DIGITAL TRACK MAP FOR THE VEXA EXPERT SYSTEM

PRESENTATION OF THE CONFERENCE PAPER

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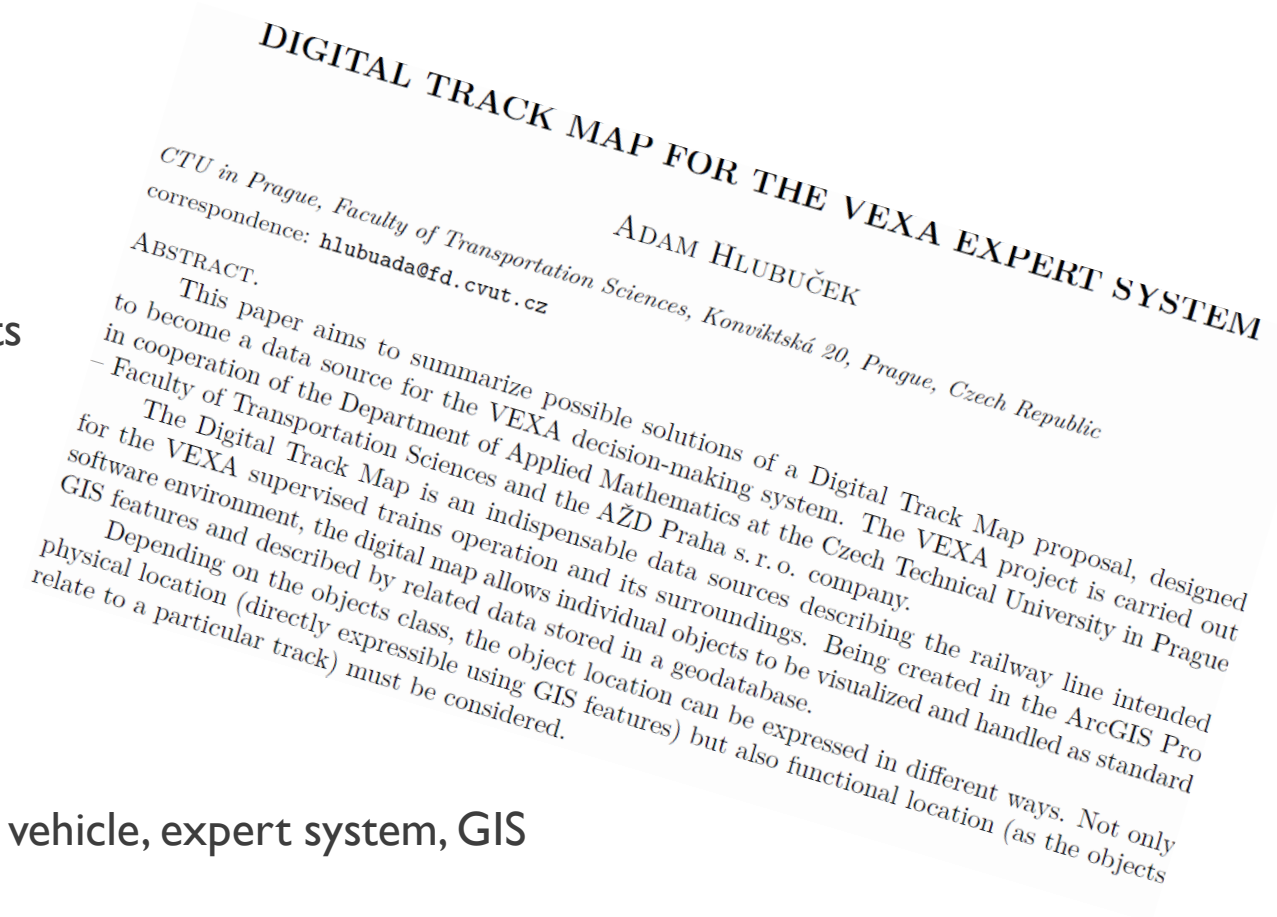
ABSTRACT

- paper aims to summarize possible solutions of a Digital Track Map proposal for the VEXA expert system
- VEXA project carried out by the CTU in Prague – Faculty of Transportation Sciences and AŽD Praha s.r.o.
- Digital Track Map supposed to be a data source for VEXA, as regards the railway infrastructure description
- created in the ArcGIS Pro software environment (objects visualized and handled as standard GIS features)
- VEXA functionalities leading to perform the tasks of an autonomous railway vehicle (decision-making processes)
- VEXA evaluates the conditions for running a railway vehicle ⇒ needs to detect unwanted objects
- Digital Track Map consists of Digital Map Trackside and Digital Map Onboard (loading data tiles)
- vehicle location information supposed to be provided by the GNS technology and by an odometry system
- presummed collaboration with the AVV system of automatic train control (source of some infrastrucrure data)
- spatial expression of infrastructure following the RailTopoModel priciples (e.g. various types of locations)

CONTENT

1. Introduction
2. Logical Architecture of the VEXA System
3. Recognition of Potentially Dangerous Objects
4. Requirements Arising from Vehicle Localization Aspects
5. VEXA and AVV Possible Cooperation
6. RailTopoModel and GIS Principles Application
7. Conclusions



DIGITAL TRACK MAP FOR THE VEXA EXPERT SYSTEM

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ABSTRACT.

This paper aims to summarize possible solutions of a Digital Track Map proposal, designed to become a data source for the VEXA decision-making system. The VEXA project is carried out in cooperation of the Department of Applied Mathematics at the Czech Technical University in Prague – Faculty of Transportation Sciences and the AŽD Praha s. r. o. company.

The Digital Track Map is an indispensable data sources describing the railway line intended for the VEXA supervised trains operation and its surroundings. Being created in the ArcGIS Pro software environment, the digital map allows individual objects to be visualized and handled as standard GIS features and described by related data stored in a geodatabase.

Depending on the objects class, the object location can be expressed in different ways. Not only physical location (directly expressible using GIS features) but also functional location (as the objects relate to a particular track) must be considered.

Keywords: Digital Track Map, VEXA, autonomous railway vehicle, expert system, GIS

INTRODUCTION

- growing need for thorough description of the railway infrastructure (ATC, ATO, TMCS, expert systems,…)
- this also applies to the VEXA system
- developed by the Department of Applied Mathematics at the Czech Technical University in Prague – Faculty of Transportation Sciences and the AŽD Praha s.r.o. control and signaling systems supplier
- aims to substitute decision-making processes of a train driver
- evaluated inputs can be outputs from detectors (e. g. obstacle, fire) and status reporting systems
- knowledge base and decision rules designed to evaluate the conditions for running a railway vehicle
- Digital Track Map developed to provide the infrastructure data

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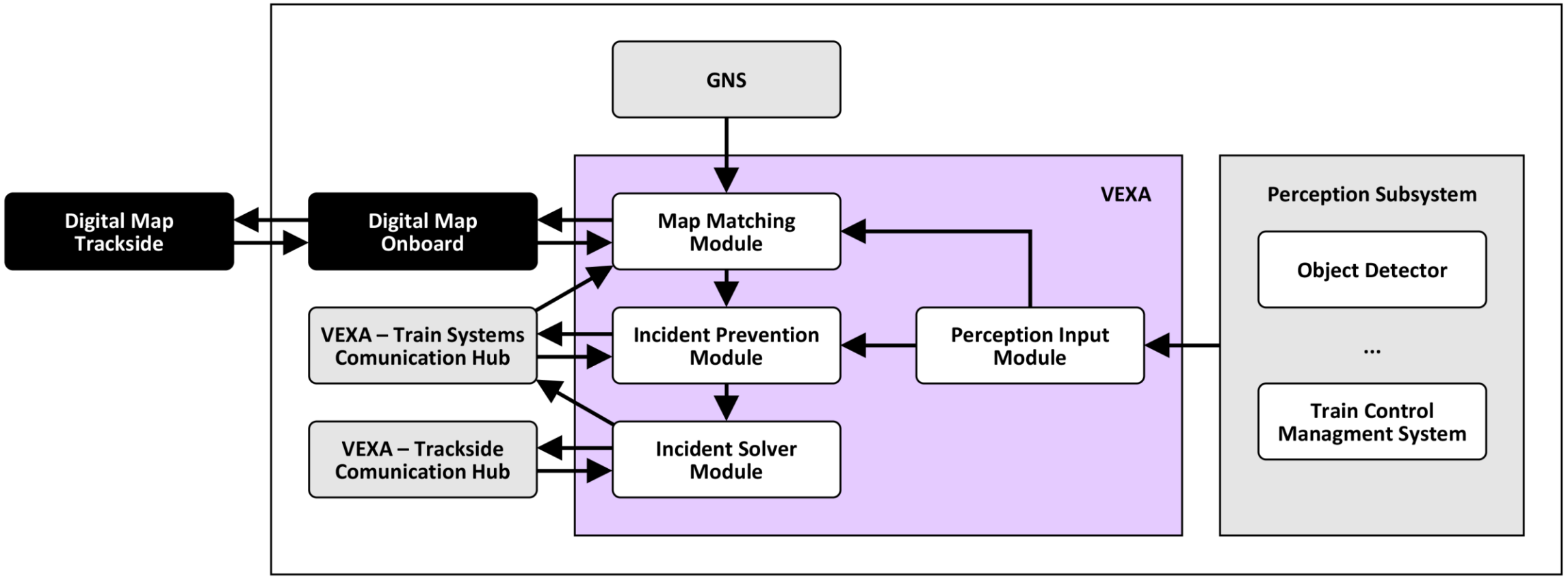
LOGICAL ARCHITECTURE OF THE VEXA SYSTEM



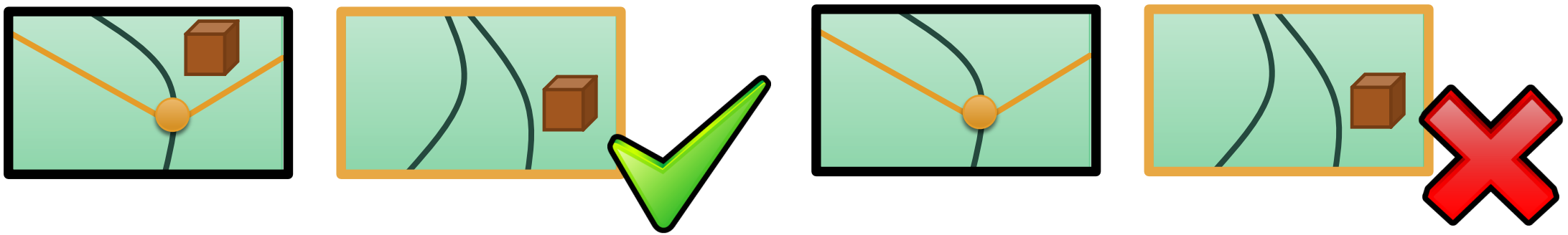
LOGICAL ARCHITECTURE OF THE VEXA SYSTEM

- Perception Input Module – aggregating inputs from train detectors
- Map Matching Module – managing information about the known surroundings of the autonomous train
- Incident Prevention Module – processes the data related to the objects evaluated as potentially unwanted, decides on the choice of reaction that is necessary to prevent or mitigate the impact of a potential incident
- Incident Solver Module – performing the correct reaction to possible incidents (rules how to react)

- Perception Subsystem – consists of the Object Detector and Train Control Management system providing data to the Perception Input Module
- VEXA – Train Systems Communication Hub and VEXA – Trackside Communication Hub – provide the interface to various railway systems
- Global Navigation System – provide the unit location data
- Digital Map Onboard – loading data tiles from Digital Map Trackside (both parts of the Digital Track Map)

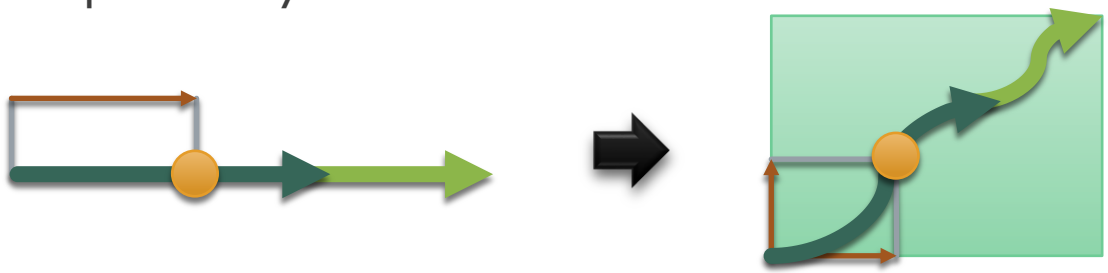
RECOGNITION OF POTENTIALLY DANGEROUS OBJECTS

- purpose of the Digital Track Map is to provide the VEXA system with the data describing the raliway infrastructure used by the autonomous vehicle and its intermediate surroundings
- one of the VEXA system goals is to detect unwanted objects around the railway line and especially on the track
- Digital Track Map serves as a basis for comparison against the recognised scene
- supposed to include the location of expected objects (which are to be evaluated as harmless) around the line
- Map Matching Module evaluates whether detected objects need to be classified as potentially dangerous
- occurs if there is no corresponding data object included in the Digital Track Map while a real object is detected



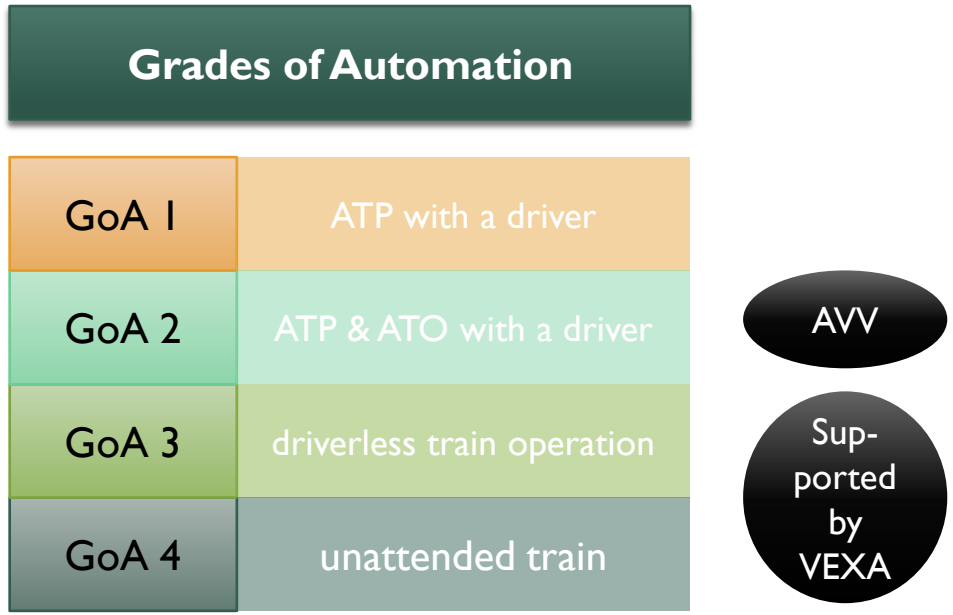
REQUIREMENTS ARISING FROM VEHICLE LOCALIZATION ASPECTS

- selection of data tiles to be loaded to the onboard module based on the knowledge of the vehicle location
- vehicle location information also needed to determine the distance and direction of expected objects
- necessary to express the object location and the location of the vehicle in a common coordinate system
- projected coordinate systems are appropriate (keeping constant lengths, angles, and areas for measurement)
- locations are identified by *x* and *y* coordinates, in a projected coordinate system
- *z* coordinate determining the elevation value can be expressed using a vertical coordinate system
- vehicle location provided by the GNS technology or determined using an odometry system using collaboration with some of automatic train control or automatic train operation systems
- in order to convert the odometry information to the x, y, z coordinates, spatial description of the track guidance required



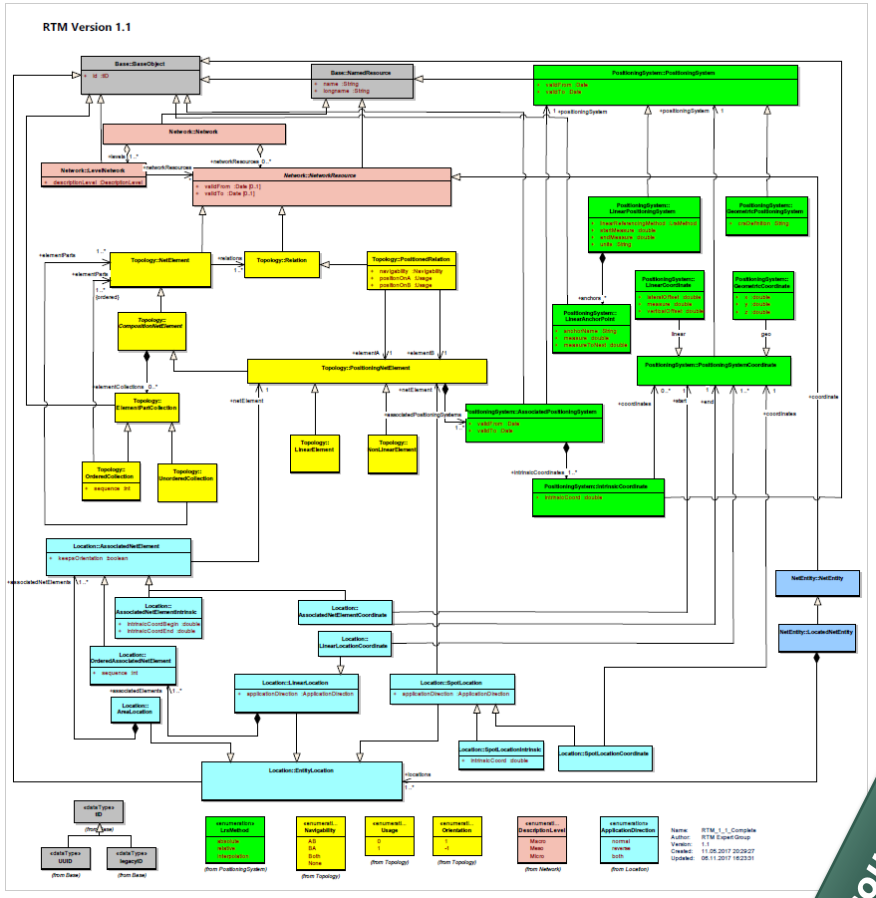
VEXA AND AVV POSSIBLE COOPERATION

- AVV is the instance of ATO used in the Czech Republic developed during the 1990s
- provides automatic driving for acceleration, cruise control and braking to control speed
- uses the infrastructure data description to the extent necessary for its purpose (segment profiles)
- VEXA has the possibility to get some infrastructure data directly from AVV
- not needed to include them to the Digital Track Map
- segment profiles do not contain relevant spatial information necessary due to the need of recalculation of coordinates
- necessary to link individual segment profiles with appropriate geographically located elements
- essential also in terms of the infrastructure data localization



RAILTOPOMODEL AND GIS PRINCIPLES APPLICATION

- UIC RailTopoModel initiative aims to unify approaches to modeling railway infrastructure under one generic model
- Multipurpose Railway Infrastructure Model is being developed at the Railway Laboratory workplace at the Czech Technical University in Prague – Faculty of Transportation Sciences based on the RailTopoModel principles
- Digital Track Map represents a field for implementation and further development of this model
- Multipurpose Railway Infrastructure Model allows the user to view recorded data as objects or object classes retaining the form of a relational database
- this allows it to be integrated into the file geodatabase working under the ArcGIS Pro software



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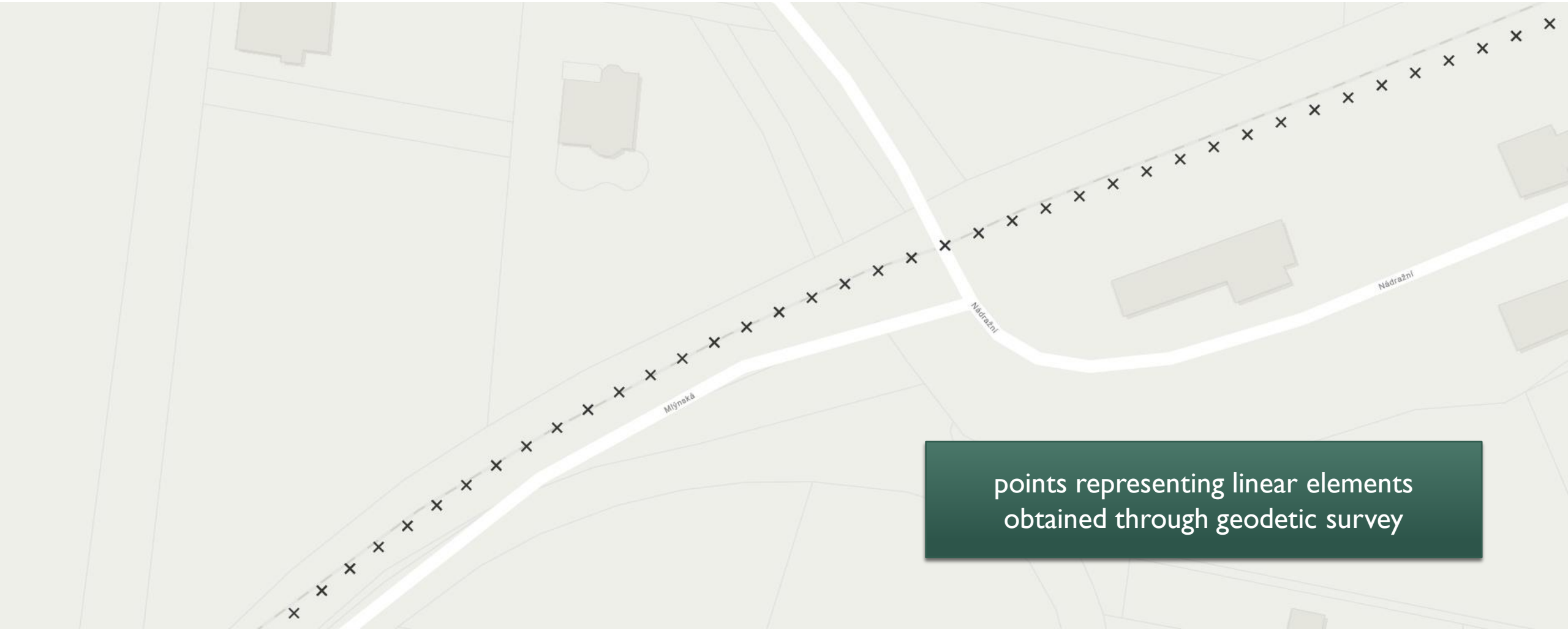
RAILTOPOMODEL AND GIS PRINCIPLES APPLICATION

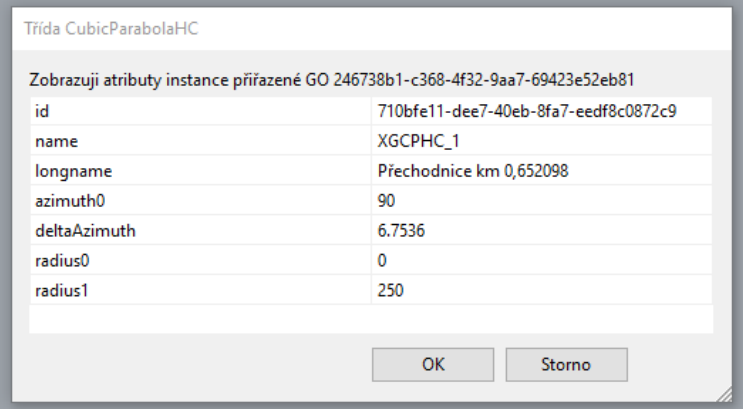
- Digital Track Map network designed using net elements and net relations, respecting the RailTopoModel principles
- micro level of detail with linear elements representing tracks, net relations at nodes representing switches
- net elements are the basis for the location of net entities (objects and properties of the railway infrastructure)
- RailTopoModel defines spot, linear and area location of net entities
- Multipurpose Railway Infrastructure Model distinguishes between physical and functional location, in addition
- ArcGIS Pro allows individual objects to be visualized and handled as GIS features (points, lines, areas)
- physical location corresponds to the localization with the use of the GIS features in geographical space
- functional location expresses the projection into associated point or segment defined within (a) linear element(s)
- main significance of the physical location for the purposes of the railway surroundings objects which have no relation to a particular track (objects to be compared with the detected scene)
- functional location of signals, balises, horizontal and vertical curves, segment profiles, platform edges,…

RAILTOPOMODEL AND GIS PRINCIPLES APPLICATION



points representing linear elements obtained through geodetic survey

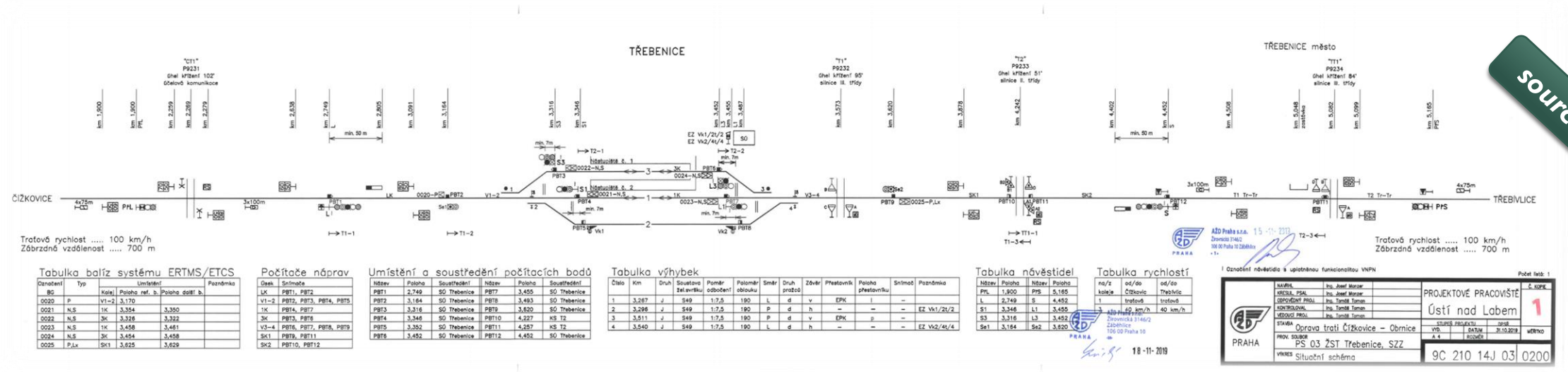
RAILTOPOMODEL AND GIS PRINCIPLES APPLICATION



horizontal curves based on the analytical description of the track geometry

CONCLUSIONS

- article outlined possible approaches to creating the Digital Track Map for the VEXA decision-making system
- introduced basic issues which must be taken into account when defining the map feature classes
- Digital Track Map supposed to be first used on the VEXA system trial implementation on the Čížkovice – Obrnice railway line, also known as Švestková dráha (the Libčeves – Sinutec line section)
- prospective intention to extend the technology to a wider range of vehicles and parts of the railway network



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