Abstract: - The article describes a proposed division of two information systems (of the infrastructure manager and the national railway undertaking) involved in designing the annual train timetable in the Czech Republic. These systems are currently closely interconnected, not allowing connecting other railway undertakings' information systems. An integrated data interface of the infrastructure manager system was proposed, being based on web services, with which information systems of railway undertakings can communicate using messages that meets the specifications of the European Union. The system is based on sending path requests by a railway undertaking and providing constructed paths by the infrastructure manager. The infrastructure manager may accept or reject the request; the railway undertaking may accept or reject the proposed constructed paths and cancel or modify its requests.

Key-Words: - timetable, train, path, information system, KANGO, TSI

1 Introduction
In the past, the annual train timetable in the Czech Republic was compiled by the national railway undertaking Czech Railways, which served both as a railway undertaking and infrastructure manager.

In 2006, the development of a new system KANGO was initiated for Czech Railways, which at that time also fulfilled the functions of a infrastructure manager. During the development of this system, the role of the infrastructure manager was taken over by the state-owned organization Railway Infrastructure Administration. The KANGO system was divided into two systems, but the module for entering railway undertakings' requirements for train paths continues to be shared by both organizations. At the end of 2010, the standard operation of these systems was launched.

Other railway undertakings pass their orders outside the system to workers of the infrastructure manager who enter them into the KANGO system.

To make the KANGO system accessible to different railway undertakings' information systems, an analysis of the integrated data interface of this system and transformation of the module for train paths requirements has been performed.

2 Present
The concept to produce annual train timetable in the Czech Republic is currently based on two information systems: KANGO and KASO [1]. The structure of these systems and links to external information systems are illustrated in Fig. 1.

Fig. 1 Present systems for creating train timetables

The KANGO system is primarily intended for the infrastructure manager, while the KASO system is used exclusively by the national railway undertaking Czech Railways.

The production of the timetable starts with the preparation of master data (rail network, engines, etc.) in the module KANGO-Kmen. The railway undertaking acquires basic data of trains in the KANGO-Vlak module [2], using which it orders trains at the infrastructure manager. Construction of trains is performed by the infrastructure manager in the KANGO-GVD module, setting time positions of
the trains, driving station and line tracks and other data. After the constructions of trains have been completed, circulations of engines and carriage groups are created in the module KASO-Voz and runs of locomotive and train crews are propounded in KASO-Pers.

KANGO modules operate over a common central database that contains a database of master data, trains and users. KASO-Voz and KASO-Pers applications read master data and data of trains from the KANGO database by means of KANGO-Vlak. They use their own central database for information on circulations and runs. The central databases are stored in the ORACLE database server.

Master data and data on trains are available for other information systems operated in the Czech Republic in the original and a new format. The original format is represented by text files, exported by the KANGO-Vlak module. The new format is provided through web services. Mutual exchange of data on trains with the international system PCS [3] (formerly Pathfinder) is provided by KANGO-Vlak through export and import of XML files.

Each module of the KANGO and KASO system is a three-layer application consisting of a database server, application server and client program. The application server provides an interface for database access, checks recorded data, and provides exchange of data with other application servers. Changes in data made by one client are automatically reflected in other clients.

Train information required by the railway undertaking and the actual data maintained by the infrastructure manager are recorded in a pair of trains: the required one and the actual one. The required train is entered by the railway undertaking in the KANGO-Vlak module as a train requirement to the infrastructure manager. The actual train is created by copying the required train, being modified by the infrastructure manager in KANGO-GVD (hereinafter referred to as the constructor). In the path of the actual train, the constructor can enter time data, information on the station and line tracks, within the KANGO-GVD structural zone (approximately the territory of the Czech Republic).

Information related to a part of the path that does not belong to the KANGO-GVD structural zone are filled in the required train by the KANGO-Vlak user directly or are imported from the PCS system.

During the creation of the train timetable, the required train goes through phases transferred requirement, requirement formation, ready for construction, construction, constructed, requirement change, agreed by railway undertaking and the corresponding actual train through phases construction, constructed, agreed by railway undertaking. The phases of trains are described in detail in [2].

The object train consists of the following groups of data:

- Train header – the data independent of the path, such as the number and name of the train.
- Train path – a sequence of transport points and related data, such as time data, train running calendar, activities.
- Objects in the path of the train with defined section and calendar of validity, such as railway undertakings, engines, train specifications.

3 Future

Czech Railways does not have their own database of trains and master data, which would enable it to maintain data intended for the infrastructure manager as well as specific data for its own use. All these data are now stored in the common database KANGO. The infrastructure manager thus has access to all data trains, at the time of their acquisition by the railway undertaking.

The current architecture of the KANGO system does not allow connecting information systems of other railway undertakings. An analysis was thus initiated concerning dividing KANGO and KASO systems in two separate systems and designing an integrated data interface KANGO, which would allow other railway undertakings to submit requests for train paths through their information systems.

To ensure liberalization of the European rail market and interoperability of infrastructure managers and undertakings, the European Union has published technical specifications for interoperability (TSI) for Telematic Applications for Freight (TAF) [4] and passenger services (TAP) [5].

In accordance with these regulations of the European Union, there are plans to create KANGO-TSI web services allowing railway undertakings' information systems using standardized XML messages. The information system of a railway undertaking will send XML messages and inquire about messages provided by the infrastructure manager.

There are two basic XML messages with which the KANGO system will work:
• **Path Request** – a request for a path sent by a railway undertaking to the infrastructure manager.
• **Path Details** – a constructed path sent or provided by the infrastructure manager to the railway undertaking.

Fig. 2 shows the planned architecture of the KANGO and KASO systems after division.

The KANGO-Vlak module will be divided into two modules:
• **KANGO-Tras** – will administer railway undertakings’ requests for paths and constructed paths by the infrastructure manager.
• **KASO-Vlak** – will be used to create the railway undertaking’s timetable. It will communicate with KANGO-TSI web services.

**Fig. 2 The future of information systems for creation of train timetables**

KANGO-Tras does not directly communicate with the KANGO-TSI module. Data exchange between these modules is realized only through a central database KANGO. KANGO-TSI module saves the message sent by the railway undertaking to the database in the XML format. At specified intervals, KANGO-Tras checks for new messages in the database in order to load and process them. KANGO-Tras saves the resulting constructed path to the database in the form of a XML message provided by the KANGO-TSI module upon enquiry made by the railway undertaking's information system. The KANGO database will therefore store the history of XML messages between the railway undertaking and the infrastructure manager.

The railway undertaking's master data management will be provided by the new KASO-Kmen module.

Railway undertakings will transmit international paths also through the KANGO-TSI module. Data exchange with the PCS system will be performed by the KANGO-Tras and KASO-Vlak modules.

**Path Request and Path Details** messages have the same structure that includes the following elements:
• Elements of the message header – contains particularly the type of message, information on the sender and recipient, and element **Type of Information** indicating the status of the request/path.
• **Identifiers** – identifiers related to the path request or constructed path.
• **Train Information** – an international request/path contains a series of important transport points of the path and related data, providing an overview of the path for each railway undertaking/infrastructure manager, involved in the path. A national request/path contains only the starting and destination point of the path.
• **Path Information** – sequence of national transport points and data relating thereto. The structure of the data relating to a transport point of the path is the same both in the element **Train Information** and in the element **Path Information**.

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Other types of messages that are described below do not contain elements **Train Information** and **Path Information**.

Unlike the object train, the path request and the constructed path can include a calendar (running days bitmap) only at any one transport point of the path, including the destination point (reverse construction from the destination to the starting point). Other transport path points bear only an indication of the number of days of calendar moving forward or backward. In each transport point, the train data can be changed (length, weight, engines, etc.), but they cannot be defined with their own calendar. The transport point data include the number of the train, i.e. the number of the train may be changed in the path.

With the object train, the train calendar is available in the starting point and it can be changed at any intermediate point (reverse construction is not possible). Most of the data train can be defined with a calendar and a section of the path. The train number may be changed in the route only from an even number to the nearest odd number and vice
versa. The train number in this case is indicated with a slash, e.g. 170/1.

The message includes the following traffic identifiers:

- **Path Request ID (PRID)** – made by the railway undertaking, identifies the path request. The identifier is also included in the constructed path to determine the links between the path request and the constructed path.
- **Train ID (TRID)** – created by the railway undertaking in the path request, identifies the business case. A number of requests can share the same TRID – the relationship between TRID and PAID is 1:N. Usually these are requests that relate to the same train. TRID cannot be stated in two requests whose calendars overlap. TRID is included in the request and is repeated in the constructed path.
- **Path ID (PAID)** – created by the infrastructure manager, identifies the constructed path. Multiple constructed paths can be provided to a single path request – the relationship between PRID and PAID may be 1:N. The KANGO system will deal with relationship 1:1.

4 Creating annual timetable

The KANGO-GVD module will continue to work with the object train. The KANGO-Tras module will work with the following objects:

- **Path request** – made by the railway undertaking's information system. It is read-only.
- **Constructed path** – made by KANGO-Tras from the path request and updates it from the required train.
- **Required train** – made by KANGO-Tras from constructed paths. The user can only view it.
- **Actual train** – made by KANGO-GVD from the required train.

In addition to constructed paths created from requests, there will be catalogue paths that are not linked to the path request. These are sample paths offered to railway undertakings and auxiliary paths generated during the hereinafter-referred-to process of making the timetable.

Because the train number may change in the object path, one path can be linked to more trains and one train can be composed of multiple paths – the relationship between the constructed path and the required train can be M:N. In the KANGO system, the relationship will be solved between the required train and constructed path 1:N. Nevertheless, the train number may still change in the path, but only from an even one to the nearest odd and vice versa, as is the case with the train. One required train can be linked to paths of various railway undertakings.

The relationship between the required and the actual train remains 1:1.

The term *route* continues to be used for the sequence of transport points of the path.

The process of creating a timetable of the path or train for an annual timetable in the KANGO system is as follows (see Fig. 3):

1. In the beginning of creating the new timetable, it is based on data from the previous timetable. The KANGO database contains just the required trains of the previous timetable that are in the phase *transferred requirement*. There are no other types of objects in the database.
2. The railway undertaking sends a *Path Request* message containing a request for a new path, from which KANGO-Tras creates a path request in the *new request* phase.
3. A KANGO-Tras user may choose one of the following commands for the new request:
   - **Refuse** – the user writes the reason for the refusal (any text) to the request, the request gets to the phase *new request – refused*, the constructed path is not created. At the same time, also the message *Answer Not Possible* is created containing the reason for refusal. The railway undertaking may then send a *Path Request* message containing a modified request with the same PRID. In this case, we proceed as if it were a new request. The request may also be refused automatically by the KANGO-Tras module. In this case, the program automatically fills in the reason for the refusal and performs the same operation as in the refusal by the user.
   - **Accept** – see the next step.
4. If a request is received, the process to create a constructed path is initiated. Path data are copied from the request. Missing points between pairs of points contained in the request are filled in by Dijkstra's shortest path algorithm [6]. The user can subsequently change the route at will in a graphical form in the railway network window. The constructed path gets to the *path formation* phase, the path request enters the new
request – accepted phase and a link is created between these objects.

![Diagram of path request and details](image)

Fig. 3 Process of creating a route timetable

A transport point of an international path has an "International Part of the Path" flag. Transport points with this flag are present in the Train Information element of the Path Details message. The initial set of symptoms is taken from the request. The user can change this flag with any transport point of the path.

5. The constructed path needs to be linked to the required train. The user can select one of the following commands:

- **Create** – A new required train is created with data taken from the constructed path. The required train gets to the requirement formation phase and the next step follows.
- **Use** – the user selects an existing required train.

If the required train is in the transferred requirement, its route changes according to the constructed path and the train gets to the requirement formation phase.

If the required train is in a different phase, its route must meet one of the following conditions:

- The route of the required train is identical with the route of the constructed path – the route of the required train does not change.
- The route of the required train also includes transport points on the part of the starting and/or the destination point – the route of the required train does not change. E.g. the route of the required train is A – B – C – D – E and the constructed path B – C – D.
- The route of the constructed path also includes transport points on the part of the starting and/or the destination point – the path of the required train extends according to the constructed path. E.g. the route of the constructed path is A – B – C – D and the required train B – C – D – E. The route of the required train extends to A – B – C – D – E.

With any adjustment of its route, the required train gets data from the constructed path, which in most cases is composed of objects with a calendar and a section of validity. In the section, calendars of constructed paths, with which the required train is linked, cannot overlap. Data entered without a calendar (e.g. arrival and departure times) are taken from the constructed path:

- to the entire route of the required train if the required train is linked only with the constructed path.
- only to a new part of the route of the required train if the required train is linked with a number of constructed paths.

We cannot use the required train in the ready for construction phase or ready for construction – change phase. In this case, the user must wait
until the required train automatically switches to the next phase of construction.

If the required train is in a phase higher than requirement formation, it is transferred to the requirement change phase.

6. A KANGO-Tras user can later edit the data of the constructed path that is linked to the required train. In that case, data of the required train are automatically updated.

If we change the route of the constructed path, one of the following operations takes place:

- If the required train in the section of this constructed path is linked only to this constructed path, the route of the required train automatically changes according to this constructed path.
- If the required train in the section of this constructed path is linked to a number of constructed paths, the link of this constructed path to the required train is automatically cancelled. If need be, the route of the required train is shortened on the part of the starting and destination point.

However, we cannot cancel the inner part of the route of the required train – in that case, a catalogue path is created with this section and linked to this required train.

A change in the calendar of the constructed path may result in a situation where calendars of the constructed paths linked to the required train overlap. In this case, the user must unlink the constructed path from the required train and create or use a different required train – see Step 5.

7. If the constructed path is bound with the required train and the calendar of the constructed path does not overlap with a calendar of another constructed path bound with the same required train, the user can move the constructed path to the path construction phase.

The bound required train is automatically moved from the requirement formation phase to the ready for construction phase or from the requirement change phase to the ready for construction – change phase if all constructed paths bound with this required train are in the path construction phase or path construction – change (see below).

8. A KANGO-Tras user may move the constructed path back from the path construction phase to the path formation phase and carry on editing it – see Step 6. The bound required train is automatically moved to the requirement change phase.

9. Once the required train bound with the constructed path has moved from the construction phase to the constructed phase (automatically after construction of the actual train in KANGO-GVD has been finished), data entered in KANGO-GVD are imported from the required train to the constructed path and the constructed path moves to the path draft. At the same time, a Path Details message is generated (the Type of Information element has the draft offer value). From this moment on, the constructed path cannot be edited and we wait for the railway undertaking to respond.

10. The railway undertaking may send one of the following messages in response to the proposed path:

- Path Confirmed (the Type of Information element has the observation – complete value) – the railway undertaking agrees with the proposed path without comments. KANGO-Tras moves the path request phase to path draft – confirmed.
- Path Details Refused (the Type of Information element has the observation – complete value) – the railway undertaking does not agree with the draft, giving any text of comments. KANGO-Tras moves the path request to path draft – refused phase, attaching a text of comments.

In both cases, the constructed path moves to the path change phase and the railway undertaking's comments are copied from the request. The required train bound with this constructed path moves to the requirement change phase.

11. In exceptional cases (usually when the railway undertaking fails to respond within a given period to the draft path), the KANGO-Tras user may move the constructed path from the path draft phase to the path change phase without the railway undertaking responding. A corresponding path request does not change its phase.

12. The KANGO-Tras user may make any changes in the constructed path in the path change phase, as in Step 6.

13. If the conditions specified in Step 7 have been met, the user may move the constructed path to the path construction – change phase. The bound required train is automatically moved to the ready for construction phase or ready for construction – change phase under the same conditions as in Step 7.

14. The KANGO-Tras user may move the constructed path back from the path construction – change phase to the path change
phase and continue editing it – see Step 12. The bound required train is automatically moved to the requirement change phase.

15. Once the required train bound with the constructed path has moved from the construction phase to the constructed phase, data entered in KANGO-GVD are imported from the required train to the constructed path and the constructed path moves to the final path phase. At the same time, a Path Details message is created (the Type of Information element has the final offer value). From this moment on, the constructed path cannot be edited and we wait for the railway undertaking to respond.

16. The railway undertaking may send one of the following messages in response to the final path:

- **Path Confirmed** (the Type of Information element has the final offer – accepted value) – the railway undertaking agrees with the final path. KANGO-Tras moves the path request to the final path – confirmed phase and the constructed path to the path pre-booked phase.
- **Path Details Refused** (the Type of Information element has the final offer – rejected value) – the railway undertaking does not agree with the final path, giving any text of comments. KANGO-Tras moves the path request to final path – refused phase, attaching a text of comments. The constructed path moves to the path formation phase and the railway undertaking's comments are copied from the request. The required train bound with this constructed path moves to the requirement change phase. Following are steps for a new path – see Step 6.

17. In exceptional cases, the KANGO-Tras user may move the constructed path from the final path phase to the path pre-booked phase without the railway undertaking responding. A corresponding path request does not change its phase.

18. If the constructed path gets to the path pre-booked phase, a Path Details message is generated (the Type of Information element has the final offer – accepted value). The KANGO-Tras user cannot edit the constructed path at this phase, but the constructor in KANGO-GVD can move the corresponding actual train to the construction phase, edit it and move it back to the constructed phase. After the corresponding required train has been updated, the constructed path is updated that does not change the phase, and the Path Details message is re-generated with the same type of information.

19. In the term of railway capacity assignment, the KANGO-Tras user moves the constructed path to the path booked phase. The corresponding required train and the actual train move to the agreed by railway undertaking phase and the Path Details message is generated (the Type of Information element has the booked value). The constructed path, corresponding required train and the actual train cannot be edited in these phases in any KANGO module.

In addition to the presented path formation procedure, procedures have been proposed for the following operations:

- the path request cancelled by the railway undertaking,
- the path request modified by the railway undertaking,
- the constructed path is deleted by the infrastructure manager,
- making regular timetable changes.

### 5 Conclusion

Since the end of 2010, the annual timetables in the Czech Republic have been compiled by the KANGO systems on the infrastructure manager and KASO by the national railway undertaking. Paths are ordered through the common KANGO-Vlak module, whose application server provides the infrastructure manager's data for the KASO modules. The introduction of these systems has improved and accelerated the creation of train timetables. However, the current architecture does not allow other railway undertakings to have their information systems connected, as they have to request for train paths through the staff of the infrastructure manager.

Therefore, an integrated KANGO system data interface has been designed being based on web services, with which railway undertakings' information systems can communicate using XML messages. These messages conform to the TAF/TAP TSI specifications of the European Union. The railway undertaking's information system sends XML messages and queries on messages provided by the infrastructure manager. The basic messages are path request (sent by the railway undertaking) and constructed path (sent by the infrastructure manager).

A process to produce the annual timetables and periodic changes has been designed. The designed system allows the infrastructure manager to keep
records of all messages sent between the railway undertaking and the infrastructure manager, keep separate records of path requests, corresponding constructed path and train, which can be bound to various railway undertaking's paths. The infrastructure manager may accept or reject requests; the railway undertaking may accept or reject proposed constructed paths and cancel or modify its requests.

References:


