1 Introduction
The determination of train runs and train graphs is an important precondition to solve railway specific tasks like the calculation of energy consumption, running times, train configuration or needed locomotive power. For the determination all relevant physical parameters and technical boundary conditions of a train run were implemented in a calculation model called Dynamis. It was developed by the Institute of Transport, Railway Construction and Operation (IVE) to solve the above mentioned tasks.

The Dynamis installation at large railway companies Austrian State Railways (ÖBB) the German Railways (DB AG) or the Hamburger Hochbahn (HHA) was especially adapted for the needs of these companies. Therefore, these installations have an extensive number of program parameters.

Newest features enable the user to consider the pneumatical behaviour of the brake system for a complete train run. On behalf of the like the Austrian State Railways (ÖBB) a Dynamis based energy management is developed to determine the amount of energy needed in a network section, running a proposed time table.

By launching an internet version of Dynamis so called DynamisOnline, IVE offers the possibility to calculate precise train runs, running times and energy consumption world wide. Using this server-based version makes the operating system no longer a restricting factor and support and bug-fixing becomes easier and faster. Consultants do not have to purchase the whole software system, they can rent an amount of time or a number of calculations. Each consultant is able to define trains and tracks on his account, which can be combined for the needed train run calculation. The data of each consultant is saved separately to ensure data safety and is protected by a username and a password. The data files can be up- or downloaded from the server to enable working offline. The e-commerce version of Dynamis offers consultants the possibility to use high sophisticated software for undertaking even smaller projects without purchasing and installing the whole software. Several international railway companies verified the algorithms used in Dynamis. Further developments consider new requirements of these companies and ensure a high level of implemented features.

2 Train run simulation with Dynamis

2.1 Basics
The computer based simulation tool Dynamis was developed since 1980 to calculate precise running times and train graphs of any train configuration on any infrastructure. These functionalities were verified and upgraded on behalf of different European State Railways. So new functionalities were developed to determinate the energy consumption, positions of safety equipment, exact braking curves or to dimension train loads and locomotive power.

The determination of the train graphs in general is based on the engineering mechanics. This means due to the one dimensional movement, a train run can be simulated by considering all forces occurring in the direction of motion. Because of the interaction of the forces with an impact on the train run it has to be divided into positive forces in driving direction and negative ones against the driving direction. Positive forces are the traction force of the locomotives or electrical multiple units (EMU) and in case of running downhill the forces of acceleration due to gravity.

Against these forces all relevant resistances have to be considered. These are forces resulting from the movement of the train, so called train relative resistances and forces interacting from outside the train. Train relative resistances are subdivided into rolling resistance, (e.g. bearings or wheel track interaction), resistances resulting from the moment of inertia during acceleration (lateral or rotating) and general
resistances (e.g. gearing). Forces from outside the train are subdivided into air resistances and track related resistances resulting from the gradient, curvature or points.

The preciseness of the determination of the implemented resistances affects directly the preciseness of the calculated running time and train graph.

The Dynamis application is divided in a train graph calculation tool and a train graph visualization tool called Dynstat. Also all data can be modified with Dynstat.

2.2 Database
For the calculation Dynamis needs as detailed as possible information about the Locomotives/EMU, the train configuration, the exact topography of the track and boundary conditions to control the calculation. All elements of the database can be edited with the train graph simulation tool Dynstat, which is part of the Dynamis Application.

2.2.1 Locomotive data
Dynamis maps the locomotives with the name, length, weight, traction force versus speed diagram and a resistance versus speed diagram. Using a brake force vs. speed diagram in addition to the standard deceleration value a speed dependant braking behaviour of the train can be simulated. Additionally it is possible to set a diagram for electrical brakes, which considers the recuperation of electric energy.

2.2.2 Train data
A train for Dynamis is composed of one or more defined traction units and wagons. Each wagon is described with its position, mass, length, additional load, rolling, air resistance and detailed brake equipment information like friction curves. The traction units are added to the train with their positions and their braking and acceleration efficiency coefficients. The train data implements standard train parameters like the maximum speed of the train and the descriptions of the rolling and curve resistances of the wagons. Each vehicle can be placed as often and at every position in the train as the user demands. The user can define a database of his rolling stock to store also the names of the wagons, their brake equipment, etc.

2.2.3 Track data
The track input needed by Dynamis is based upon the length of each parameter and considers the gradient, switches, electrification, signals, ramps and superelevation of the track, transition curves and curvature. Various resistance formulas can be set interactively, platforms and signals are displayed in the resulting graphics. Each stop has a local stopping pattern, which defines whether the train is halted. The global stopping pattern is defined in the control data to enable calculation of many different stopping patterns.

2.2.4 Control data
The Dynamis control data is needed to define the start and end speed at the beginning and end of the simulation. Other settings for the calculation are, for example, the stopping pattern, protocol-mode and different modes of energy saving and braking strategies.

2.3 Output
Dynamis generates for each simulation graphical information about the train speed, traction forces, energy consumption versus way and time. The calculated train graph can be customised to the users requirements. The resulting diagrams like speed and traction force vs. way or time can be combined and printed. It is
possible to display the front and the end of the train to get information about signals at platforms or the position at kilometres markings.

If detailed data for the calculation of engine temperature or electrical efficiency is known, graphical information about the energy consumption at the pantograph and the temperature during the train run is produced. The graphics can be displayed and printed with the evaluation tool Dynstat.

2.4 Running time calculation

Running times have a big impact on the capacity of the track, attractive for customers and nevertheless for the stability and on time running of the timetable.

To calculate an exact train graph, Dynamis uses different driving modes. The system detects automatically when traction power is needed or when the train has to brake. Implements driving modes are:

- **Acceleration**
  The possible speed is higher than the current speed; the train can accelerate
- **Braking**
  The train has to brake because of speed restrictions or a stop ahead
- **Coasting:**
  In case of not electrified sections or if energy saving driving schemes shall be used
- **Constant speed**
  Maximum speed of the infrastructure is reached
- **Downhill braking**
  If the maximum speed of the infrastructure is reached, but the train still accelerates due to downhill track, this braking is needed.
- **Decreasing Speed**
  The train uses maximum traction power, but the speed still decreases

To simulate each of these modes as exact as possible the Dynamis needs a traction force vs. speed diagram for each locomotive. For braking braking force versus speed diagrams can be used. Each section of the diagrams is described with polynomials and hyperbolas.

Resistances are described with standard formulas (polynomials of second degree) or implementations of railway specific resistances. The system can handle the resistances for locomotives and trains. Track resistances have a big impact on the acceleration of trains. Therefore, even changing gradients underneath a train are considered. The influences of points/switches curves are calculated.

Dynamis uses different braking modes to calculate braking curves as exact as possible. Based on the input information the following modes are used.

- **Constant brake**
  Is used if the braking force vs. speed diagram is not available. The train uses the same deceleration at every velocity.
- **Variable braking**
  Is implemented to change the calculated deceleration, depending on the speed of the train.
- **Braking simulation**
  Calculates a train braking curve with a very high accuracy. Even coasting to a defined stop is possible regarding all speed dependent resistances.
- **Pneumatical brake**
  The input of braking forces of each wagon depending on pneumatics and the braking time. Friction curves of different brake shoe types are considered.
The pneumatical braking can be used by providing a brake force vs. time matrix for each wagon of a defined kind of braking in an interface file. The interface file can be established by editing it manually or using the IVE program TRAIN that simulates the occurring longitudinal forces during a train run.

3 Train run simulation with DynamisOnline

3.1 Basics

Train run simulation with DynamisOnline simplifies the handling of Dynamis. DynamisOnline is a new state of the art front-end of the standalone program system Dynamis. It is available world wide over the internet through an encoded and corticated connection and it is easy to use.

DynamisOnline reduces the editing possibilities to make the system and calculations easier for online users. Also it is not necessary to install any specialised software on the local system. Only a standard internet web browser and a connection to the internet are needed. This makes the operation system no longer a restriction factor. So the user can access his database worldwide and has always the latest software without the need of installing software updates.

Every communication with the user uses the "HyperText Markup Language" (HTML) and the results will send back as an e-mail. The data is transferred securely by the "Secure HyperText Transfer Protocol" (HTTPS), which disables a man-in-the-middle-attack.

Each user belongs to one group. One group has one database. So users of the same group can share their data. Each account is protected by username and password.

3.2 Database

All data are at low-level identical to the corresponding Dynamis data. DynamisOnline reduced the data to the necessary ones to simplify the calculation. Internally DynamisOnline expands its data to standard Dynamis data.

3.2.1 Locomotive data

The locomotive data used in DynamisOnline is at the moment not editable. The user is only able to upload own locomotive data from Dynamis or he can use provided locomotive data by the IVE.

3.2.2 Train data

The train parameters can be edited by using the Train-Editor (see picture 1) of DynamisOnline. It is also possible to up- and download the Dynamis data of a train and edit these files offline.
DynamisOnline reduces the number of parameters to one locomotive and a set of wagons, represented by one wagon. A train with one locomotive and 10 wagons each 10 meter long and a weight of 15 tons is mapped using the locomotive at the front and adding one wagon with the length of 100 meters and the weight of 150 tons at the end. If this accuracy is not detailed enough, upload possibilities for complex train sets are provided.

**Picture 1: DynamisOnline - Train-Editor**

DynamisOnline reduces the number of parameters to one locomotive and a set of wagons, represented by one wagon. A train with one locomotive and 10 wagons each 10 meter long and a weight of 15 tons is mapped using the locomotive at the front and adding one wagon with the length of 100 meters and the weight of 150 tons at the end. If this accuracy is not detailed enough, upload possibilities for complex train sets are provided.

<table>
<thead>
<tr>
<th>Description:</th>
<th>Test Train for WCRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{max}}$ [km/h]:</td>
<td>120.00</td>
</tr>
<tr>
<td>Brake [m/s$^2$]:</td>
<td>0.50</td>
</tr>
<tr>
<td>Trainset resistance:</td>
<td>Sauchoff</td>
</tr>
<tr>
<td>Curve resistance:</td>
<td>0.50</td>
</tr>
<tr>
<td>Locomotive:</td>
<td>1192.00</td>
</tr>
<tr>
<td>Length of trainset [m]:</td>
<td>100.00</td>
</tr>
<tr>
<td>Mass of trainset [t]:</td>
<td>150.00</td>
</tr>
</tbody>
</table>
3.2.3  Track data

The track parameters can be edited by using the Track-Editor (see picture 2) of DynamisOnline. It is also possible to up- and download the Dynamis data of a track.

![Track-Editor](image)

**Picture 2: DynamisOnline - Track-Editor**

A track is divided in kilometre-based sections with speed limit, gradient, radius, electrification, tunnel, name, etc. All this data can be modified for each section. It is also possible to add or remove section easily through the Track-Editor.
3.2.4 Control data

The control data for Dynamis is reduced for DynamisOnline (see picture 3). For a running time calculation you can set a track, a train, start speed, end speed and the stopping pattern. If an e-mail address is provided the result and some additional results will be send to this address.

![DynamisOnline - Control-Data](image)

*Picture 3: DynamisOnline - Control-Data*
3.3 Output

The output of DynamisOnline is divided in two sections. First you get the values of running time, energy consumption braking energy and average speed in the web-browser (see picture 4).

![Picture 4: DynamisOnline - Results of a calculation](image)

Picture 4: DynamisOnline - Results of a calculation

Second, if you provided an e-mail address in the control data, you get an e-mail with the results (see picture 5) and additional a train graph in PDF format (see picture 6) and a detailed protocol in ASCII format.
Subject: Calculation HNbg-HLl.str/wcr.zug  
Date: Fri, 20 Jul 2001 08:57:42 +0200 (CEST)  
From: DynamisOnline <dynas@tuv.uni-hannover.de>  
Organization: Institute of Transport, Railway Construction and Operation, University Hannover  
To: ncaseke@tuv.uni-hannover.de

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track</td>
<td>HNbg-HLl.str</td>
</tr>
<tr>
<td>Train</td>
<td>wcr.zug</td>
</tr>
<tr>
<td>Start speed</td>
<td>80.0 [km/h]</td>
</tr>
<tr>
<td>End speed</td>
<td>0.0 [km/h]</td>
</tr>
<tr>
<td>Stopping value</td>
<td>1</td>
</tr>
<tr>
<td>Running time</td>
<td>2274.5 [s]</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>543.03 [kWh]</td>
</tr>
<tr>
<td>Breaking energy</td>
<td>229.09 [kWh]</td>
</tr>
<tr>
<td>Average speed</td>
<td>85.86 [km/h]</td>
</tr>
</tbody>
</table>

*Picture 5: DynamisOnline - Results of a calculation delivered by e-mail*
DynamisOnline is based on a multi-tier application (see picture 7). For the user it is based on a client-server application from the local computer to the Web-Server at the IVE. The Web-Server runs Apache with special modules to run Servlets and secure connections. The communications between these modules were done by the "Secure HyperText Transfer Protocol" (HTTPS) with "HyperText Markup Language" (HTML). The data input from the user will be provided by using HTML forms.

The Web-Server generates the HTML pages with Java Servlets using the Apache module JServ. Servlets are little Java programs on the server side like normal CGI scripts (Common Gateway Interface). Besides the Web-Server there are two more servers, e.g. the Compute-Server and the Database-Server.

On the Compute-Server the Dynamis application is installed and the physical locomotive, train and track data is stored. The communication between the Web-Server and the Compute-Server is done by the Java API (Application Program Interface) "Remote Method Invocation" (RMI). RMI enables the invocation of methods form another computer like methods of the local computers. This is also done by a client-server solution.

On the Database-Server a MySQL Database is installed. In the Database all data is stored. The communication between the Web-Server and the Database-Server is done by the Java API "Java Database Connectivity" (JDBC). through this client-server connection the Database is queried by standard SQL (Structured Querying Language).

If the user wants to start a calculation, he sends a request with the control data parameters by using the calculation page to the Web-Server, if he has authenticated himself with his username and password before. The Web-Server expands the parameter by connection to the Database-Server and starts the calculation on the Compute-Server. The Compute-Server sends the results back to the Web-Server. The Web-Server responds with an HTML page and an e-mail with the additional results by e-mail back to the user.
4 Conclusion and further development

Dynamis computes a train graph, the running time and the mechanical energy consumption using the exact physical basics. For the simulation the train is mapped as a mass band, therefore, especially the length and the distribution of the masses (load and weight of the wagons) in the train are considered.

The acceleration process is calculated by using exact traction force versus speed diagrams. The braking simulation considers different levels of accuracy. Starting with a constant deceleration value the preciseness can be increased by defining deceleration versus speed diagrams or using a pneumatic interface that contains pressure versus time diagrams and friction curves for the braking equipment of each wagon. Using this interface a simulation of the failure of braking equipment is possible.

Outputs are protocol files and graphics of all train graph relevant parameters. The Outputs can be evaluated using the graphical based tool Dynstat.

DynamisOnline uses the same database, but the graphical internet documents only allow to modify a reduced number of parameters. The graphical outputs and text files are sent by email.
In the near future, IVE plans to develop more features. The main focus is to improve the interface between the user and the web-front-end. For example the HTML forms to built up locomotives and an automatic assignment of the chosen language or other settings for each user will be realised.

Further advancements are the online consideration of additional DYNAMIS program parameters. The simulation of energy saving driving modes and the implementation of international accepted roll- and curve resistances should be mentioned here.

Another focus is to enhance the number of plots. Users will be able to choose between different kinds of plots to be sent by email.

5 References

• Ralph Anthes, Lars Monecke, Lars Müller, "DynamisOnline - train graph simulation via the internet", Proceedings: 7th International Heavy Haul Conference 2001, Brisbane, Australia


• Lars Monecke "Entwicklung eines Verfahrens zur interaktiven Fahrzeitrechnung mit Hilfe des Internet", Thesis 2000, University of Hannover, Hannover (only in German, not published)