there is a high performance in punctuality or the frequency of trains is so high that timetables and punctuality become irrelevant. The requirements concerning punctuality have strong implications for the investment in infrastructure. The timeframe of the implementation of IRIT depends on the infrastructure investments and the available financial resources for the realisation of the project. If IRIT are introduced for the whole rail network, the national offer of transport services (and the respective timetable) with its network nodes for the national connections has to be planned first. The regional transport services can then be integrated in the national offer. Ideally, the national timetable integrates international connections in its offer.

4.2 Regulatory implementation of IRIT

4.2.1 Main issues of regulatory implementation

The regulatory implementation of IRIT is an important issue to be discussed in the context of the requirements for a successful introduction of IRIT. It includes the following elements:

(1) Priority rule for IRIT

(2) Obligation to coordinate timetables according to IRIT
(3) The acceptance of alternative parallel rail offers within IRIT
(4) Linking IRIT to the tendering of public transport services to one or more rail undertakings

The introduction of IRIT calls for a **priority rule** which gives priority to regular train connections (which are part of the IRIT) in the process of capacity allocation. See also the description of priority rules in the case studies.

The **coordination** of timetables between rail undertakings has to be **obligatory** and linked with an obligation to coordinate timetables according to the requirements of the IRIT. Ideally the regulatory framework would include some rules with reference to the procedure e.g. concerning the network nodes, the requirement to include all rail undertakings in the process etc. The case studies include examples for the obligatory coordination in connection with IRIT.

The question if **parallel offers of rail services within the IRIT** are allowed is of special relevance for the competition conditions. If they are excluded this may hinder competition. However, parallel services by third parties (within the geographical footprint and the timetable of the IRIT) reduce the efficiency of IRIT.

As discussed above, there is a large spectrum of possible designs for the framework to be applied (while complying with the non-discrimination rule) with reference to the providers **(market conditions)** as well as the **licensing regime**.

The separation of infrastructure and transport is not directly relevant for the regulatory implementation of IRIT but it can have implications for the success of or at least the cost of introducing IRIT. While in the Netherland infrastructure and transport are operated by functionally separated undertakings, in Switzerland both are operated by a holding with separate organization and accounting for each area. In both countries however, there is a strong coordination and cooperation between infrastructure and transport. This coordination and cooperation does not only take place for the timetable process but also for the planning of infrastructure investment. As already mentioned before, the separation of infrastructure and transport can be counterproductive.

4.2.2 EU regulatory framework and IRIT

The regulatory implementation of IRIT in countries which are members of the EU must comply with EU regulation. The answer to the question whether the introduction of IRIT for rail services is compliant with EU regulation, depends to a great extent on the regulatory measures chosen for the regulatory implementation of IRIT and the design of the IRIT (scope of the IRIT, exclusive licensing, allowance of parallel rail services within IRIT, geographical reach of IRIT). The main issues arising in this context refer to competition law, open access and market mechanisms in the provision of rail services. When introducing IRIT, EU Member States will have to ensure that the regulatory implementation of IRIT in national law complies with the EU regulatory framework concerning competition (general and sector specific rules), particularly the transport regulation on open access for the provision of rail services.

5. Conclusions

Integrated regular interval timetables have a direct impact on the QoS of rail passenger services ensuring

- a high geographical network coverage with optimal connections including connections requiring to switch the trains at network nodes,
- faster connections (not only of direct routes but especially of routes with transfers at network nodes),
- more direct connections,
- punctuality (because it is a requirement for a successful introduction) and
- easy to memorize timetables.

The combination of the different performance indicators of IRIT, i.e. regular train connections, reliable connections for train transfers and punctuality in total provide a service level for rail passenger transport which together with the coverage adds up to a rail system which enables the customer to use rail passenger transport or public transport respectively in a very flexible way. IRIT strengthen rail passenger transport in the modal split and very likely result in a more efficient investment in infrastructure as well as capacity usage. In this context, it would be interesting to add an in-depth analysis of the costs of railway services to complete the picture.

The introduction of IRIT is linked with the challenge to make a priority list of project steps which does not put at risk the success of IRIT. In the long-run, the right measures have to be taken to deal with scarce capacity at rush hour, so that punctuality is ensured and inefficiencies in capacity usage are avoided. The conciliation of non-discrimination and effective competition rules with the regulatory implementation of IRIT represents another challenge.

The introduction of IRIT requires long-term planning of infrastructure investment and of financial resources. The regulatory framework should include a priority rule for IRIT in the allocation of capacity and an obligatory coordination process between rail undertakings and the infrastructure operator concerning the timetables. The exclusive offer of rail services within the IRIT may hinder competition. However, parallel services by third parties (within the geographical footprint and the timetable of the IRIT) reduce the efficiency of IRIT.

There is a large spectrum of possible designs for the regulatory framework to be applied (while complying with the non-discrimination rule) with reference to the providers as well as the licensing regime. With respect to the providers of services within the IRIT, it is thinkable the services on the network are all provided from one rail undertaking or from several rail undertakings (the overall offer can be split in regional networks, in connections or bundle of connections). The licensing regime can include direct concessions or tendering procedures. Eventually, the regulatory implementation of IRIT at national level has to comply with the EU regulatory framework.

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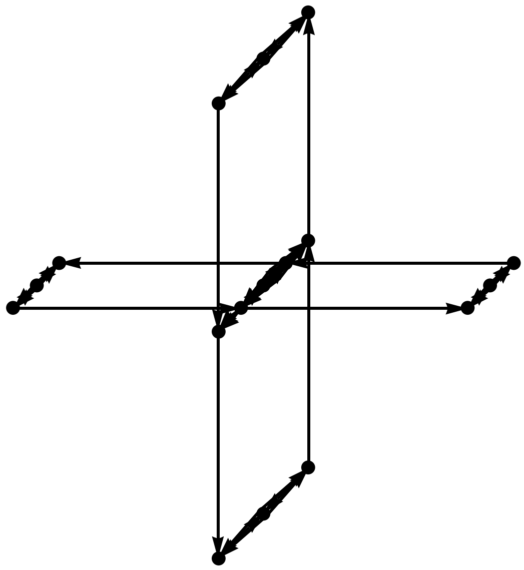
Annex: Effect of delays on IRIT

Intuitively, punctuality is essential in an IRIT environment. In order to understand the role of punctuality on overall travelling times, a quantitative model is constructed to estimate passenger's utility under several time table regimes. Based on an illustrative example, it is then discussed how passenger's utility in a certain time table regime depends on the punctuality of the trains. The simulation shows that punctuality has much stronger effects on overall travelling times in an IRIT regime. If delays are large, then the positive effects of an IRIT can be offset. It follows, that punctuality is a requirement in an IRIT environment.

Model Setup

From a given time table a directed graph is constructed. The vertices of the graph correspond to railway stations, the edges represent the connections between the stations and the edge weights represent the traveling times. Dijkstra's Algorithm is used to get shortest traveling routes (from each station, to each station) and the corresponding traveling times. The basic idea of the model is illustrated in the figure below.

Figure 8: Railway network represented by a directed graph



To model delays and their effect on traveling times it is assumed that delays underlie a certain probability distribution. For each edge a delay time, positive or negative, is drawn from a distribution and then added to the traveling time of this edge. Hence, the delay in one point is the sum of all delays occurred so far. Delays potentially also affect the transfer time between two connecting trains. The transfer time from train *i* to train *j* is therefore determined by

$$t_{trans} = \begin{cases} departure\ time_j - arrival\ time_i & if\ arrival\ time_i - departure\ time_j \geq 0 \\ time\ intervall_j + \left(arrival\ time_i - departure\ time_j\right) & else \end{cases}$$

or shorter

$$t_{trans} = Mod[departure\ time_j - arrival\ time_i, time\ intervall_j\ ]$$

where $arrival\ time_i$ is the real arrival time of train *i*, i.e. the scheduled arrival time plus the total delays of train *i*, and $departure\ time_j$ is the scheduled departure time of train *j* plus the total delays of train *j*.

The literature on train delays finds that arrival delays are well described by weighted exponential distributions (see Schwanhäusser, 1974, Meng, 1991, Kaminsky, 2001, Briggs and Beck, 2007, and Ullius, 2004b). Hermann (2006, p. 75) states: “In contrast to the simple exponential distribution an additional parameter $0 \leq \mu \leq 1$ is introduced that indicates the share of delayed trains. This parameter ensures that exact on-time arrivals do not have probability 0, but a positive probability $1 - \mu$, whenever $\mu \leq 1$. Hence the probability function of the exponential distribution is only changed in 0, where the mass $1 - \mu$ is introduced."

By the construction of delays in our model, i.e. as the sum of delays per track section, we are interested in overall delays and would like to allow also negative delays on a track section. Therefore a slightly different approach to model train delays is taken. Following Hermann (2006) two weighted exponential distributions are used to construct the delays in our model. Namely, delays in one track section are determined by

$$delay[track\ section\ i] = X_d - X_u$$

where $X_d \sim wexp(\lambda_d, \mu_d), X_u \sim wexp(\lambda_u, \mu_u)$ are both weighted exponentially distributed. The density and distribution of delays is plotted in Figure 9. Figure 9 illustrates that these delays approximate the desired properties[31]. Total delay in a point *j* is defined by the sum of delays incurred on the previous track sections. We assume that trains do not depart too early (in such a case trains simply wait at the station), hence total delays in point *j* are

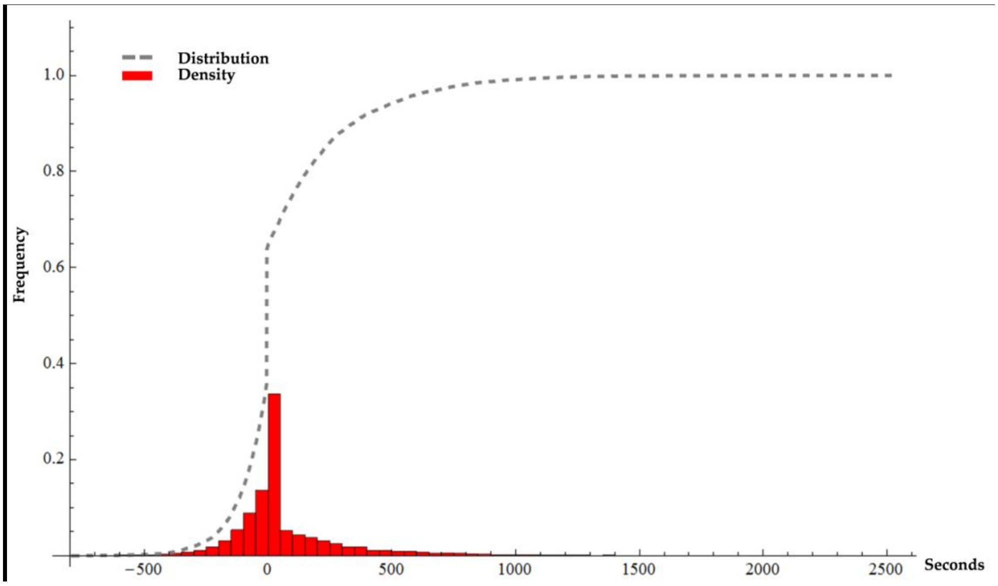
$$delays_j^{tot} = \max\left(\sum_{i<j} delays[track\ section\ i], 0\right).$$

Furthermore, we assume that delays do not occur at the starting stations of a line. This assumption is mainly empirically motivated. Delays affect total traveling times through two channels. A delay on a track section increases the traveling time in this section one-to-one (direct effect). On the other hand in case of a change of trains during a journey delays influence the transfer time between two connecting trains (indirect effect). The sign of the indirect effect can be positive or negative.

If delays are large enough an integrated time schedule can break down. The stability of the time table with respect to delays is not taken into account. This would make the model much more complex. However, this is less of a drawback in this context because we analyze existing and stable time tables and discuss the effects of delays of rather small amplitude. The primary interest is not the stability of the timetable.

[31] The precise properties of this delay variable and the corresponding proofs can be found in Hermann (2006).

Figure 9: The Density Function and Probability Distribution of the Delay Specification



With this setup it is straightforward to compute traveling times between all stations. To simplify the representation of traveling times the (weighted) average traveling time is introduced, which is the sum of traveling times from every station *i* to every station *j* multiplied by the number of passengers on each line divided by the number of total passengers P multiplied by the number of possible connections C. This is

$$t_{\mu} = \frac{1}{C * P} \sum_{i \neq j} traveling\ time(i, j) * p(i, j)$$

The described model allows making direct comparisons of traveling times between two time table regimes and discussing the effect of delays on traveling times in both regimes. By introducing assumptions on the structure of the utility function of railway passengers further analysis can be made. The model then also allows a discussion of the trade-offs between railway service prices and traveling times as well as effects of traveling times on demand of railway services. Following Gronau (1970) the costs of a journey, π, consist of two parts: the money costs involved, *P*, and the opportunity costs *K* of the elapsed time *T*.

$$\pi = P + KT$$

A rational individual will always choose the mode of transportation with the lowest costs. With stochastic delays traveling times become uncertain. A risk neutral individual will simply minimize the expected traveling time $E[\pi]$. A risk averse individual also cares about the reliability of the service. The reliability of the service is closely linked to the distribution of traveling times an individual might encounter. One can think of many measures to describe this distribution. We decided to take the variance. Hence, we assume that an individual chooses its mode of transportation by minimizing

$$\tilde{\pi} = \alpha\,(P + K\,E[T]) + \beta\,Var(T)$$

With this simple equation the value of time and value of reliability are captured. In the literature both concepts are found to be fundamental determinants of transportation demand[32]. Estimating (or assuming) the parameters α, β and its distributions allows making statements about the change of the utility of railway passengers and about the change in demand of railway services if an IRIT is introduced. Furthermore, it can be discussed to what extent prices can increase if traveling times decrease to keep the utility of railway passengers constant. Imposing the assumption that coordination of trains becomes more difficult, i.e. delays become more likely, with many operators on the infrastructure the discussion about traveling times and prices can be linked to a discussion about exclusive licensing and vertically integrated railway operators. The next section illustrates the model and its applications in a simple example.

Illustrative example

In this simple example it is assumed that there are four different lines which all meet at one station in the middle. This corresponds to the situation in Figure 10. Two artificial time tables are constructed, an IRIT and a NON-IRIT time table as shown in Table 2. In the IRIT time table all trains meet at station Z at the same time. In the NON-IRIT time table this is not the case. Under both time tables all lines are equally fast and it is assumed that all lines follow a time interval of 20 minutes.

Figure 10: Railway Network

[32] For a review of this literature and concepts see Small (2012) and the references therein.

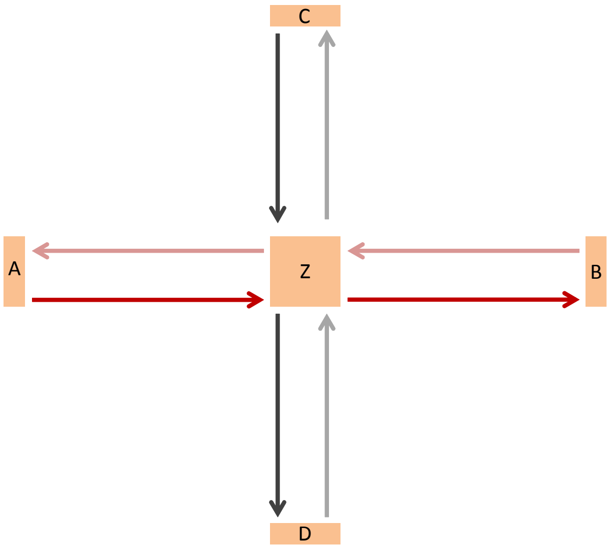


Table 2: Time Tables

IRIT Time Table:

Line 1		Line 2		Line 3		Line 4	
Station	Time	Station	Time	Station	Time	Station	Time
A	xx:15	B	xx:15	C	xx:15	D	xx:15
Z	xx:25	Z	xx:25	Z	xx:25	Z	xx:25
B	xx:35	A	xx:35	D	xx:35	C	xx:35

NON IRIT Time Table:

Line 1		Line 2		Line 3		Line 4	
Station	Time	Station	Time	Station	Time	Station	Time
A	xx:15	B	xx:01	C	xx:25	D	xx:40
Z	xx:25	Z	xx:11	Z	xx:35	Z	xx:50
B	xx:35	A	xx:21	D	xx:45	C	xx:00

Without delays it is straightforward to calculate traveling times under both time table regimes. Table 3 shows the traveling times (in minutes) of both time tables. Unsurprisingly, without delays the IRIT allows shorter traveling times on routes with changes of trains. More interesting is the question of the influence of delays on traveling.

Table 3: Traveling Times without delays

NON IRIT:

6. IRIT:

to / from	A	B	C	D	Z
A	0	20	20	20	10
B	20	0	20	20	10
C	20	20	0	20	10
D	20	20	20	0	10
Z	10	10	10	10	0

to / from	A	B	C	D	Z
A	0	20	25	30	10
B	20	0	39	24	10
C	36	30	0	20	10
D	21	35	20	0	10
Z	10	10	10	10	0

In this illustrative example it is for simplicity assumed that on all connections there are equally many passengers. Under this assumption and without any delays the average traveling time is 16 minutes for the IRIT and 20 for the NON-IRIT. With the weighted exponential distribution of delays there are two ways to increase overall delays. On the one hand one can increase μ_d, the share of trains delayed, keeping the distribution of incurred delays constant. On the other hand λ_d can be decreased, which increases the variance of incurred delays and the expected minutes of incurred delays, keeping the number of delayed trains constant. Taking these approaches it turns out that the IRIT is much more sensitive to delays than the NON-IRIT in both scenarios. While in the NON-IRIT scenario, the overall impact on travelling times is rather small, higher delays increase travelling times up to 25%. For rather small delays however, overall traveling times are still smaller for the IRIT. Figure 11 and Figure 12 show the average traveling times dependent on μ_d and λ_d respectively[33]. The figures also change when the train intervals are chosen differently. If the intervals become larger, then an IRIT becomes more sensitive to delays.

[33] In both figures we fixed $\lambda_u = 0.01, \mu_u = 0.52$. In figure 12 we fixed $\lambda_u = 0.00372$ and in figure 11 $\mu_u = 0.42$

Figure 11: Avg. Traveling Times and Share of Delayed Trains

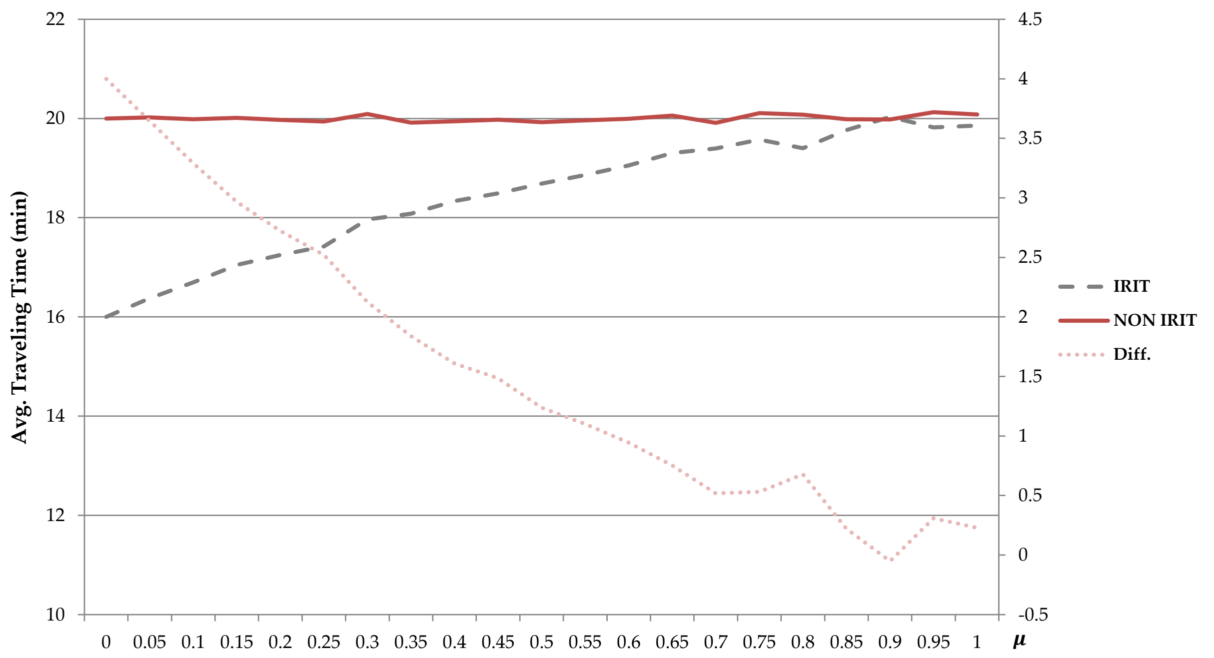


Figure 12: Avg. Traveling Times and Distribution of Delays