The added value of sharing tram and train expertise

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Abstract

Tram- and railways are different types of public transport, offering different kinds of service to specific markets. Generally speaking, the systems are developing towards each other in an attempt to combine the advantages of both worlds. Cities introduce faster and longer light rail connections, and the heavy rail industry tends to operate fixed corridors with higher frequencies as is common in tramways.

Although the systems seem to come closer, the methods of planning are not changing alike. This paper describes, illustrated with three examples, the possibilities to improve planning of both worlds by combining the best elements of the approaches:

- Running times determination: using both empirical data and theoretical calculations will help to determine the optimum driving time.
- Conflict management: in case of restrictions (due to e.g. infrastructure), it is important to take limited capacity into account in the design of the schedule. Nevertheless, one should be careful not to create needless limitations due to conflicts which will only appear on paper.
- Quality targets: speed and punctuality are useful quality indicators but the focus should not completely be on one indicator. Taking the actual travel time as overall quality target solves the trade-off between speed and punctuality.

The examples show that an unconventional approach can be business as usual elsewhere. Other organisations in related business may address similar issues in a fresh and possibly more efficient way, and a balanced approach often combines the best of different worlds.

Keywords

Timetable planning, Capacity management, Quality indicators

1 Introduction

Tram- and railways are different types of public transport. They have proven their added value for solving mobility problems of various kinds. While both systems have their own specific characteristics, new systems in between are arising in the field of rail-bound public transport. Generally speaking, the systems are developing towards each other in an attempt to combine the advantages of both worlds. In and around the cities new light rail connections are introduced, implying a move from tram in the direction of train: operating on dedicated infrastructure with higher speeds and serving larger areas [5]. In the field of heavy rail, ideas arise about higher frequencies in fixed corridors as is common in tramways [7]. Figure 1 illustrates these developments.

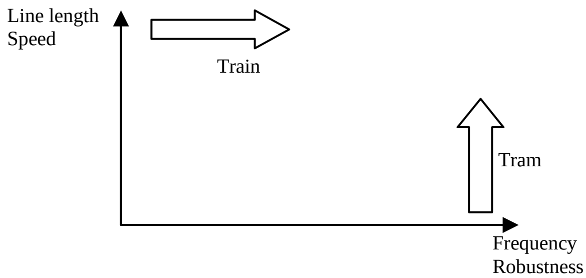

Figure 1: Train and tram systems are moving towards each other

Although the systems seem to come closer, the methods of planning are not changing alike. This paper describes, illustrated with three examples, the possibilities to improve planning of both worlds by combining the best elements of the systems. It does not pretend to be an extensive scientific research but rather aims to propose a paradigm shift in tram and railway operations. In order to show problems and chances most clearly, the paper describes pure tram and railway approaches in their traditional way. Of course, this does not mean to deny recent initiatives reconsidering these philosophies – those are very much in line with the intentions of this paper and greatly encouraged.

2 System description

2.1 Train

Passenger trains provide fast links between cities, and also connect suburbs and villages. Short and long distance services have different stopping patterns, and use rolling stock with different running characteristics and comfort. Trains use a dedicated infrastructure designed for relatively high speeds. Because of the complicated technology allowing that, a large part of delays has a cause within the system. The low-friction steel wheels on steel rails that limit energy losses, also cause braking distance to exceed sight distance, hence requiring a signalling system. This leads to considerable technical headway times.

A train system is economically viable thanks to bundling in space and time. Long trains with a limited frequency are a logical consequence from a cost perspective. The length of a train is mainly restricted by practical issues like space for platforms and reasonable walking distances. With frequencies of 1-2 trains an hour since the 1970s, good connections at node stations are essential for attractive travel times to a range of destinations.

2.2 Tram

Trams offer a frequent connection between one city centre and the surrounding residential areas. It shares crossings and possibly part of the line with road traffic. As a result, delays are likely to be caused by external causes. On the other hand, trams can run early because stops are served on demand. Sharing the infrastructure restricts the vehicle length and makes driving on sight necessary; the low speed allows this. This regime enables short technical headway times.

At the same time, short units *require* a high frequency in order to provide sufficient passenger capacity, especially in peak hours. This high frequency reduces waiting time, thus serving another quality purpose as well.

2.3 Comparison

Table 1 lists some typical characteristics for Dutch trains and trams. The differences may give reason for slightly different ways of planning. The methods traditionally used, however, sometimes differ quite extremely. For three scheduling issues, the next sections will consider the approaches and solutions of both industries. The current evolution of rail-bound public transport may lead to metro-like systems, combining high speed and high frequency. With growing system similarities, challenges in tram and train scheduling practice may increasingly have a similar nature. Therefore, opportunities are suggested to combine the best elements of both approaches.

Table 1: System characteristics of train and tram

Train		**Tram**
40 km, 30 min	**Typical trip**	3 km, 10 min
Every 5-25 km (local/IC)	**Stops**	Every 500 m, on demand
Planned	**Connections between lines**	Not planned
15-30 min	**Service interval**	5-15 min
140 km/h	**Maximum speed**	60 km/h
Signalling	**Safety system**	None (on sight)
50-300 m	**Vehicle length**	30 m
2 min	**Technical headway**	10 sec
Most internal	**Delay causes**	Most external

3 Running times determination

Running times are an important element in timetable design. On one hand they are the basis for the public timetable, and thus for the commercial product, rider ship and revenues. On the other hand, running times determine the required amount of vehicles and crew and hence costs. In addition, running times influence work perception of crew. The way running times are determined, is different for tram and train planners.

3.1 Train: calculation

To design driving times, train schedulers make calculations based on characteristics of infrastructure, vehicles and processes, see e.g. [8] and figure 2. A standard percentage of slack is included in order to cope with small variations. In common Dutch practice, a periodic timetable is designed with uniform departures and running times throughout the day.

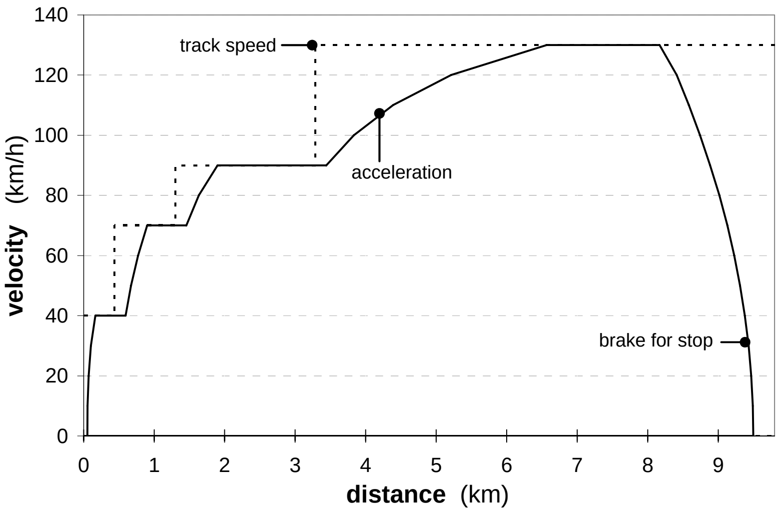

Figure 2: Example of speed profile, basis for running time calculation

3.2 Tram: feedback

Tram planners use empirical data of the previous timetable to design the new schedule [4]. All internal and external influences that cause variations are taken into account this way. Figure 3 shows the distribution of driving time, illustrating these variations. Running times vary over time of the day and day of the week. Although less transparent, this kind of timetable reflects the (im)possibilities of the network at any time.

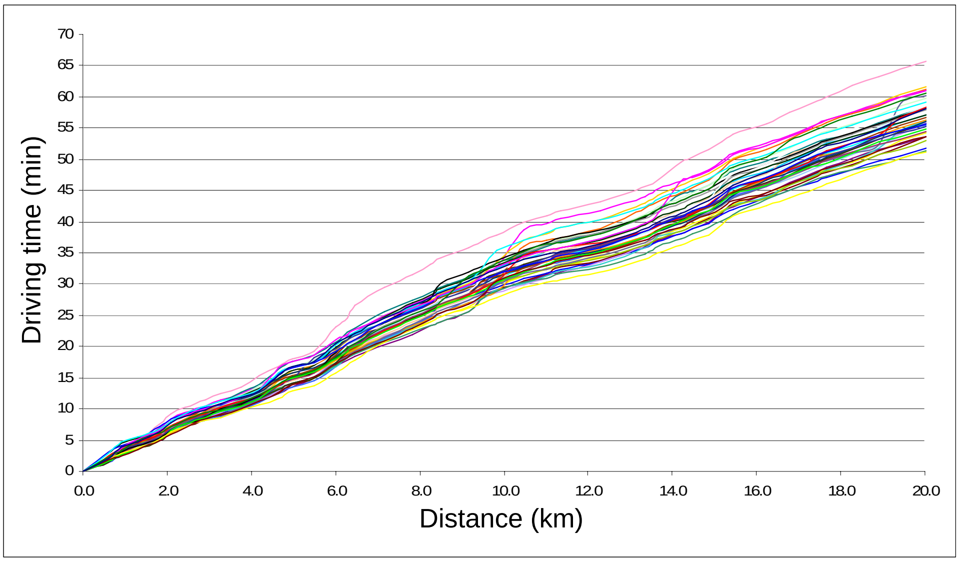

Figure 3: Example of distribution in driving times (tram line 1 in The Hague)

3.3 Synthesis

Both processes mentioned above are schematically visualised in figure 4A. The traditional method of the train planner implies a high level of (promised) quality by using maximum achievable speeds, but does not guarantee any feasibility. The tram method leads to a realistic timetable, but the feedback loop may cause running times to increase over years. Since both approaches have their strengths in providing a high level of service, combining might be optimal as shown in figure 4B. Operations are monitored and analysed to achieve a feasible timetable, as introduced in Dutch railway practice in recent years [12,13]. A comparison with theoretical times avoids unnecessarily long travel times. This way the control loop is closed, and running times can be both realistic and ambitious.

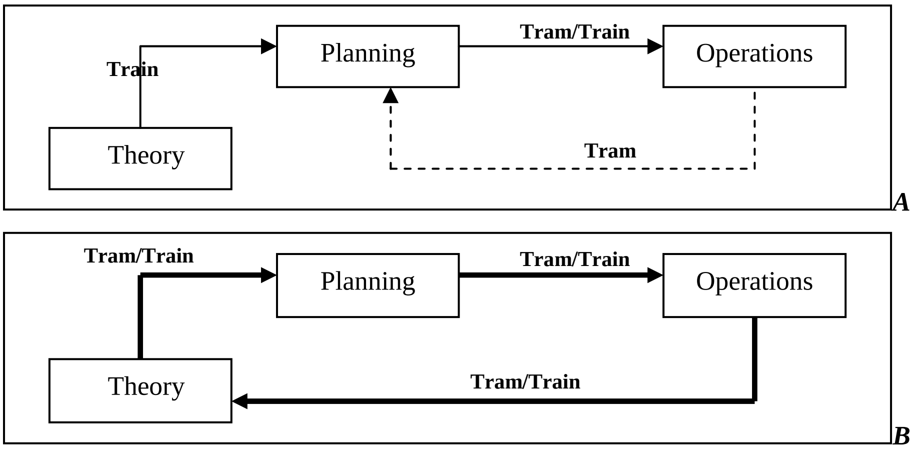

Figure 4: Planning of running time for tram and train (A) and in a combined situation (B)

4 Conflict management

When two vehicles need a common piece of infrastructure at the same time, they face a conflict. The extend to which this is taken into account in advance, varies with tram and train.

4.1 Train: prevention

Railways deal with conflicts explicitly by solving them in the timetable. Prevention in the planning stage seems sensible, because signalling leads to relatively long headways and delays in case of conflicts. Headway restrictions are taken into account by “booking” every piece of track for one train at a time, with preferably some buffer time between trains [2,11]. This approach applies to line sections, but also to points, crossings, platforms and terminals. By specifying minimum headways between successive and crossing vehicles, conflicts can be avoided and smooth operations are obtained. This is schematically visualised in figure 5B.

In certain situations, this method works out too rigid, especially with an hourly pattern approach. Freight paths may be reserved every hour but used a few times a day. Sometimes planners carefully solve conflicts between trains that are unlikely to run in the same hour in real life, such as international trains or certain freight trains. This way, a railway line may become full like a warehouse filled with empty boxes. Too much attention in the timetabling stage for theoretical conflicts implies fixing capacity claims that may change over time. That limits planning possibilities more than is useful for good operations.

4.2 Tram: pragmatism

A tram timetable does not address conflicts. Trams usually suffer disturbances due to other road users. Planners are used to dealing with uncertainty and do not take all disturbances into account separately. A timetable is designed according to commercial wishes and logistic possibilities on all lines. Making it conflict-free is hardly possible, and neither necessary: a conflict on paper will resolve itself in the operations because headways are short and two conflicting trams are unlikely to be both exactly on time. No conflict management means no capacity limitations and allows high traffic flows in the timetable, as is shown in figure 5A.

With growing intensity of tram traffic, capacity starts to be an issue especially at crossings and terminals. Signalling is introduced on regional lines, enabling higher speeds, but raising technical headways. Individual conflicts may be acceptable, but an overcrowded warehouse causes stability problems.

4.3 Synthesis

Both philosophies make some sense, but a joint approach might be best. Figure 5C (a combination of figures 5A and 5B) suggests that utilisation of the infrastructure is optimal when headway restrictions are taken into account, but not in an over-rigid way. Railway practice is developing the concept of Dynamic Traffic Management, where headway conflicts are dealt with in a more flexible way [10]. In the end, traffic hardly runs according to schedule exactly and conflicts may solve themselves in real life. On the other hand, certain capacity restrictions can be foreseen in advance and that information is to be

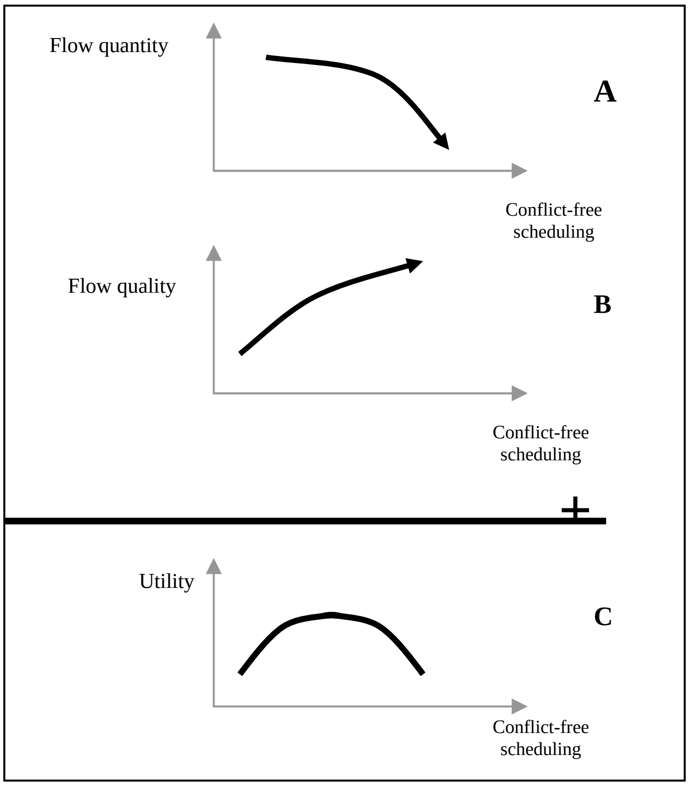

Figure 5: Effect of conflict management on traffic flow quantity (A), quality (B) and overall capacity usage (C)

used. Tram business starts studying queuing effects [3] in order to check in the planning stage whether the infrastructure can handle the desired traffic flow. Balanced conflict management will enable a high capacity utilisation in terms of both quantity and quality: prevention of predictable delays, and avoidance of needless restrictions.

5 Setting quality targets

Operational quality has different faces and focus can be quite on-sided. This paragraph presents the main indicators used by train and tram operators. The method of monitoring and judging by transit authorities is important as well in the process of choosing the company's main quality indicators.

5.1 Train: punctuality

Running on time is a key attribute in public transport. An interesting example from a questionnaire illustrates this [9]: given a choice between a sure 80 minutes travel time, or a travel time of 70 minutes with a 50% chance of 15 minutes delay, 85% of passengers prefers the first option. The Dutch railway industry has been strongly focussing on punctuality in recent years. It must be said that performance has been poor around 2000 so there was reason for attention to delays. To that end, passenger organisations and the railway operator agreed upon about a punctuality-dependent ticket price increase. Among other measures, there has been a tendency to include more slack in the timetable and stop guarding passenger connections, absorbing delays (as figure 6A illustrates) but extending travel times.

5.2 Tram: velocity

At tramways the focus on schedule adherence used to be relatively poor, although the effects of low schedule adherence can be large for travellers and operators [6]. Bunching of vehicles due to variability in driving time leads to longer waiting times, overcrowded vehicles and inefficient use of vehicles. Operators and transport authorities used to focus mainly on (theoretical) speed. Improving speed creates double benefits: first shorter running times save money in resources. Secondly it creates a more competitive position compared to other modalities and a higher share of use. Ticket revenues will increase and travellers will be more satisfied. In the attempts of achieving a high operational speed slack in the timetable works adverse. The relation between slack and scheduled times is shown in figure 6B.

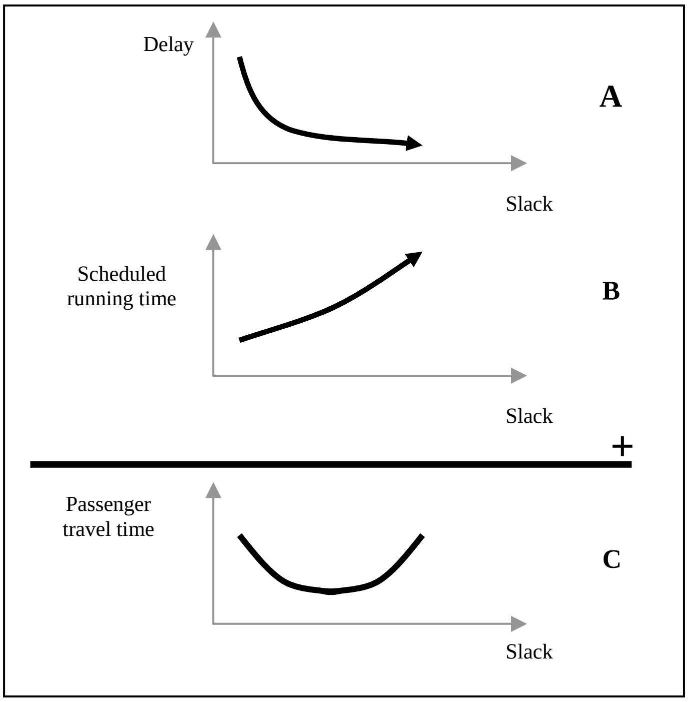

Figure 6: Effect of slack time on delays (A), running time (B) and overall travel time (C)

5.3 Synthesis

Despite speed-based running times, train scheduling has seen a one-sided focus on punctuality. A similar but contrary thing happens in tram business: determining running times on an empirical basis does not automatically make planners choose the right percentiles. An overstated look at operational quality does not guarantee an optimum. Some measures, such as eliminating delay causes, serve both speed and punctuality. With others like adding slack, both targets call for the contrary. Evaluating operational quality needs an indicator on a higher level, not surprising yet important: the actual travel time of passengers. This indicator takes into account both the effect of speed and punctuality. Figure 6C shows the relation of slack and travel time. Applying insufficient slack leads to an unreliable timetable, while adding too much slack creates long running times and unattractively slow services [1,6]. The optimum lies in between.

6 Conclusions

Train and tram planning practice address similar issues in different ways. Although system characteristics give reasons for certain differences, the traditional approaches differ quite extremely. Now that the gap between train and tram disappears, an intermediate scheduling method may be more appropriate. Three examples in this paper illustrate how best tram and train practices can be combined into a balanced planning process:

- Running times determination: using both empirical data and theoretical calculations will help to determine the optimum driving time.
- Conflict management: in case of restrictions (due to e.g. infrastructure), it is important to take limited capacity into account in the design of the schedule. Nevertheless, one should be careful not to create needless limitations due to conflicts which will only appear on paper.
- Quality targets: speed and punctuality are useful quality indicators but the focus should not completely be on one indicator. Taking the actual travel time as overall quality target solves the trade-off between speed and punctuality.

These examples reveal that a seemingly unconventional approach may be business as usual elsewhere. It is therefore highly recommended to meet people at other organisations in related business. Needless to say the authors have learned a lot when writing this paper. A look around may inspire to address issues in a fresh and possibly more efficient way. At the same time, one should guard not to exaggerate innovations, for a balanced approach often combines the best of different worlds.

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