Central Asia Regional Economic Cooperation Program

TRACK CAPACITY AND TIMETABLE SOFTWARE

CAREC
Central Asia Regional Economic Cooperation Program

PROJECT NUMBER: TA-9641
FEBRUARY 2020

TRACK CAPACITY AND TIMETABLE SOFTWARE

PREPARED FOR THE ASIAN DEVELOPMENT BANK

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Introduction

In 2017, the eleven Member Countries (MCs) of the Central Asia Regional Economic Cooperation (CAREC) program approved the CAREC Railway Strategy 2030 with a view to expanding the role of railway transport in the region. The strategy aims to accelerate the identification, preparation and financing of feasible railway investment projects and, at the same time, advance the commercialization and reform of railways to improve their performance.

An important focus of the strategy is to improve regional rail corridor efficiency and capacity. While some improvements require costly physical investments such as double-tracking, there is also scope for optimizing efficiency and capacity through the use of track capacity and timetable software (TCTS). The majority of CAREC railways do not use any information technology (IT) support for track capacity planning. This leads to many inefficiencies, such as complicated and slow timetabling processes, low asset utilization, inefficient use of resources (energy, human resources), and limited coordination of international train services.

The use of TCTS can help to overcome some of these shortcomings. It can also support performance-based decision-making for the construction and upgrading of infrastructure. With a simulated target timetable and a defined future demand expressed in number and type of trains, TCTS can identify the infrastructure improvements offering the highest benefit.

This report outlines all relevant aspects of the implementation and use of TCTS by infrastructure managers and train operators. It describes the requirements and functions of software solutions currently available on the market, highlights the potential for operational efficiency gains, and discusses the main challenges in implementation of TCTS.

Overview of Track and Timetable Software

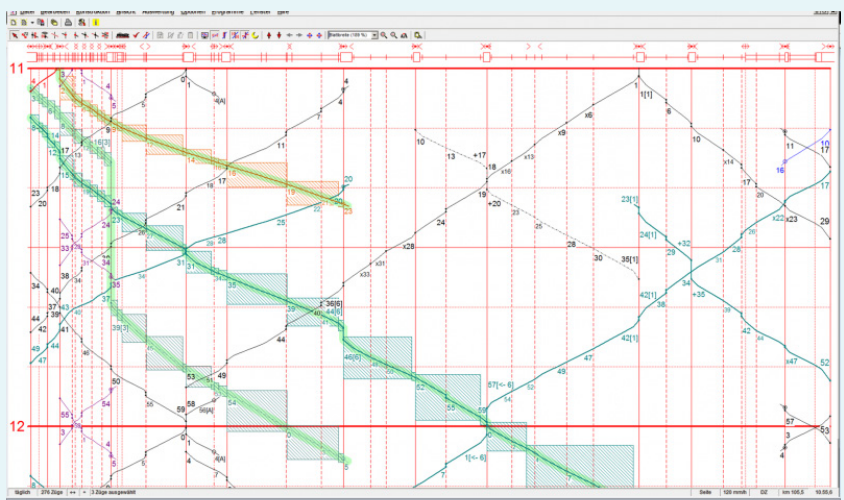
TCTS is a tool to organize and manage railway traffic as well as railway infrastructure. It simulates the operations of railway transport on existing or planned infrastructure. Using such a tool, it is possible to simulate various adjustments in the railway system and identify their likely impact on infrastructure, operations quality, capacity, and efficiency of asset utilization. The effects of new infrastructure layouts or new train service schedules can quickly be assessed. From a management perspective, these tools provide a sophisticated option for evaluating large investments in a reliable manner. This is useful for both infrastructure managers and rail operators.

TCTS allows the user to construct timetables of various kinds and to evaluate railway operational data. In order to generate accurately modelled train paths, it requires detailed data inputs, mainly on infrastructure and scheduled operations (Figure 1). With the input data in place, other changes can be quickly simulated.

The timetable on a railway network consists of train paths for scheduled movements of all trains in the defined infrastructure network. Analyzing them in TCTS makes it possible to:

- solve conflicting train paths
- optimize the use of capacity
- optimize track and train utilization
- identify necessary infrastructure measures
- provide solutions for operational problems
- coordinate international train runs
- plan operational deviations or restrictions (e.g. during maintenance)

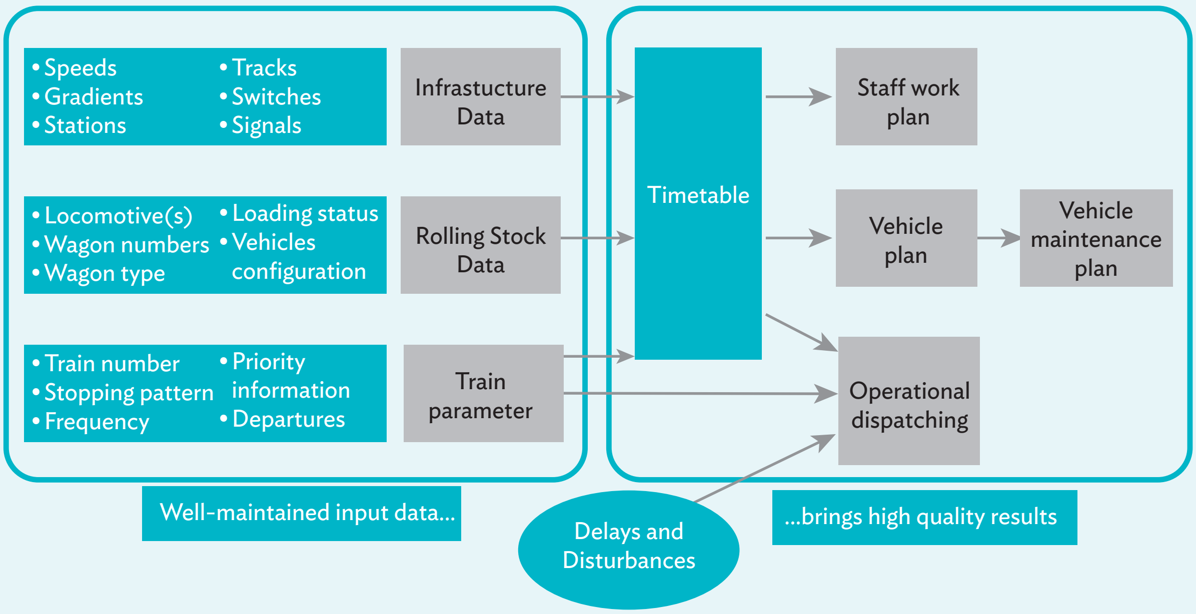
Figure 1: Graphic Timetable



Use of TCTS applications requires the preparation of an accurate inventory of infrastructure, rolling stock and train parameters by a skilled team of experts. The processing of input data is shown in Figure 2.

The more accurate the input data of infrastructure, rolling stock and train information, the better the results of the TCTS application. Timetable modeling requires the following type of data:

Figure 2: Data Processing in TCTS



Infrastructure data

- Detailed length of lines
- Detailed layout of stations/nodes
- Position of signals referenced to a defined km 0.00
- Gradients in 0.0 ⁰/₁₀₀ accuracy
- Allowed speed (e.g. over switches)
- Type of line restrictions
- Type of interlocking
- Number of tracks in stations
- Position of switches and the accessibility of the station tracks

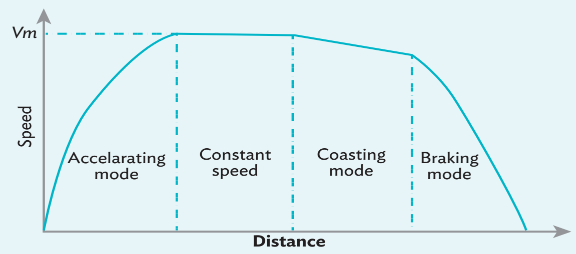
Train parameter

- Traction power
- Weight of locomotive and train
- Brake system and braked weight percentage
- Stopping time in stations
- Freight trains exceeding loading gauge
- Days of operation

The quality of the detailed infrastructure inventory needs to be of good quality if it is to support reliable asset management and planning using TCTS. Additional detailed information may be needed for particular tasks.

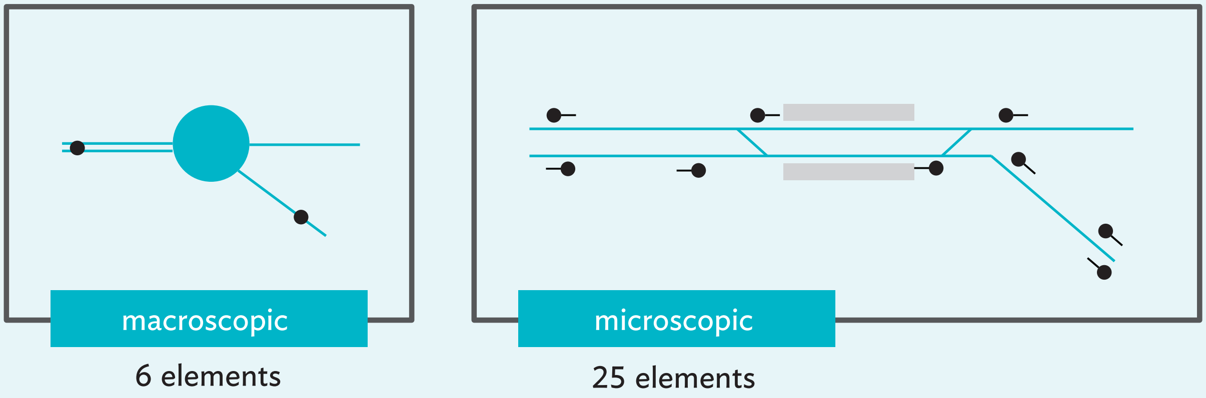
One of the advantages of TCTS over traditional timetable planning using hand-calculated graphs on paper or the use of standardized running times is that it calculates running times between stations based on the actual speed profile, combining the line parameters and the train configuration with its weight, power and speed (Figure 3). As the tool is able to calculate several trains at once, it provides a much more accurate overview of network capacity and the precise timings of trains.

Figure 3: Speed Profile for Trains



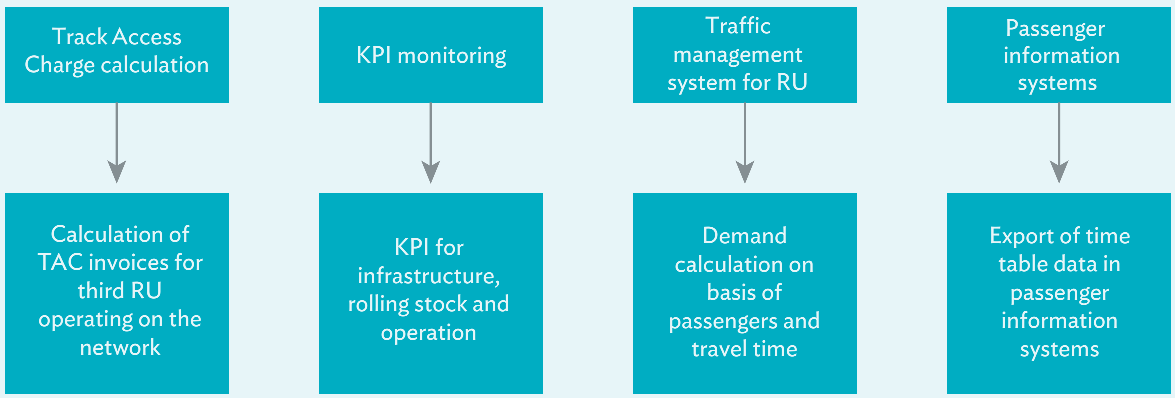
Depending on the level of detail, TCTS can use a fast or a detailed analysis method. These are based on either a microscopic or a macroscopic model of the applicable infrastructure depending on the question to be answered (Figure 4). While the macroscopic model only uses nodes and lines as the infrastructural basis, the microscopic model includes every switch, signal and station track in the simulation. The microscopic approach needs more effort to generate and implement infrastructural data but provides a more powerful analysis of the effects of timetable changes. The macroscopic approach can be used for strategic timetable planning and for rough cases of network capacity analysis. Most TCTS is based on the microscopic modelling approach.

Figure 4: Macro- and Microscopic Infrastructure Model



TCTS generates a lot of valuable information that can be processed in other applications (some examples are shown in Figure 5). Drawing upon the detailed TCTS information about distances travelled by all different train types, the calculation of track access charges or other user charges is a much easier task. For the performance of infrastructure management, important key performance indicators (KPIs) such as track utilization and track reliability can be directly collected. Important information for operators, such as average speed, expected energy consumption and asset utilization, can be quickly derived from such systems. Traffic management of operators can supported by TCTS with short-term adjustments of the timetable, or rolling stock demand calculations. For passenger information systems, all long-term timetable information as well as short-term adjustments and ad-hoc timetables can easily be provided.

Figure 5: Add-ons for TCTS Systems



Software Functions and Requirements

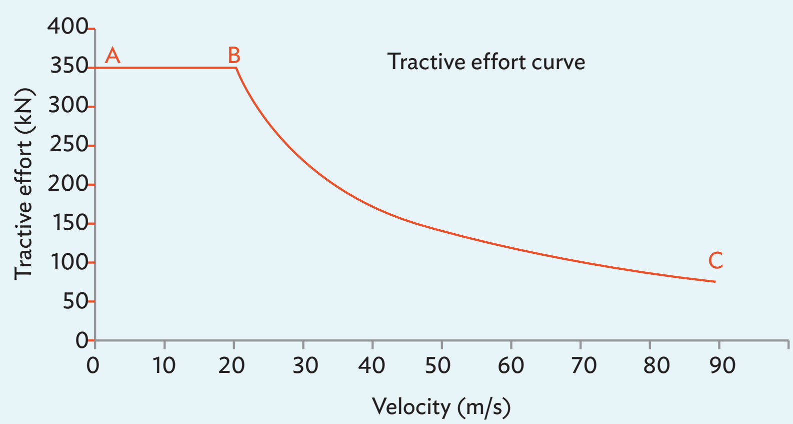
Databases

TCTS applications require several datasets. The main datasets are the infrastructure database, the rolling stock database, the calendar of train services, and route information.

Infrastructure database: The infrastructure database is a virtual model of the rail network. It contains lines, stations, junctions, signals, tracks, etc. All operationally important elements in the railway system are modelled and connected with attributes such as speed, gradient, and position. The infrastructure parameters need to be defined before the TCTS application can be used. This task can be substantial, but once completed, the virtual network can be easily adjusted. The effort for updating the infrastructure database is relatively low if done regularly. It is best to implement structured processes for regular updating of infrastructure data.

Rolling stock database: Most TCTS standard versions already include various types of rolling stock. For custom built locomotives and vehicles, the traction data may need to be entered, especially the tractive effort curve. The tractive effort is converted in acceleration curves and speed profiles in relation to the train load. Preparation of the rolling stock database is much simpler than the infrastructure database. The required information can usually be provided by the manufacturer of the rolling stock.

Figure 6: Tractive Effort Chart



Calendar: To regulate trains running on different days (e.g. reduced holiday service), each TCTS has a calendar within which trains are attributed according to their running days.

Route information: In many cases it is necessary to know which routes a train can use within a station and how those routes are prioritized. Usually priorities differ between passenger and freight trains. In most TCTS, this information is entered in the infrastructure database.

The infrastructure and rolling stock databases not only provide the basis for timetable calculations and capacity improvement, but also function as a register for assets. If sufficiently detailed and accurate, the register can be used as asset management tool, defining maintenance requirements. It also builds a sophisticated basis for cost-benefit analyses as the software can determine in detail the impact of changes (investments) in infrastructure and/or rolling stock on quality (performance) and costs.

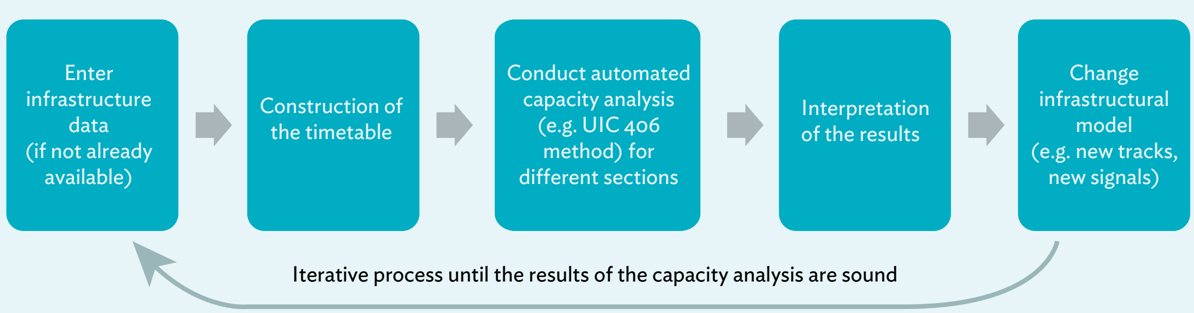
Infrastructure Capacity Analysis

All TCTS applications enable the user to conduct capacity analyses for rail lines based on the possible headway, blocking time stairway and track occupation times. The international standard for capacity analysis UIC 406 is generally supported, which defines most required parameters to obtain such information. TCTS enables the user to detect capacity reserves in existing networks, to analyze bottlenecks versus improvements options, or to define the required rolling stock for certain transport tasks (passenger and/or freight services). In applications with microscopic infrastructure models the ability to produce accurate capacity analyses for complex nodes is also provided.

The iterative process of infrastructure capacity analysis using TCTS is illustrated in Figure 7. After inputting of infrastructure data, the model makes it possible to calculate a precise timetable (e.g. the "as-is" situation). This can then be compared with the existing timetable to identify improvement potential including improved passenger and freight capacity allocation, options to increase punctuality, and the impact of possible investments in new or upgraded infrastructure elements (different speed, new signals, etc.) or the use of new rolling stock. All these elements can be analyzed in comparison with the existing situation to find the best solution in terms of operational costs, investment costs, reliability of operations, customer satisfaction or to other strategic goals.

The interpretation of the results provides an improved foundation for decision-making at management level. The expected impact of possible management decisions can be simulated within the model.

Figure 7: Iterative Process of Railway Capacity Analysis



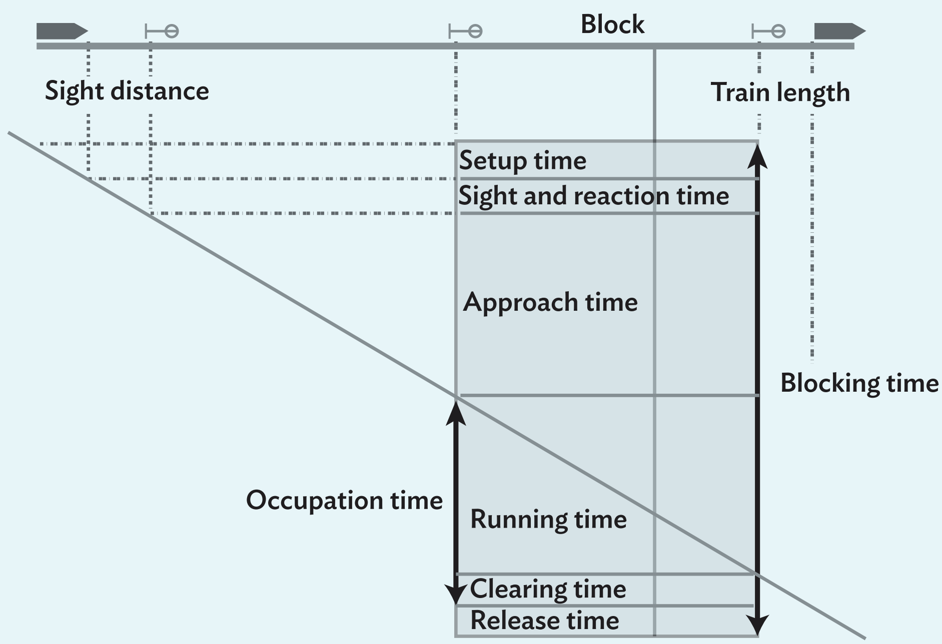
Timetable Planning

Timetable planning is the core feature of TCTS. Timetables are based on blocking time stairways, which are calculated from train movement models. This blocking time includes the overall time frame a train requires to block the track section between two signals. It reflects the exact performance of the train, including traction power, maximum speed, and weight of the train. Furthermore, it includes the reaction time of the driver, braking and accelerating, and the related approach into or out of the section. With this approach the system makes it possible to also address differences between different train types using the same tracks. This is of particular importance for defining the ideal coordination of passenger and (heavy) freight trains using the same tracks.

Conflicting train paths are detected automatically. Conflicts need to be solved by experts weighing various factors such as train priority, international connections or station track occupation. In rail networks with high density traffic the construction of a stable and market-oriented timetable is a permanent task for a group of well-trained experts. The preconditions and priorities for their decisions, however, have to be defined at a political and managerial level.

With high-quality TCTS, users are able to solve problems within the existing or a planned timetable. Options to avoid conflicts include "bending" train paths by prolonging the running time, or shifting train paths into a slightly earlier or later slot. For instance, it might be useful for a freight train to depart later to avoid intermediate stops, saving energy and thus operational costs.

Figure 8: Basic Calculation Principle of Blocking Time on Railway Infrastructure



As a result of TCTS analyses, various types of timetables can be generated, such as a graphical timetable, a timetable book for drivers, station timetables, etc. Timetable data can be exported to online systems or mobile applications for passengers or freight customers. Figure 9 shows the different planning stages in which generated timetables are used. Especially important is the ability in TCTS to process immediate, short-term changes that can be communicated to all stakeholders in real-time.

Figure 9: Timetable Uses

Timetable Resilience Assessments

A timetable constructed using TCTS can be used to simulate the real timetable situation on the network. The overall quality of the timetable can be determined as the number of conflicts identified in this simulation. Conflicts that in reality would lead to delays or changes of the scheduled train runs. If the simulated timetable is finally operated in reality, the assessment of operational KPIs, such as delays in a defined time frame, will show the overall quality of the timetable. The quality of a timetable should be tested beforehand through simulations of different scenarios. These simulations ensure operational resilience of the timetable.

The quality of simulations depends on an accurate interpretation of data and well-chosen improvement measures to overcome bottlenecks and conflicts. This task is often complex and requires long-time experience and a thorough understanding of the particular railway network, including the operational demand of the different market segments of railway business.

It is essential to include all trains expected to run on the network, even if not yet exactly known. The inclusion of irregular freight trains needs to be handled in pre-defined train paths to ensure the quality of resilience simulations. If in reality these trains would run without being included in the timetable, unpredictable situations would occur.

There are two different methodologies for simulations – the synchronous and the asynchronous approach. The synchronous simulation integrates the operational actions in the timetable construction, while the asynchronous simulation splits the timetable construction from the operations simulation. The synchronous simulation generates a very realistic model of the network operations, as it is independently able to vary the train order in case of delays. But it requires a strong computing capability. The asynchronous simulation is easier to implement, but it executes the timetable in an operational analysis without automated dispatching. The timetable is determined, and the train order can only be altered with specific conditional constructs (IF-THEN-ELSE). The asynchronous simulation is therefore not suited for dispatching purposes, as the alteration of train paths is essential for the performance of dispatching activities.

Operational Dispatching

A predefined timetable is never perfect. In reality it gets disturbed by delayed trains. To mitigate the consequent disruption of other trains, active dispatching is necessary. Effective dispatching orders rely on real-time information about the expected train movements and conflicts. To process this information, TCTS generates preview timetables, indicating conflicting train paths. It also allows the dispatcher to alter the train paths to forecast different scenarios. To mitigate delays, concrete decisions can be taken, such as changing the order of train departures.

Dispatching is only possible if the relevant information is available: (i) the location of trains within the network, (ii) the foreseeable movement (or non-movement) of trains, and (iii) the real-time status of infrastructure (e.g. closed tracks, signal failure).

Another technical requirement for dispatching is the availability of a capable communication system between the dispatcher and the train. A stable communication method to the signalmen in the interlockings is required. However, it is strongly recommended to also use communication channels to the train crew on board (other than signals) to inform them about the dispatching decision, the causes and the foreseen consequences of the decision. This is needed to avoid confusion and the risk of undesired actions by the crew. For passenger trains it is important to be able to inform passengers about the situation. This information can be created automatically if the passenger information system has an interface to import the timetable from a TCTS application.

Optimized Use of Bottleneck Infrastructure

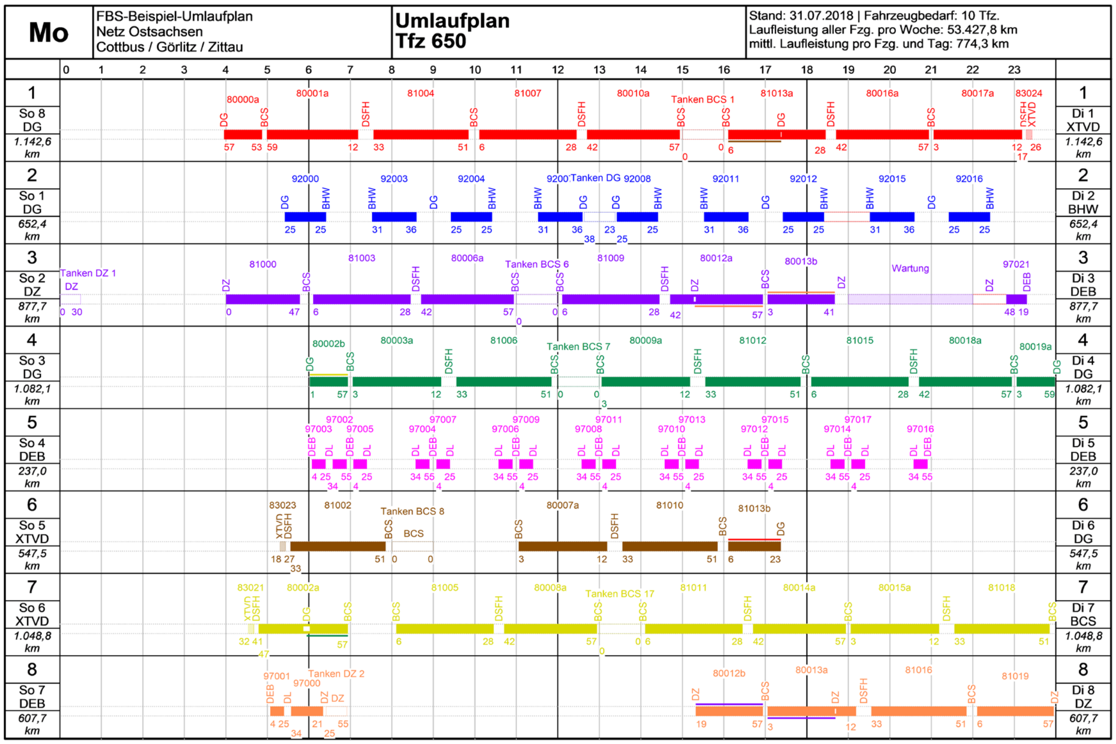
When a rail network has known, fixed capacity constraints such as single-track sections, TCTS can be used to find the optimum solution to use available capacity, for example through the usage of support locomotives. Other constraints, such as bridges (often on rail sections in ports), high gradients, and switches can also be analyzed precisely to find the most suitable use of the network.

During track construction or maintenance, often limited capacity is available (single-track sections, slow speed sections, closures, etc.). TCTS can provide revised and optimized timetables for such situations to allow all or a certain number of trains to pass the restricted area. It can also be used to define the limits for the construction/maintenance track possession time and the operational cost of these interventions.

Optimization of asset utilization

As TCTS is provided with the specifications of rolling stock used for each train journey, a rolling stock usage roster can easily be extracted (figure 10). The number of vehicle units can be displayed for certain days or mid-term periods. Regular maintenance or service stops can be scheduled, and the overall utilization of assets can be optimized. Similar types of information can also be retrieved for infrastructure.

Figure 10: Rolling Stock Roster



For regional networks with a homogeneous fleet of railway vehicles, TCTS makes it possible to extract an optimized vehicles deployment plan and calculates the minimum number of vehicles required to operate the timetable.

Since TCTS can monitor network capacity and usage, it is possible to optimize operations by adding additional trains where there is idle capacity in the network, or by re-routing or removing trains from a bottleneck, to make most economical use of the network.

Operational Staff Planning

Operational staff planning is in general not a core task of TCTS but, with the allocation of personnel to the generated roundtrips, it is possible to adapt TCTS results for staff planning. However, for complex networks, especially those with long running trains involving several crew changes, the use of a dedicated application for staff planning is recommended. Some staff planning software is able to import timetables from TCTS. If both are going to be used it is important to specify the interface.

KPI Monitoring

Different KPIs can be generated and monitored for several capacities in railway operations.

Railway operation data

Many operational KPIs such as running times and asset utilization (e.g. km per asset per year) can be directly retrieved from TCTS. This is also why railway operators are using TCTS applications, particularly when the system has direct access to the information of the infrastructure manager. One other important aspect relates to energy consumption, which depends much on the quality of the train slot. Many stops increase the consumption and operators are therefore interested to smoothen their own train runs to avoid accelerations. This can be simulated with TCTS.

Infrastructure utilization

The efficient use of infrastructure is a key objective for infrastructure managers. TCTS registers the use of the network and provides information on expected maintenance needs. It shows the overall performance of railway operators on the network, indicating the number of trains per track-km and the utilization of the network versus its capacity and eventual investment needs to increase network capacity.

Rolling stock

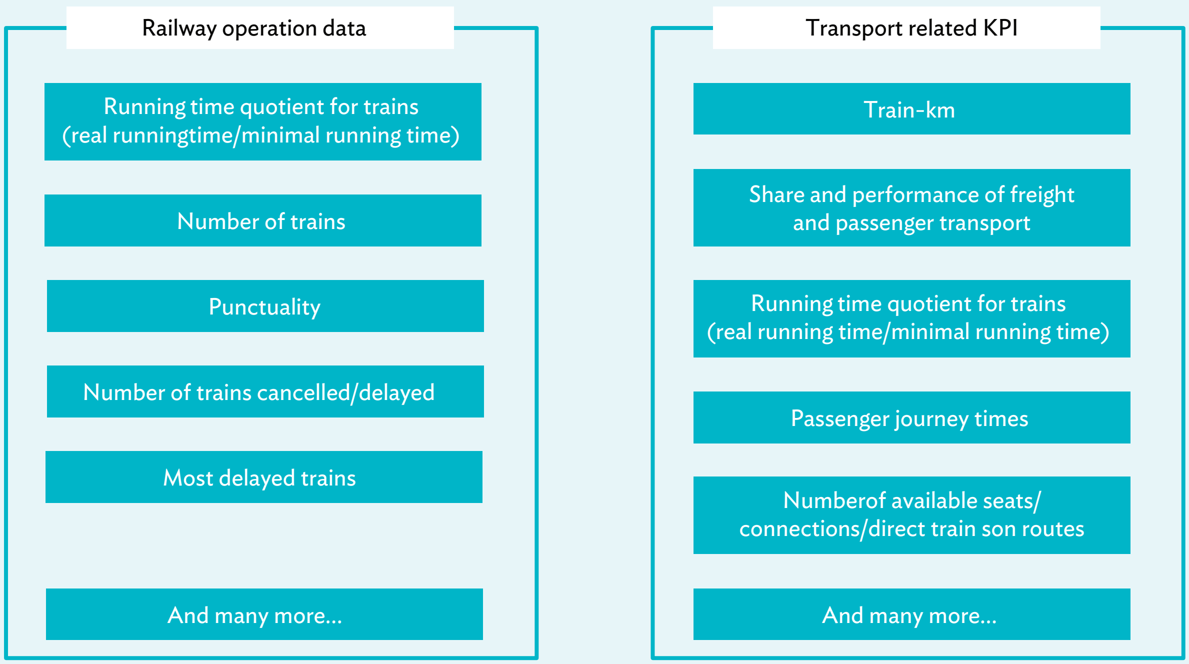
For rolling stock owners and users, the TCTS provides an overview of roundtrip planning, which includes the performance of each asset (locomotive, wagon, coach, EMU, DMU) and data regarding forecast maintenance needs. It further provides the necessary KPIs to optimize asset utilization.

Transport related KPIs

For customers, such as passengers and freight clients, the TCTS provides a quick insight of alternatives when scheduled trains are facing any type of deviation from the timetable. The immediate transfer of relevant data to passenger information systems allows passengers to react properly to changes (new departure time, change platform, etc.). For freight customers, information on timetable disruptions is valuable to revise loading/unloading planning accordingly. In some cases, factories and facilities may need the information to adjust their processes.

An overview of KPIs that can technically be monitored using TCTS applications is provided in Figure 11. The coverage of KPIs depends on the specifications of the chosen requirements.

Figure 11: KPIs that can be Monitored with TCTS



Procuring the Software

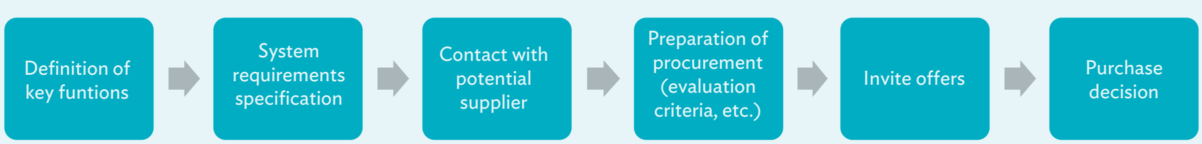
Decision-making Approach

As there are several systems that focus on different elements of timetabling and capacity management, various questions need to be answered before contacting potential suppliers.

(i) What functions should the software should fulfil? For instance, are dispatching functions required?
(ii) Are there sufficient data available (infrastructure, rolling stock)? If not, how much time and what efforts and expenses are needed to create (or update) the database(s)?
(iii) Can the train safety systems (if existing) be modelled in the software?
(iv) Are any interfaces with other systems required?
(v) Should the system focus on freight transport (less complexity), passenger transport (medium to high complexity) or mixed traffic (high complexity)?
(vi) What budget is available, not only for procurement but also for system maintenance?
(vii) Are there sufficient experts with sufficient understanding to properly use the system? If not, what are the training needs in terms of persons, skills and qualification? What are the related costs and how much time will it take to have sufficient trained staff in place?
(viii) Are all planning tasks to take place in-house or will they be supplemented by consulting services when needed (e.g. for timetable feasibility studies)?

The process of acquisition of a TCTS application is similar to other procurement processes, as illustrated in Figure 12.

Figure 12: Procurement Procedure for TCTS



Contact with Suppliers

There are only a small number of companies offering established TCTS to the market, so the market structure can be classified as a seller's market. It is strongly recommended to contact potential suppliers before preparing procurement conditions to learn about functions, system requirements, complexities, training needs and possible customizations of various software packages. To a certain extent, customizing of the software is a common practice.

Preparation of procurement

One of the major factors determining the software price is the number of workplaces to be provided direct access to the software and the number of workplaces to work in parallel using the software . For large countries with several traffic control centers or regional departments, different workstations with different groups of staff may need to be established, a system structure that will much costlier than a single office equipped with the required hard- and software. The particular user needs of different departments need to be analyzed to ensure efficiency in traffic management. A close connection between infrastructure and transport operations is needed to make best use of TCTS applications.

The licensing model of TCTS is another price-determining factor. There are several licensing models in the market. These include a one-time investment in program software and a service contract with yearly updates and yearly payments. The options differ between suppliers. Furthermore, it is important to consider the type of support needed, and whether this is covered by the service contract, or to be paid for separately.

Most programs are designed in English or Russian. If necessary, suppliers may have to take special symbols or certain translations into consideration. The possibility of such requests should be defined beforehand.

The necessary interfaces with other programs should be stated in the requirements specifications and the terms of reference. Even though some TCTS standards exist (e.g. *railML*), it is important to list precisely which systems need to be able to communicate, and which type of interface should be used. Ideally, data of the applicable systems should be provided to test the interface. More interfaces make TCTS implementation more complex and will therefore increase the costs. However, investment in interfaces for automated data transfer can be valuable in daily operations, for example to feed passenger information systems or staff planning systems.

For the use of TCTS on CAREC corridors it could be worth to consider forming a buyer's consortium to acquire a TCTS system. This would increase interoperability and reduce the cost for individual participating member states. This would also require a high level of data transparency and strong cooperation between railway agencies.

APPENDIX
TCTS applications on the market

The table below provides an overview of suppliers of TCTS, indicating the scope and main functions of their software applications. Besides these standard functions, there are many detailed specifications in individual applications that need to be defined when preparing to purchase TCTS. Applications may also be available in versions with limited or reduced functions.

The price range of TCTS depends on various factors as discussed in Chapter IV. Generally, an application with limited scope can be purchased for about $150,000, but the price may rise to $500,000 for a full scope application. In addition, the entry of infrastructure data needs to be considered (this may require several person-months of inputs), and the annual costs for service and operation of the system by skilled staff.

The table lists commonly used TCTS applications. It is not exhaustive, nor does it imply an endorsement of any of the applications.

	SMA	Hacon	VIA-Con	iRFP	RMCon	Oliver Wyman	Trenolab
Product name	Viriato	TPS	LUKS	FBS	RailSys	MultiRail Planning Suite	Trenolab
Infrastructure database	Macroscopic	Microscopic	Microscopic	Macroscopic *Data gathering by drone is possible*	Microscopic	Macroscopic	Microscopic
Infrastructure capacity analysis	Yes	Yes	Yes	Yes	Yes	No	Yes
Timetable planning	Yes	No	Yes	Yes	Yes	Yes	Yes
Timetable resilience assessments	No	Yes	Yes	No	Yes	No	Yes
Operational dispatching	Yes	Yes	Yes	No	No	Partly *Dispatching decisions based only on roundtrip information – no train paths conflicts detectable*	Yes
Vehicle planning	No	No	Yes	Yes	No	Yes	Yes

continued on next page

Table continued

	SMA	Hacon	VIA-Con	iRFP	RMCon	Oliver Wyman	Trenolab
Staff planning	Yes	Yes	No	No *Staff planning is possible on basis of vehicle roundtrips*	No	Yes	No *Staff planning is possible on basis of vehicle roundtrips*
Maintenance planning	Yes	Yes	Yes	No	Yes	No	Yes
Other functions	*Inclusion of behavioral models for passengers (journey times analysis and train occupation calculation)*	*Integration of passenger information systems*	No	No	No	*Freight demand forecast and traffic flow analyzer*	No
Website	https://www.sma-partner.com/en/software/viriato	https://www.hacon.de/en/solutions/train-capacity-planning/	https://www.via-con.de/en/development/luks/	http://www.en.irfp.de/functions.html	https://www.rmcon-int.de/railsys-en/railsys-suite	https://www.oliverwyman.com/our-expertise/insights/2012/mar/multirail-planning-suite.html	https://www.trenolab.com/tools/

About Track Capacity and Timetable Software

Track capacity and timetable software (TCTS) is a tool to organize and manage railway traffic as well as railway infrastructure. It simulates the operations of railway transport on existing or planned infrastructure. With such a tool, different types of adjustments in the railway system can be checked for their impact on the infrastructure, operations quality, capacity, and efficiency of asset utilization.

About the Central Asia Regional Economic Cooperation Program

The Central Asia Regional Economic Cooperation (CAREC) Program is a partnership of 11 member countries and development partners working together to promote development through cooperation, leading to accelerated economic growth and poverty reduction. It is guided by the overarching vision of "Good Neighbors, Good Partners, and Good Prospects." CAREC countries include: Afghanistan, Azerbaijan, the People's Republic of China, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan.