



## Green Track – Environmental Performance Evaluation for “Green” Tramway Superstructure

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### Abstract

In view of the construction of new tram lines in Vienna and due to unsatisfactory experiences with existing green track sections, Wiener Linien launched a project, funded by the Austrian Research Promotion Agency (FFG), to develop a new Viennese green track design. During conception particular attention has been paid to the ecological aspects of tram tracks in general and green tracks in particular. Therefore an environmental performance evaluation for different tram track concepts has been performed.

The special features of the new green track are slow growth, self-sufficiency and adapted turf. Draught and salt resistant flowering plants of local origin are added to commercial mixtures for dry meadows. Three different seed mixtures have been selected and are currently tested on a small section of existing green track. The development of the plants is observed for about a year before the seed mixtures are deployed on the green track sections of the new tram lines. Favouring grasses and forbs that are indigenous in Austria is one key-aspect to meet the expectations of developing an eco-friendly new green track with low maintenance demands and economic life cycle costs.

*Keywords: tram, green track, environmental benefits, adapted local seeds, environmental performance*

### 1 Introduction

The public is very fond of green tracks; they are believed to be optical highlights [5] and to cause little noise [1]. Some other important reasons are: reduction of sealed areas, improvement of urban climate by regulating the rain water regime, and reducing dust [7], [8]. The public often asks for more green tracks and politics (sometimes) accept this [1].

The aim of the Green Track project is to map the requirements of a modern, site specific green track and to analyse how to meet the challenges of sustainable

maintenance. It follows a new approach to develop an alternative to already existing types of green track by introducing a blend of domestic plant species, which are perfectly adapted to the local environmental conditions.

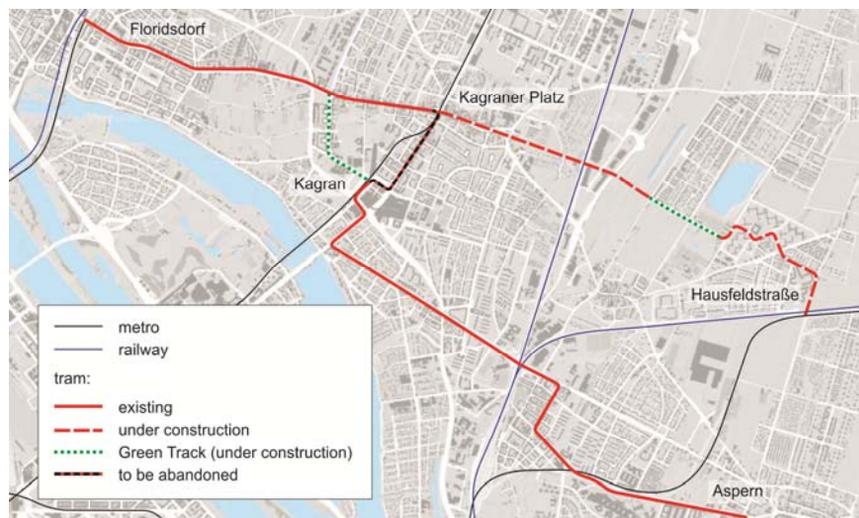
## 2 Reasons for the “Green Track” Project

### 2.1 New Tram Lines for Vienna

For the first time since May 1996 and after a number of line closures, Vienna’s tram network will be expanded in 2012 and 2013. As a result tram line 26 will partly follow a new route, whilst the old route will be operated by the relaunched line 25.

The new tram line 26 will connect Strebersdorf and Hausfeldstraße via a 4.5 km extension. The new line will leave the existing line at Kagraner Platz, then cross the Ostbahn railway line and Gewerbepark Stadlau on elevated track and follow Oberfeldgasse eastwards towards the terminal stop at Hausfeldstraße. About 3.5 km will be dedicated tram track, 1 km of which will be built as green track. Operation is expected to start in October 2013.

Almost one year earlier tram line 25 will start operation between Floridsdorf and Aspern. Line 25 will leave the existing track at Josef-Baumann-Gasse, then pass Tokiostraße and Prandaugasse before re-joining the existing line at Kagran and following it all the way to the terminal stop. A short section of track connecting Kagraner Platz and Kagran will be abandoned once this new branch connection and the extension of line 26 to Hausfeldstraße is in service.



**Figure 1.** Route of lines 25 and 26 in Donaustadt, Vienna.

Construction of the extensions started in January 2012. In total there will be about 2 km of new green track, for which a new green track superstructure had to be developed [10].

## 2.2 Conditions on Existing Green Track Sections in Vienna

Wiener Linien, Vienna's public transport operator, has run only two green track sections for more than 20 years [4]. One of them, situated in the rather quiet and green surroundings of Lainz, is still in a good shape, the other one, alongside Vienna's most frequented road, shows very low plant cover. The unsatisfactory condition of the latter sparked the desire to develop a new green track layout with optimised vegetation.



**Figure 2.** Existing green track in good (left) and unsatisfactory shape (right).

The green track at Lainz is dominated by (mostly seeded) grass species, whereas the “ugly” green track is dominated by immigrated herbs and forbs. Above ground there are 346 grams of oven-dry plant mass per m<sup>2</sup> for “good” green (lawn) track and 67 grams for “ugly” green track with very sparse plant layer.

**Table 1.** Relative portions of plant groups on a “good” green track and a highly strained (“ugly”) green track with respect to their origin (immigrated – possibly seeded) in Vienna.

green track appearance	relative portion (%)						
	grasses		herbs/forbs		seedlings	moss	plant litter
	seeded	immigrated	seeded	immigrated			
“good”	40.4	0.3	10.5	6.8	< 0.1	1.2	40.8
“ugly”	6.2	11.0	27.7	32.0	0.0	0.1	23.0

## 2.3 Ecological Aspects of Tram Track

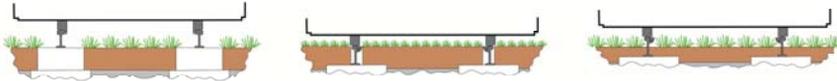
Ecological aspects are of rising importance in railway construction. Public tenders, however, have frequently been reluctant to implement them due to missing criteria for environmental evaluation. Therefore some environmental performance indicators for tram tracks in general and green tracks in particular will be defined in the process of developing the new “Viennese green track layout”.

### 3 Green Track in Europe

In the past few years, green track has become a common sight in tram networks. About one in three tram networks in Europe includes green track sections, albeit to a very different extent. Rather new tram networks that were built in the past two decades tend to consist of green track to a much greater extent than tram networks that have evolved over time.

For example Barcelona's tram network, inaugurated in 2004, totals 18.7 km of green track, equalling 64.5% of the network. In France most of the tram networks recently launched feature about 20% of green track or more. In Freiburg, the "German capital of green track", the percentage of green track is more than 45%, and still rising. Of course the larger and the more urban tram networks are the higher is the demand for covered track, especially where space is restricted. Still up to 10% of green track are quite usual in some major German cities. However, in Vienna currently just about 1.5 km are green track, that is about one percent of the network [1].

Green track exists in various designs. The most common distinctive features are the kind of plants used – different species of grass, herbs and forbs or Sedum – and the vertical spacing between top of rail and vegetation, the latter usually specifying whether to use Vignol rails or grooved rails. High vegetation is characterized by a vertical spacing of just two or three centimetres (or less), low vegetation by a vertical spacing of about 10 centimetres or more. In between, the vegetation layer is more or less in an intermediate position.



**Figure 3.** Schematic diagram of the limited space between the tram underbody and the vegetation layer, depending on the vertical spacing between top of rail and vegetation. (From left to right: low vegetation, high vegetation and intermediate vegetation.)



**Figure 4.** Illustration of the extremely limited space between the vegetation and the underbody of Strasbourg's Eurotram (left). In Bremen the more distinctive vertical spacing between top of rail and vegetation is clearly visible and resembles low vegetation (right).

The vertical spacing between top of rail and vegetation is of special importance because it determines the maximum plant height considering that the underbody of low-floor trams is only few centimetres above the top of rail. Another distinctive feature is whether long sleepers or rail chamber filling profiles are clearly visible along the track, significantly influencing the visual beauty of the green track.

Each green track design has both advantages and disadvantages. Maintenance activities such as trimming have to be performed more often with high vegetation, but trimming with large maintenance equipment might be easier. The need for artificial irrigation depends on the climatic conditions and the plants used, the former also determining if winter service has to be considered. With high vegetation (and substrate) a shear-off by snowploughs is more likely than with other green track concepts. Emergency vehicles are allowed to run on some green tracks, though this most likely causes damages. The concept to create a green track that can – in case of emergency – also be used as a route for ambulances or other cars, is based on the idea to construct a compacted gravel bed and seed this with slow-growing gravel turf [2]; however the weight of the vehicles and the frequency of their trespassing is an automatic “plant killer” [6]. Overall it seems that intermediate vegetation is a good compromise between the appearance of green track and cost-effective maintainability, but depending on regional and political preferences every public transport operator has to specify its own “ideal” green track. Sometimes even safety considerations are decisive; overtopping rails could trip up inattentive pedestrians.

In Europe the majority of public transport operators favour green track with high vegetation. This is probably due to its visual advantages, as the beneficial influence of green track on shaping the cityscape is among the most frequently mentioned reasons for building green tracks.



**Figure 5.** Perfect green track (left) in Mulhouse and the damaged green track at a terminal stop (right) caused by (too) long idle time and multiple mechanical impacts by trespassing passengers.

Green track maintenance costs are often believed to be higher than those of conventional covered tram tracks. In fact they are very dependent on the track design and consequently also on the necessary maintenance activities. Green lawn tracks in summer-dry areas for instance – as in the Mediterranean basin or in Pannonian south-eastern Europe – need high amounts of water. Therefore these traditional green tracks can be very costly in maintenance. Consequently

maintenance costs of the different green track concepts range from significantly less to double the amount of costs for covered track. In this context also the number of trams running on green track per day – usually between 100 and 200 trams, but a lot more on heavily frequented sections – and their impact on maintenance activities should not be disregarded. In the area of terminal stops green track is unsuitable wherever trams spend a lot of idle time, as plants will not grow properly without sufficient daylight.

## **4 New Viennese Green Track**

### **4.1 Scope and Objectives**

The aim was to create a green track that meets all the urban challenges, combining a minimum of efforts in maintenance with the best ecological performance.

Thus the objective was the adaption of the hitherto prevailing state of the art (in Vienna) – an English lawn, causing costs for frequent mowing and watering – and creating a new type of slowly growing, self-sufficient and adapted turf. More draught and salt resistant flowering plants of local origin should be added to commercial mixtures for dry meadows. Subsequently their success for the use on green tracks should be monitored.

### **4.2 Background and First Lessons Learned**

#### **4.2.1 What challenges do plants meet on a track?**

Physical and chemical soil characteristics (grain size, water holding capacity, compaction by trampling or vehicles, immission of heavy metals and/or salt from adjacent streets) can differ widely from site to site, but especially from natural soils. The open, mostly unshaded habitat is characterized by strong irradiation and heat; the frequently passing trams cause steady wind. This enhances the danger of draught, and it hampers the development of high flowering stems of the plants. The vehicles may also influence the pollinating insects that are necessary to guarantee on-site seed production of the flowering (dicotyledonous) plants in use. Due to the world-wide production and trade of the typical turf grasses in use, very often those species cannot cope with the local climatic conditions under stress.

So it is of crucial importance to choose indigenous seed material of regional species equipped with the following traits: slowly growing, short height of flowering stems, low water and nutrient demand as well as a reasonable shoot-root ratio. Resistance against salt and/or heavy metals and a certain trampling resistance (for instance necessary near tram stops or at street crossings) is also advantageous.

#### **4.2.2 Winter problems**

Apart from a considerable immission of salt from the streets, serious problems arise during periods with permanent snow cover. When the vegetation layer is at one level with the track, winter services can cause enormous damages in the

vegetation layer; this results from the steady accumulation of dead plant material on the soil surface within some years; thus the soil surface is elevated above the track, and the snowploughs eliminate not only the snow, but also plants and some centimetres of soil from the tracks, causing permanent costs for re-seeding every spring and spoiling the visual impression of the green track.



**Figure 6.** Damages by winter service: Grass sods peeled from the track and dumped alongside the track (left). View of the test field at Lainz before re-cultivation (right).

### 4.3 The Test Field at Lainz

Before the application of the new Viennese green track for the first time in Prandaugasse, the concept had to be tested. Therefore a test field was set up at the southern end of the existing green track at Lainz.

#### 4.3.1 Preparations

Previous to the installation of the test field at Lainz, phyto-sociological relevés, accompanied by micro-meteorological and pedological measurements were made at the test site. On the same tram line, but a few 100 metres outside the test site, wind speed (raised by trams passing by) and above ground plant mass were assessed. The meteorological data comprise air and soil temperature, soil moisture and radiation between 11 a.m. and 2 p.m. on a hot day in July. Soil samples from the uppermost 10 centimetres of soil were taken in autumn and spring and analyzed with regard to N, P, K,  $C_{org}$ ,  $C_{tot}$ , Ca, Mg, Na, Cl,  $SO_4$ , electrical conductivity and pH.

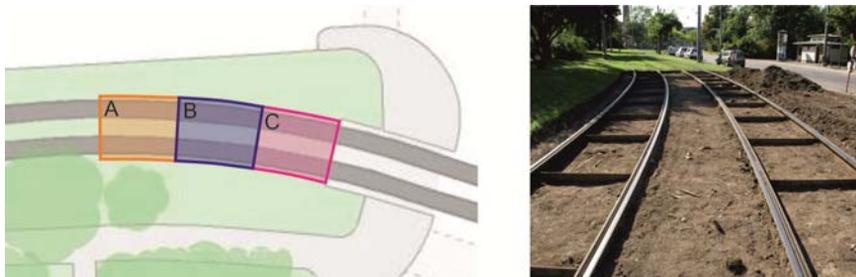
#### 4.3.2 Vegetation

Currently three seed mixtures are tested, one consisting of moderately draught resistant and/or salt tolerating grasses and forbs; one for very dry, sunny sections without salt immission, and one for partly shaded sections; the latter is enriched by forbs growing at forest glades and slightly shaded meadows. Almost all forb seeds for the three mixtures were hand collected, and some of the grasses as well. Except for *Cynodon dactylon*, the Bermuda grass, all grasses and forbs are indigenous in Austria.

#### 4.3.3 Development on the test field

In August 2011 soil material was excavated and refilled roughly up to five centimetres under the top of rail in an area of about 100 m<sup>2</sup>. Seeding was

performed by AREC Gumpenstein on 1<sup>st</sup> September 2011. Additionally to the seeding, some pre-cultivated plants of *Cynodon dactylon*, *Potentilla* spp., *Centaurea jacea*, *Prunella vulgaris*, and *Malva sylvestris* were planted one day after the seeding, their development is also monitored.



**Figure 7.** View of the test field during excavation (right) and schematic diagram of the test field (left). The seed mixture for partly shaded sites is tested in sector A, the dry meadow mixture in sector B and the salt tolerant mixture in sector C.



**Figure 8.** The test field a few days after seeding and planting in September...



**Figure 9.** ...and in late December 2011.

Due to an extremely long dry and hot period after seeding in September, regular watering was necessary for the germination phase despite the generally low water demand of the seeded plants. The development of the herbs and forbs was nevertheless satisfactory; the grass species in the dry meadow section showed

an unusually long germination delay, but in November the grasses there started to germinate, too. One reason for this delay is certainly the uneven concentration of the adhesive (Soil Star 100P) that had to be used because otherwise the wind of the passing trams would have blown away the seeds. The “glue”, a relatively new product, was very difficult to dilute and formed a hard crust in the first centimetre of topsoil. Apart from the germination delay the development on the test field is satisfactory.

#### 4.4 Future Green Track Layout

Although the green track on the test field was built with intermediate vegetation (because it would not have been possible to completely rebuild the track at the test site), the green track for lines 25 and 26 will be built with low vegetation, as requested by Wiener Linien. In particular technical criteria for both economical and fast construction at a high level of quality as well as proper and safe tram operation at low maintenance demands are decisive factors. These are for instance accessibility and replaceability of components, avoidance of leakage currents (and corrosion) and the possibility to straightforward re-establishment of the position and level of track.

## 5 Environmental Performance Evaluation

One fundamental objective of the project is the elaboration of an assessment model to evaluate the environmental impacts of tram construction projects by defining “environmental performance indicators”. Such indicators are for example “use of resources” or “emissions”, comprising also the technical evaluation of noise emission, and the cost comparison (life cycle costs) with other track systems. For the evaluation of the noise emission, measurements on the existing track with high vegetation and on the new track with low vegetation will be performed.

Within the project four different tram track concepts are compared: Ballasted track, conventional covered track and two green track designs (low and high vegetation) with optimized plant species composition.

**Table 2.** Comparison of material requirements (illustrated as aggregated material categories) to build one kilometre of track (in absolute and relative figures). Concrete includes aggregates, mineral material summarises all kinds of ballast, gravel, sand and rock. Green track (a) is with low vegetation, green track (b) is with high vegetation.

track concept	concrete		min. material		steel		plastics		substrate		total (tons)
	t	%	t	%	t	%	t	%	t	%	
<b>ballasted track</b>	793	7	10805	91	288	2	9	<1	---	---	11895
<b>covered track</b>	7481	93	190	2	286	4	47	1	---	---	8004
<b>green track (a)</b>	3578	36	3466	35	370	4	14	<1	2403	25	9831
<b>green track (b)</b>	2071	26	2364	30	337	4	13	<1	3105	40	7890

For each of the four mentioned tram track concepts material requirements have been analysed and evaluated with regard to cumulated energy demand, green house gas emissions and recyclability.

Further evaluation analyses the life cycle costs of the different types of tram tracks. The monetary assessment of economic investments is a common practice in the private and public sector. Some decisions can lead to a short-term success, whilst long term effects are not taken into account. This harbours substantial financial risks in the future. Life Cycle Analysis offers the possibility of performing all-inclusive cost considerations for investments, revealing the costs for a life-long service of the product. Especially when comparing very different track concepts, such a life-time approach is very important, as some cost drivers are likely to appear at different ages of the tracks [9].

In the end the life cycle analysis allows to trade off the environmental benefits (illustrated by the environmental performance indicators) of green track (and the disadvantages of other track concepts) against possibly higher or lower life cycle costs, thus enabling (future) decision-makers to choose from a number of track options after estimating more than costs only.

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