Regular-interval timetables:
Theoretical foundations and policy implications

(Topic: A3 Urban and Inter-City Rail Transport)

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Abstract

Opting for operations according to a regular-interval (cyclic) timetable was initially motivated by operational concerns: repeating a given pattern through daily operations both increases the infrastructure capacity (and, thus, the network productivity) and smoothes out the operational tasks (which does not only lightens the personnel stress, but is also expected to have positive impacts on safety). Then, separation between infrastructure management and train operations required by European regulations since the beginning of the 90s, and the progressive introduction of competition in the train operations business push more and more infrastructure managers to apply regular-interval scheduling of the train paths.

Due to its periodical nature, operation with regular-interval timetables exhibits a set of specific properties. Those are particularly both interesting and hampering in the case of so-called coordinated timetables, where requirements of symmetry are further added to those induced by periodicity. In real life, regular-interval timetable properties translate into significant implications for: a) the quality of service, as seen by the passengers' side; b) the set of constraints, as seen from the operators' side; c) the geographical and functional distribution of investment, as seen from the policy side (state owned infrastructure managers).

The paper starts by developing the theoretical foundations of regular-interval timetables. It then shows how the fundamental relations generate a set of peculiar properties and, further, how those properties are related to the level of service, operation constraints, and investment philosophy. It shows explicitly the advantages and disadvantages of those properties for all stakeholders. It then ends with considerations on the high-level transport policy options and how the latter have been affected by the shifting of paradigm imposed by adopting regular-interval operations.

Keywords: Regular-interval timetable, coordinated regular-interval timetable, transport policy shift

Introduction

Regular-interval timetables are based on scheduling identical services at fixed, regular time intervals. This was usually the case for densely serviced urban lines, such as underground metropolitan lines, urban and suburban bus lines with high frequency, and shuttle services. At the authors' knowledge, the Dutch railways were the first to apply this principle for a national rail network in 1942, though so-called "military timetables" (i.e. war time timetables) may have been designed before this date.

Running operations on a line according to a regular-interval (cyclic) timetable responds to several operational concerns: strictly repeating a given pattern throughout the day both [10]:

- increases the infrastructure capacity and, thus, the network productivity, and
- smoothes out the operational tasks, which does not only lightens the personnel stress, but is also expected to have positive impacts on safety, by standardizing common nominal operations.

Operating a line with regular-interval timetable produces an interesting consequence: any single operation, such as train crossings at a given point, is repeated periodically. In a network composed by regular-interval operated lines, if planners manage to cross trains of two different lines in a common station, this "meeting" of trains is repeated throughout the day [8]. That makes it possible to ensure passenger transfers between the two lines and, thus, to extend geographical coverage of origin-to-destination links (O/D) over the combined territory served by the two lines. This property is the foundation of the so-called "coordinated" or "clock-face" timetable [7] where, in selected nodes, train meetings from all origins ensure passenger transfers to any destination, periodically.

Running regular-interval trains enhances the level of service, by providing the customers with consistent time coverage of the services throughout the day. We shall call this property the "time coverage". Adding line coordination to his principle, by providing transfers to main nodes in a coordinated timetable, further increases the level of service, making it possible to reach more destinations from more origins, thanks to guaranteed connections. This is the "spatial coverage" property [11].

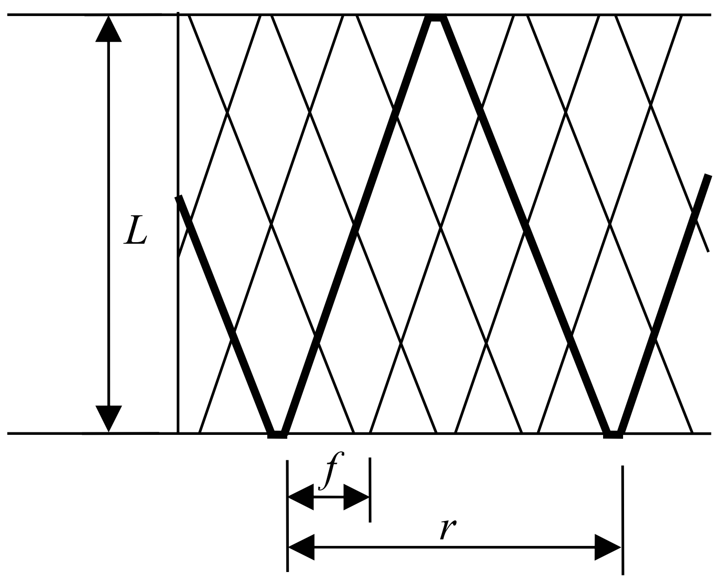
As a consequence, coordinated, regular-interval timetables offer advantages for both:

- the customers, thanks to enhanced level of service in terms of time and spatial coverage, and
- the train operators, thanks to standardised operational procedures and better productivity of their resources (rolling stock and personnel).

The separation between infrastructure management and train operations required by European regulations since the beginning of the 90s [4], and the progressive introduction of competition in the train operations business create new incentives to plan services according a coordinated regular-interval timetable. Infrastructure managers, thanks to a clear structure of services that can be defined explicitly as travel time and scheduling requirements, are able to split train services among several operators, while keeping a desired level of service to the ultimate customers (the passengers and the haulers) and ensuring that the whole process remains manageable. There comes into play the third stakeholder: infrastructure managers that also have clear advantages in applying regular-interval scheduling of the train paths to ensure better infrastructure productivity and manageability of their mission in densely used networks.

Regular-interval timetable for a line

Regular-interval operation of a line with a unique service obeys to some basic rules (Figure 1).



Let be:

L: the line length [km]

f: the time interval between services [h]

c_u: the unit capacity of a vehicle/vessel/train-set [pass]

K: the actual flow (or the line capacity) [pass/h]

Then:

$$f = \frac{c_u}{K} \quad \text{(Equation 1)}$$

(NB: Substitute **passengers** by **tons** for freight operations)

Figure 1: Fundamental structure of a regular-interval timetable (space - time diagram)

There are mainly two readings of Equation 1:

- either K is the actual flow to be carried; in this case, f is the maximum interval between two successive services, derived from the equation;
- or f is the minimum headway; in this case, K is the line theoretical capacity.

Now, let define:

r as the turnover time for a vehicle / vessel / train set

v_c as the commercial speed of the service on the line (including turnround time in terminuses)

n as the size of the rolling stock (number of units in operation)

The rolling stock fleet necessary to provide the service can be computed as:

$$n = \frac{r}{f} \quad \text{(Equation 2)}$$

The turnover time for a unit (the time needed to restart a service with the same unit) is:

$$r = \frac{2L}{v_c} \quad \text{(Equation 3)}$$

By combining the three equations above, we get the fundamental relationship for a shuttle service operated with regular interval as (Equation 4):

$$n = 2\frac{K}{v_c \cdot c_u}L \qquad \text{(Equation 4)}$$

This equation links the resources, i.e. the fleet size (and, indirectly, the number of drivers), to the unitary capacity of a vehicle / vessel / train-set, the length of the line, the commercial speed, and the transport supply level.

Depending on the fixed elements in a given configuration, those equations can be used to optimize operations. For instance, if the flow K and the line length L are given:

- planners can jointly optimize safety installations [which determine the minimum headway, that is $min(f)$], the commercial speed v_c, and the unit capacity c_u to minimise overall investment cost;
- if safety installations are also given, they can jointly optimise commercial speed v_c and unit capacity c_u; etc.

Beyond flow and line length which are usually given in a specific case, optimisation usually faces 2 technical/economic constraints:

- an absolute limit value for the minimum headway;
- an absolute maximum value for the commercial speed.

Experience shows that by structuring the timetable, productivity gains are usually achieved, especially when no additional constraints degrade the optimisation opportunities (Figure 2).

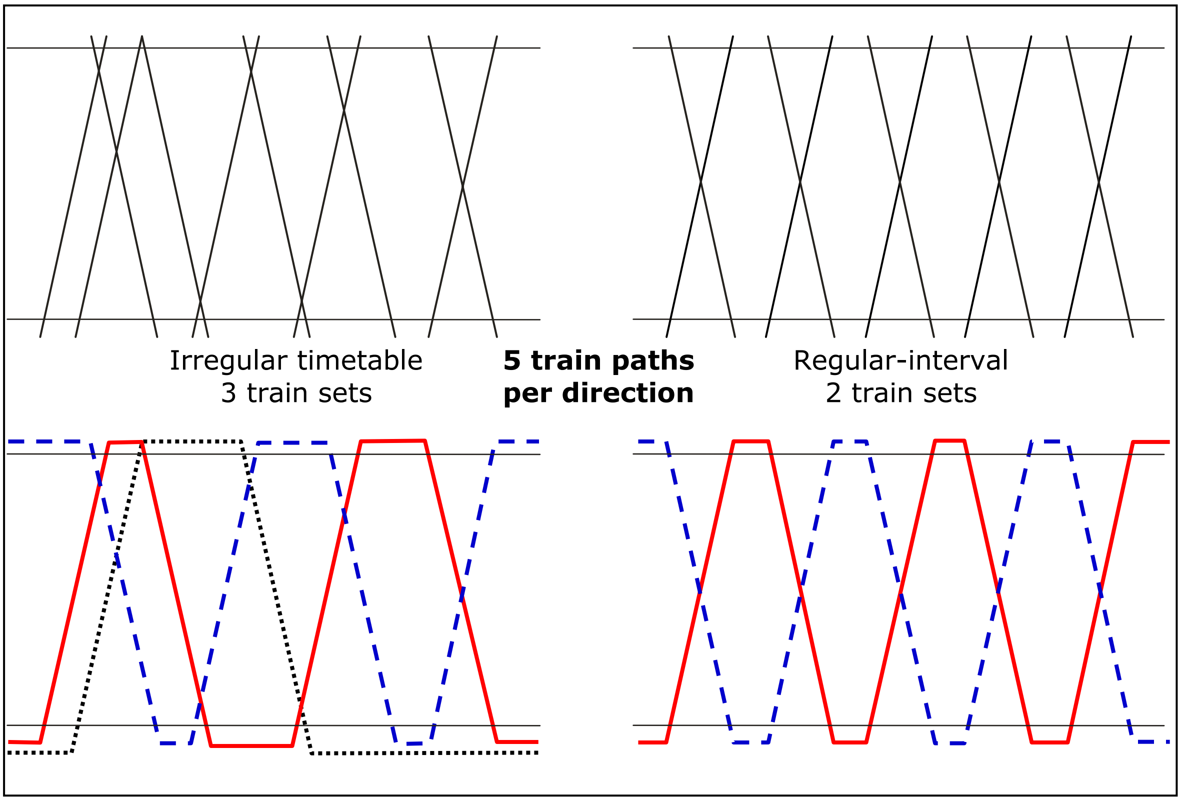


Figure 2: Structuring the services reduces the need for resources

In case of multiple services running on the same line, each service follows the same regular-interval logic, and the various services are "stacked one upon another", provided that the infrastructure allows for such a superposition (Figure 3). In this case, infrastructure constraints for guided ground transport (such as railways) usually generate an extra requirement: regular-intervals should be identical for all services or, at least, modulo between regular intervals should be null (i.e. longer intervals should be a round multiple of the shorter ones, such as - for instance - 30/60/120 minutes).

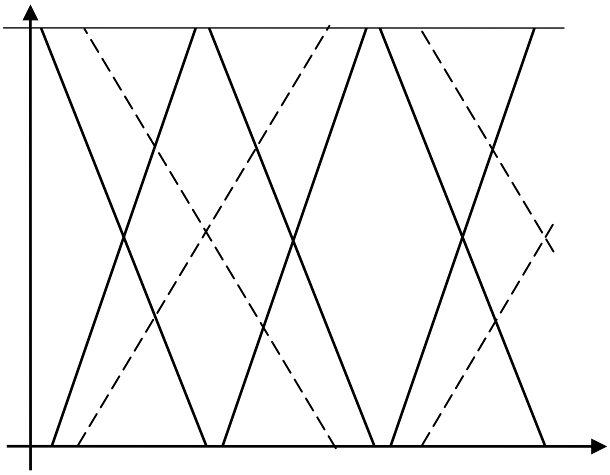


Figure 3: Two different regular-interval services stacked on the same line

However, for international, national, and many regional services, practicality leads to set regular intervals at 60 minutes (or, sometimes, to an integer multiple of 60 minutes). By doing so, customers are freed from the need to consult the timetable: thanks to the periodicity of operations, they should only learn once and remember the minute at which their service is provided to their station. If my train leaves at 08h12, I know that service will also be provided at 09h12, 10h12, and so on.

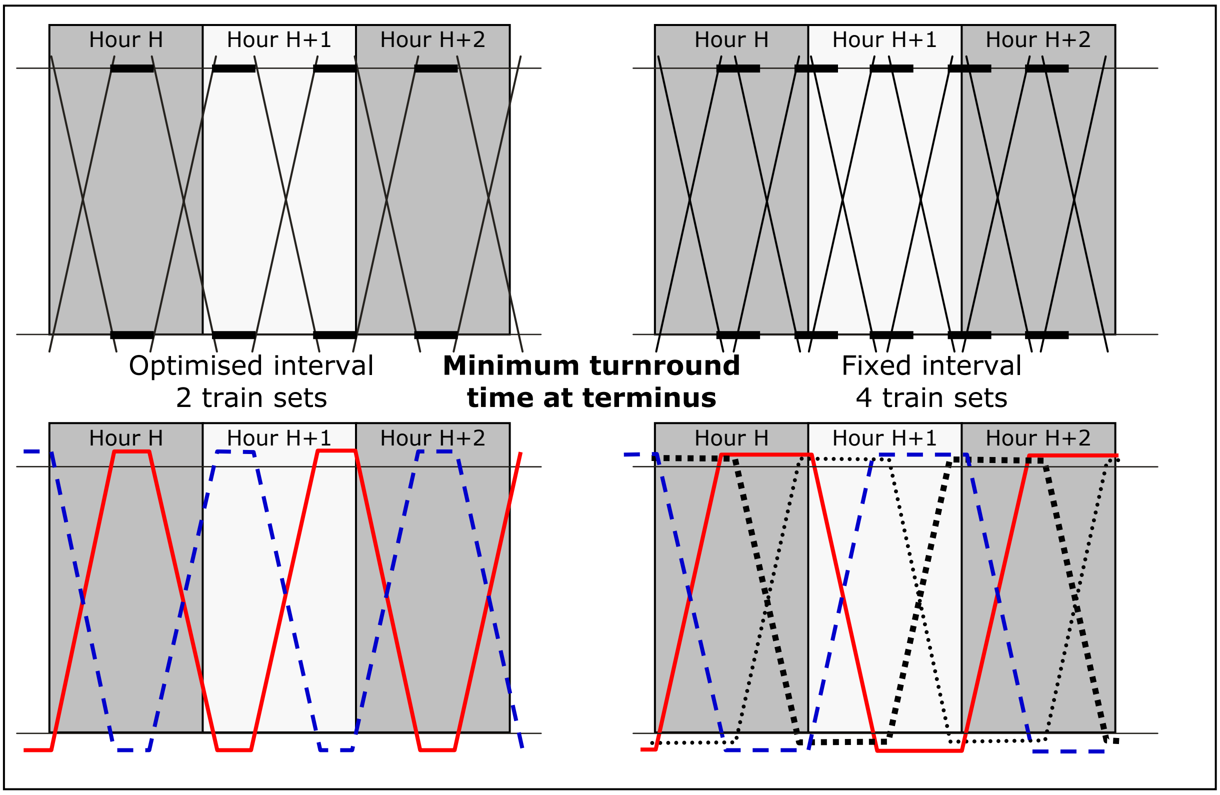


Figure 4: Effect of setting a fixed value for the interval

This easiness comes with a price: reduced system productivity [12]. Arbitrarily setting the interval value introduces an extra constraint in the optimisation process. In some cases (Figure 4), depending on the turnover time (i.e. running times plus turnround times at terminus), this constraint may be quite detrimental to a sound allocation of resources (rolling stock and, therefore, road crew).

Coordinating over the whole network

One of the most interesting properties of regular-interval timetables is its periodicity: any particular event is repeating with a period equal to the interval. Therefore, if ever trains meet at any moment in a station, this meeting will occur repeatedly, every hour if the interval is set to 60 minutes. Setting such a meeting in a central node of the network is straightforward: one has just to plan this unique meeting once, by scheduling nearly simultaneous arrivals of all trains in the node, letting enough time for passengers' exchanges, then letting the trains go (Figure 5). The timetable for each line joining the meeting station is wedged in time by means of the arrival/departure times of trains in the central node.

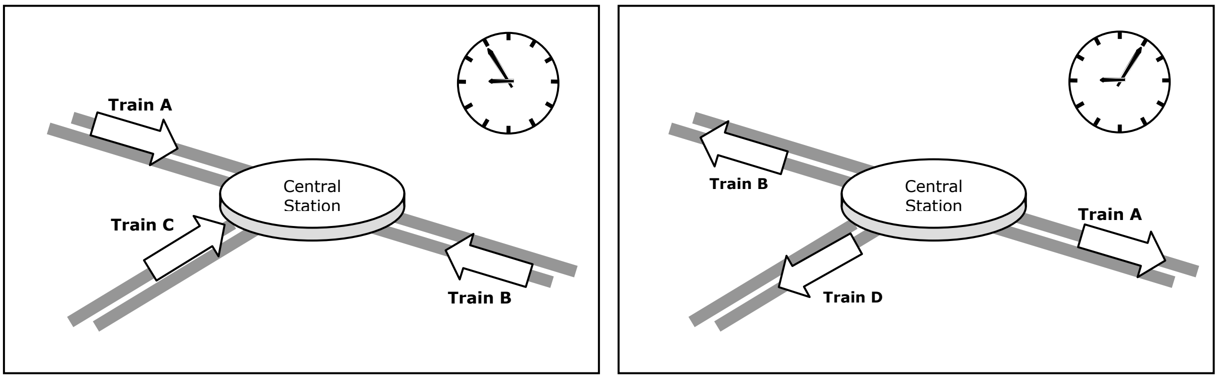
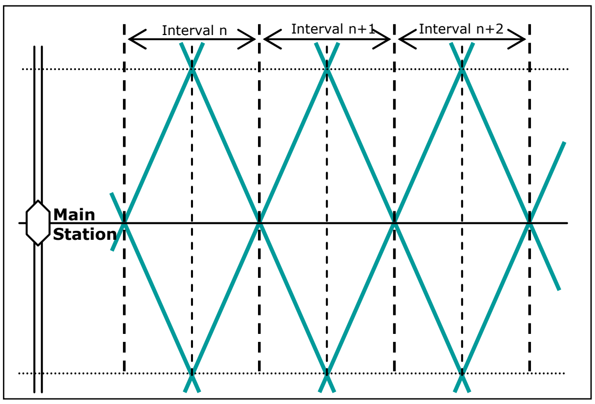


Figure 5: Scheduled meeting of trains in a central station, wedged around minute 0



Now, if trains running in opposite direction cross at the central node at a given time, and provided that running times are identical for both directions (which is fairly the case in modern networks), crossing of trains will occur at half-the-period time intervals along the line and through time (Figure 6).

Figure 6: The symmetry propriety

This symmetry propriety [6] can be used to extend the meeting of trains in any station that is distant from the central station to an integer multiple of half-the period. Obviously enough, crossing of trains running in opposite directions along the same line is not of much interest. However, if running times make it possible to apply the principle to a triangle of 3 lines, what happens to the central node is exactly repeated to the 2 other nodes of the triangle (Figure 7).

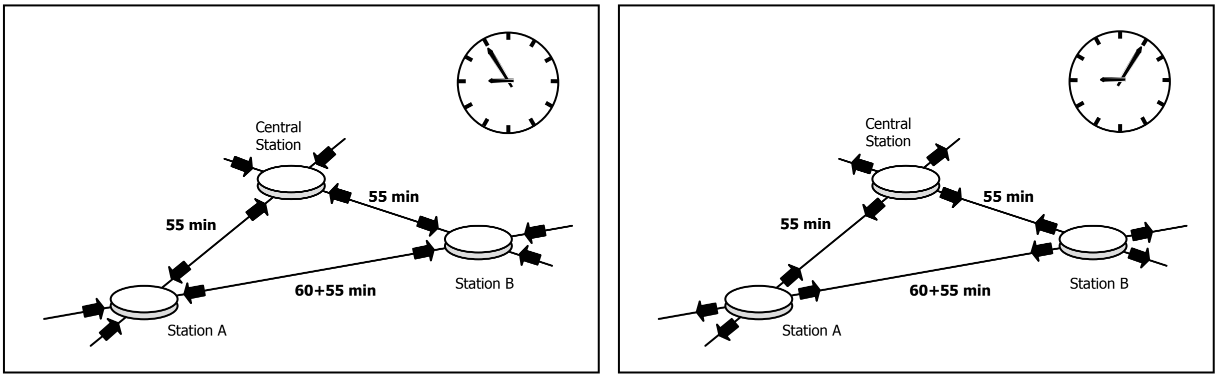


Figure 7: A coordinated 3-nodes network, with link travel times being an integer multiple of the 60-minutes period

Systematic application of the coordination principle and shear luck (travel times between major stations were already in the magnitude of the 60-minutes period) led to the Swiss Rail 2000 project. Rail 2000 is the heart of operations for the Swiss national railway network.

Adding coordination to a regular-interval operated network brings some peculiar consequences:

- extra stress is put on infrastructure and resources in major stations where trains meet, because of the concentration of traffic;
- the need for a common axis of symmetry [6] may degrade the turnover of rolling stock and personnel (Figure 4);
- ensuring transfers create extra constraints and, therefore, extra rigidity, which may further impede optimisation of train-sets' turnover (Figure 8).

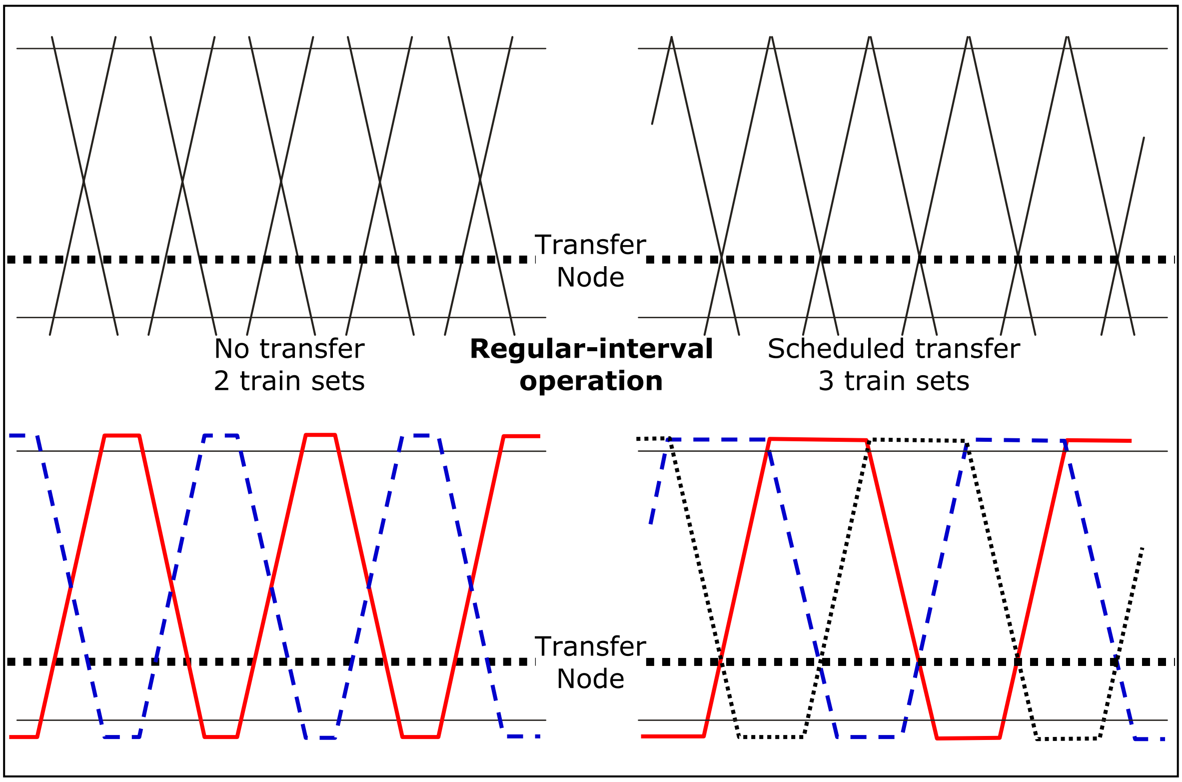


Figure 8: Effect of adding guaranteed transfers

Interpreting the proprieties

Regular-interval and coordinated timetables bear advantages in two fields: the technical operations, and the transport policy. Among the technicalities, one should mention - besides easiness of planning - the fact that systematization of operations simplifies most operational tasks, which alleviates the workload on the ground and improves indirectly safety as well. As already stated, and despite the theoretical drawbacks already shown, real life experience shows that introducing regular-interval operations results very often in net overall gains in productivity.

From a transport policy point of view, regular-interval timetable ensures time coverage of service through the day. Customers have the certainty that any given service is available at any moment. Coordinated timetables extend geographically the service coverage: by making it possible to transfer in main stations from any origin to all possible directions, passengers now that it is possible to reach "any" point in the territory, much like using their private cars [13]. This is a significant leap in level of service.

On the other hand, particular issues stem out of the periodicity, too: bottlenecks are located in singular points of the network instead of being split randomly across it. Requirements in infrastructure enhancement are located in particular spots. Investment based on those may become useless if ever the timetable structure changes [2]. In cases of coordinated timetables, capacity is particularly stressed in major stations where all trains must enter and leave almost simultaneously to ensure transfers. Stringent requirements on uniformity (especially for the rolling stock) may also be seen by some companies as tremendously hard to achieve.

Four categories of stakeholders are involved when passenger services are planned (see Table 1 to Table 4 for stakes involved with increasing systematisation, going from structured services up to coordinated timetables [12]):

- ultimate customers, i.e. the passengers
- train operators
- infrastructure managers
- the administration, which sets the transport policy (usually according to higher level social and environmental objectives, too) and "pays the bill" for unprofitable services

Type of services: STRUCTURED
Characteristics
- Finite set of well defined and distinguishable services - Every train path is linked to a service
Passengers
- Transport supply is easy to understand - There is still a need to check the timetable
Train operators
- Reduces the variability of possible events, simplifies processes and operations
Infrastructure manager
- Increases network capacity - Simplifies order of train paths, dialogue with customers, and timetabling
Administration
- Simplifies planning, placing orders, communication and social dialogue - Hard to impossible to respond to special requests (e.g. providing an extra stop of a train in the morning)

Table 1: Proprieties and consequences of structuring a timetable

Four stages can be defined in trying to increasingly standardise the system's operations:

- Give a structure to services, namely define a consistent service set (in terms of service type, i.e. fast, regional, high-speed, etc.) and define the transport supply by associating service types to all train O/Ds; then, assign each train path to a given service.
- Schedule the different services to run at regular intervals.
- Set regular interval to a "round" value (of, usually, 60 or 120 minutes).
- Coordinate the transport supply over the network by providing guaranteed connexions for passenger transfers in selected stations.

Type of services: REGULAR-INTERVAL (Shuttle-like)
Characteristics
- Services scheduled at regular time intervals
Passengers
- Ensure time coverage (service available "at any moment" over the operational range) - Annoyances (e.g. maximum waiting time) become predictable - Regional services more rigid, unable to adapt to specific demands (to match school hours, for instance)
Train operators
- Simplifies planning (timetabling, turnover of rolling stock and personnel) - Reduces system flexibility and tolerances by both o concentrating in singular spots the need for extra infrastructure capacity o limiting the freedom of choosing rolling stock (uniformity of performances is required) - Improves productivity of resources - Makes it possible to jointly optimise infrastructure / rolling stock / services, but pushes train operators to place the margins on the infrastructure side (at the expenses of IMs)
Infrastructure manager
- Codifies the need for investment in infrastructure by precisely locating the bottlenecks - Increasing network capacity - Simplifies production planning (timetabling and all associated procedures) - Makes it possible to jointly optimise infrastructure / rolling stock / services, but pushes infrastructure managers to place the margins on the scheduling side (at the expenses of TOCs)
Administration
- Time coverage of services is a prerequisite to implement policies favouring modal shift - Further difficulties to respond to special requests - Increases overall cost at short term (although, experience shows that the resulting induced demand generally offsets those extra costs)

Table 2: Proprieties and consequences of setting a regular-interval service

Type of services: REGULAR 60-MINUTES INTERVAL
Characteristics
- Services scheduled hourly (every 2 hours, or 30/15 minutes for some of them) - Extra peak services provided at 30 or 15 minutes interval
Passengers
- No need to check the timetable for usual (frequently used) services - Transport supply becomes clearly readable
Train operators
- Reduces human error risks thanks to standard operations - Increases human error risks due to loss of awareness - Reduces efficiency of turnover and, thus, productivity compared to an optimal value for the interval
Infrastructure manager
- Simplifies cross-border operations if neighbour countries also run hourly based services (synchronised)
Administration
- Enhances public transport image thanks to better readability of services - Supports even better policy efforts towards more "sustainable" transport policies - Nearly impossible to satisfy special requests [3]

Table 3: Proprieties and consequences of setting a "round" value for the interval

Type of services: COORDINATED TIMETABLE
Characteristics
- Common axis of symmetry for all lines - Balanced transport supply in opposite directions on the same line - Guaranteed connections in selected nodes
Passengers
- Adds spatial coverage to the time coverage - Shorter origin-to-destination time for connecting travellers - Opens the door to overall coordination of public transport (by coordinating feeder bus lines to trains) - Waiting time for transfers becomes reliably predictable if connections are guaranteed
Train operators
- Faces the obligation to run with high punctuality [5] - By guaranteeing connections, the risk of disturbance propagation between lines increases dramatically (unless the operator accepts to break the connection and to support the high commercial cost of doing so) - To alleviate traffic load in major connecting stations, lines are usually diametric, further increasing the risk to propagate disturbances in one branch to the other branch
Infrastructure manager
- Heavy capacity requirements in major stations (where usually real estate prices are high)
Administration
- Cost-effective territorial coverage (compared to exclusively direct relations) - Significantly enhances all other advantages and disadvantages of regular-interval operations

Table 4: Proprieties and consequences of coordinating across the network

Going up the ladder through those 4 stages results in increasing rigidity for the system, and tolerance to exceptions becomes thinner and thinner. To cope with the extra rigidity, operations should obey to strict discipline requirements in terms of both reliability and standardisation.

To increase operational reliability and robustness:

- Planners should provide sufficient buffer times [1] in all critical places and situations, to allow operators to recover nominal operations as early as possible after ordinary disturbances [5].
- Network operators should be equipped with efficient dispatching systems (installations and procedures) to correctly forecast in time any possible diversion from nominal operations, and the means to act in anticipation to avoid or reduce diversion.

On the other hand, disturbances should be kept as infrequent as possible and of the lowest possible magnitude. To control disturbances at their source, system components should be kept homogeneous, with the smallest possible variability:

- Rolling stock assigned to a mission should be homogeneous.
- Exceptions (variations of service in terms of stopping pattern of trains or scheduled travel times) should not be tolerated.

To less disciplined train operators, running according to regular-interval (and even more so with coordinated timetables) constitutes a real challenge. Success calls for dramatic changes in company mentality and culture [10]. Succeeding such a transition is a key to the overall success. Experience so far suggests that company's operations, eventually, run more smoothly than before and that may become a win-win situation for all the stakeholders, though transitional stages have sometimes been fairly painful.

Dealing with variable demand levels and the cost issue

Clearly, demand levels are seldom constant through the day. There are two philosophies, in regular-interval timetabling, to deal with this issue (Figure 9):

- Either vary the supply level. The basic transport supply is set to an average (generally slightly higher than the level strictly needed to cover off peak periods) level and reinforcement services are planned for peak periods.
- Or, keep the transport supply constant throughout the day. In this case, transport supply is based on peak-period demand volumes, which results in providing extra capacity during off-peak.

As an example, when a train per hour is sufficient to cope with off-peak demand volumes, but 2 hourly trains are needed in peak periods, planners may:

- Schedule one extra hourly train during peak periods. Depending on the fare structure, this may or may not result in increasing the financial loss. Marginal revenues, i.e. revenues from the extra trains, are usually lower than average revenues, as those trains carry proportionately more passengers with monthly or annual passes. Moreover, marginal costs are higher than average, as companies cannot use spare resources during peak periods and have thus to resort in increasing both the fleet size and the personnel.
- Provide a constant service of 2 trains an hour throughout the day. This leads to a significant improvement of the level of service but increases also the operational cost. The latter is not as dramatic as the improvement of level of service, as the marginal cost of running a train-set instead of parking it during off-peak is lower than average cost. Proponents of regular interval timetables assert that this strategy eventually improves the financial performance of the service. Revenues of induced demand not only offset the actual increase of cost but result also in some net profit, which is combined with productivity gains resulting of structuring the timetable. To the knowledge of these authors, there is solid - but not consistent - evidence to support this thesis. Unfortunately, most of the figures cannot be reproduced here, being covered by commercial confidentiality.

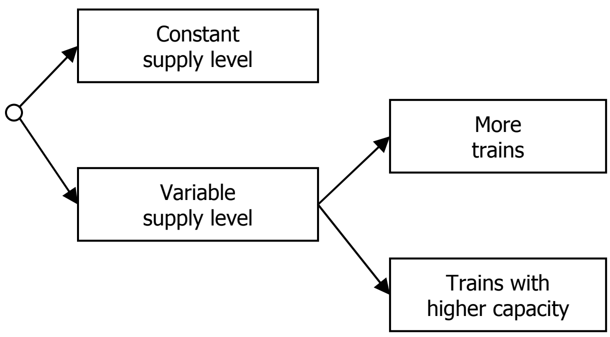


Figure 9: Dealing with variable demand levels

To summarise, the first solution induces high marginal costs and brings low marginal revenues. The second solution induces low marginal costs and brings revenues based only on induced demand. All-in-all, economic performance differences between the two philosophies are not as large as one could expect (or fear). As a matter of fact, there is no clear choice between those two philosophies, at least not a universal one. Decisions should be based upon a per case analysis.

In some cases, providing extra capacity during peak periods can be achieved by running train-sets with higher unitary capacity (longer trains, or double-deckers). This may be possible and/or effective for some cases, or impossible in other situations. When operating long lines, for instance, varying the train composition is not possible. The same train-set runs during peak time in part of its journey and off-peak for the rest. In such a case, change of train composition is irrelevant. Train-set turnover constraints may also make it absurd to consider varying a train-set composition. There are however cases in which changing train-set during the day may provide some marginal savings in operational cost.

One may argue that the cost issue can be considered as partly irrelevant per se, precisely because introduction of operations according to regular time intervals adheres to a supply-oriented planning principle.

Demand- vs. supply-oriented planning

Traditionally, planning the services comes back to design the transport supply according to the demand requirements. This is demand-oriented planning and is a common way of making business in industry. It is still (and it will remain) the most commonly used approach.

The core logic underlying the regular-interval services goes the other way round. By providing a consistent and more balanced transport supply across the operational time range (say, from 6 am to 8 pm), planners proceed in anticipation. The result is transport supply levels that remain relatively high, even during 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. The supply itself stops being a restriction for using public transport: the latter is "naturally" available throughout the day. This is the objective at the heart of the supply-oriented planning approach: time coverage.

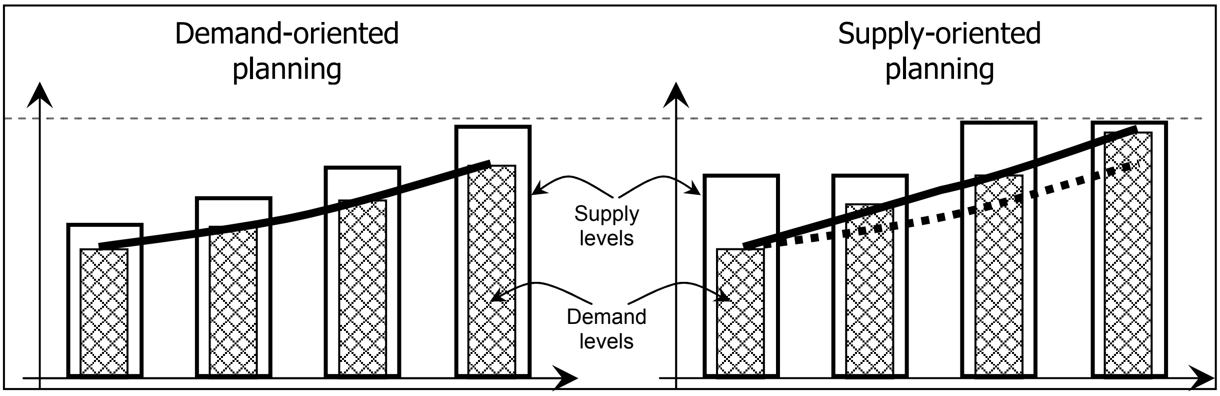


Figure 10: Demand-oriented vs. supply-oriented planning approach

What planners and decision-makers expect out of this approach is to induce higher demand levels than natural evolution of demand (which, by the way, was spontaneously declining in several cases).

Demand-oriented planning is reactive. Transport is seen as a service necessary to the society and the economy that should be sized according to forecasted needs. "Naturally" evolving demand sets the required levels of transport supply. On the opposite, supply-oriented planning is proactive. It matches a more aggressive policy option. It explicitly recognises that transport and economic development are interdependent, and transport can be used as a wedge to steer economic and social evolution along a desired path.

Supply-oriented planning plays better in situations where demand management is part of the public policy objectives, namely when:

- Supply levels are set low to restrain demand on specific modes, usually to respond to environmental concerns.
- Supply levels are set higher than technically needed to sustain demand development, usually to achieve modal shifts, or to favour economic development for selected areas. Policy makers expect that higher levels of supply will generate induced demand by both increasing individual consumption (more and longer trips by existent customers) and enlarging the customer base (new trips by people who previously gave up on travelling or by those who were using alternative means of transport).

Most cases of actual introduction of regular-interval services are related to an expansion vision: enhance the supply to attract more customers. Those are mainly passenger transport cases, although freight benefits also from this effort wherever the initial framework offers also space for freight train paths.

Both approaches coexist in real life. And, in any case, lines with low levels of supply should be (and are) planned according to the expected demand levels. The main issue is not to decide which approach is universally the best, but rather the order in which they appear during the planning stages and, especially, during the timetabling process. There are two factors that currently push to design services by applying first a supply-oriented approach, then by completing the final set of services [9] using a demand-oriented bunch of extra services: opening to competition, and concerns related to sustainable development.

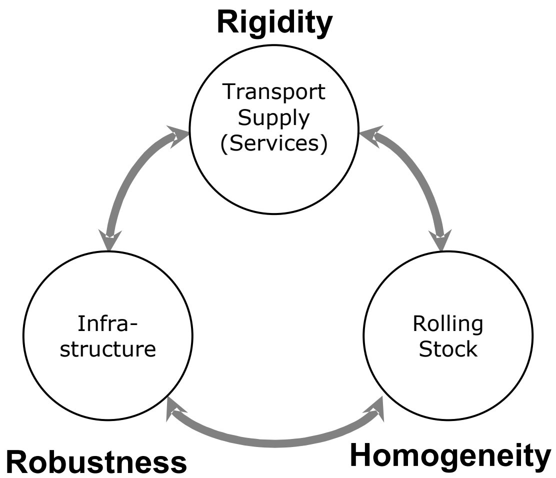
Opening to competition actually forbids implementing supply that is tailor-made according to the vision of a single train operator. On the contrary, infrastructure managers are forced to design a consistent framework of train paths that both cover the structural pattern of transport demand (usually at the national and the regional levels) and are able to be assigned to different competing operators. Sole a structured supply meets those requirements.

Moreover, sustainable development requires that further growth of transport demand should be directed towards the most environmental-friendly and economically-sound transport modes: for a broad range of journeys, rail is clearly the best current solution. The exceptions are:

- very short journeys, where walking or cycling can be considered;
- quite long journeys, for which railway is not a reasonable alternative to flying in terms of travel time;
- transport in low density areas or corridors, for which lighter public transport (busses) is economically more adequate.

Now, shifting from demand-oriented mindset to supply-oriented thinking is a deep cultural revolution for many railway professionals who raised and acquired their skills within the old monopolistic national railway companies. This is the reason for which, in the previous section, the transition they have to undergo was called a real challenge, further complicated by the need to consider new methodologies and tools [10].

Setting the process straight



The production assembly for railways is governed by three components [2] that tightly interact: infrastructure, rolling stock, and supply (Figure 11). In the conventional planning process, design started with the hardest component, the infrastructure, and was finished by the softest one, the easiest to modify: supply. Studies followed the same time sequence than creation of a line or a network: build - buy - operate.

Figure 11: A 3-players game

Many projects of new lines, such as high speed ones for instance, followed this pattern in time sequence:

- design the alignment (the line, the infrastructure project)
- choose the rolling stock (to match the technical requirements of the infrastructure, and the commercial ones of the company)
- design the timetable

Such a planning sequence leads to tailored-made services that are gradually completed, year after year, to adjust to the growth of demand (whenever the overall operation proves successful).

Going for clock-face operations (coordinated regular-interval timetable) cannot put up with such a design sequence. As already stated, this type of operation is highly rigid and generates severe constraints. To make it work, running times should adhere to preset values, and infrastructure should provide enough capacity and margins to ensure smooth, reliable and robust operations. The "soft" part, the services, becomes actually the hardest one, the less flexible in its structure. As a result, the planning time sequence has been turned upside down. Planners start by designing the services, first, which become a prerequisite to derive the needs in infrastructure capacity and/or rolling stock performances (Figure 12).

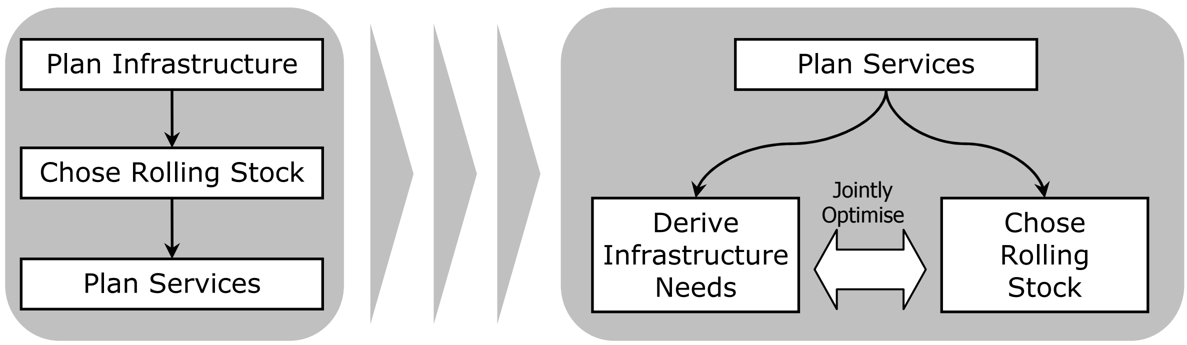


Figure 12: A major shift in planning philosophy

The consequences of IM/TOC separation

Whenever actual running times should be shortened to meet the coordinated timetable's requirements, there raises the possibility to jointly optimise infrastructure and rolling stock. Time savings may be achieved either by modifying the infrastructure, or by acting on the performances of the rolling stock [2]. Dealing with this issue is straightforward in integrated companies that manage both infrastructure and rolling stock: they just have to solve the technicalities of the optimisation. The situation becomes trickier when there is actual separation of infrastructure management and train operations, where choices for the rolling stock are those of the train operators, whereas infrastructure investment is controlled by infrastructure managers. This is clearly a setback for the overall system optimisation, as each stakeholder tries to - legitimately - optimise its own component.

Infrastructure managers tend thus to request from train operators to make their best effort in meeting running time requirements through adequate choices and investment in rolling stock, whereas train operators naturally expect infrastructural improvements to be the major contributors for the needed time savings [12].

The same debate, incidentally, goes on for at least two other issues: maintenance (linked to the aggressiveness of rolling stock), and margin / buffer creation to ensure stability of operations. On both issues, interests of infrastructure managers and train operators clearly diverge.

By dismantling the framework for joint optimisation, and by creating the conditions and incentives for only partial optimisation of components (and thus sub-optimisation of the overall system), separation sets a new situation that calls for referee functions and regulatory provisions to avoid sub-optimisation. This is a real challenge which, by far, is not currently fully addressed.

Winding down

Railways are versatile transport systems, able to address a large spectrum of human travelling, going from few-kilometres-long journeys up to several hundreds of kilometres. They are economically efficient as long as transport flows meet some minimal requirements of density. Moreover, they are fairly environmental-friendly, compared to their main competitors. Sustainable development concerns push in favour of their use and, actually, modal shifts to railways (as to short shipping, too) are a key component to transport policies.

To succeed in their role, railways should face adequately an extremely strong competitor: private cars that are perceived as been available at any time (time coverage) to reach almost any destination (geographical coverage). In this, coordinated regular-interval services may offer an interesting opportunity as they address both of those concerns, though less efficiently (public transport is still based on discrete flows instead of cars' continuous flow).

A second element favours such an evolution of rail services in European countries. The requirement to open the rail transport to competition makes almost compulsory for infrastructure managers to design a comprehensive, systematic framework of rail services that may be assigned among competitors.

However, by - somehow - forcing a separation of branches of this highly integrated system, there is an extra risk of ending up with suboptimal solutions, each stakeholder tending to optimise strictly its own position. Correcting this issue through regulation and check-andbalances is one of the major challenges for the European Union and several European countries in the upcoming years.

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