Guidelines, State of the Art and Integrated Assessment of Weed Control and Management for Railways

"HERBIE"

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uic INTERNATIONAL UNION OF RAILWAYS

HERBIE – GUIDELINES, STATE OF THE ART AND INTEGRATED ASSESSMENT OF WEED CONTROL AND MANAGEMENT FOR RAILWAYS

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UIC Guideline for Integrated Vegetation Management

PART A

Final version

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Content

1. Introduction

The “UIC Guidelines for integrated vegetation management for sealed/ unsealed surfaces and for the railway track area” has 3 objectives:

1. It puts the integrated vegetation management of railway companies and the herbicide use within this context into perspective.
2. It shows that the vegetation management of railways and especially the use of herbicides are embedded into an overall environmental strategy of railway companies aiming at improving the environmental performance and into a legal context on EU, national and local levels.
3. It demonstrates that railways are using herbicides in a responsible way governed by clearly defined principles, guidelines and quality standards and that systematic effort is put into the further reduction of the total amount of herbicides used and the areas treated.

Integrated vegetation management for railways and herbicide use

Railways are important property owners managing a great variety of different types of areas – unsealed surfaces such as embankments, protective forests, meadows; sealed surfaces such as roads, pathways, station platforms and track area with different needs and requirements for vegetation control. Vegetation growth may have positive and negative impacts depending on the type and function of these areas. On unsealed surfaces vegetation has typically positive impacts – it stabilizes the soil of embankments, supports biodiversity and has aesthetical value. The main requirement here is to support healthy local plant populations which do not interfere with the obligation of safe railway operation. These areas often form a valuable part of the landscape and they serve as important greenways, biological migration corridors and habitats for rare species.

On sealed surfaces and in the track area vegetation growth is not desired since it can destabilize supporting structures of jeopardize the safe and reliant performance of railway systems.

Railways are well aware of their responsibility towards safe operation on the one side and optimum environmental performance on the other side. Therefore they have developed dedicated and transparent guidelines and implemented integrated systems for vegetation management which comprise a great variety of methods and techniques – from constructional and mechanical to chemical, thermal and biological ones, depending on the area of application and the specific requirements with regard to railway operation. In contrast to agriculture, railway companies do not use herbicides for plant protection but for guaranteeing the safe and reliable operation of railways, which is a legal obligation for all railway companies.

The amount of herbicides used within the framework of vegetation control for railways is very small. On the national and European scale, railways have a share of less than 0.5 % of the herbicide market whereas agriculture is by far the biggest player. The overall amount of herbicides used by European railways is about 400 t of active substances p.a. in comparison to about 130,000 t of the total annual sales of active substances in Europe.

Total amount of herbicides used for railways has been already significantly reduced over the last 20 years. Today less than 50 % of amount used in the 90 ties is applied and the railways

are working hard on further reductions.

Herbicide use for railways is mostly restricted to the track area and all substances have to be approved for the specific use by the national authorities It is only applied according to strict regulations or not applied at all in areas under special protection – e.g. water protection areas or nature reserves. Vegetation control on sealed and unsealed surfaces of railways such as paths, roads, station platforms, loading zones (sealed surfaces) and embankments, meadows, protective forests (unsealed surfaces) is already mainly based on mechanical methods such as mowing and mulching.

For the railway track area there is currently no alternative to herbicide use which ensures the same level of safe operation and operational performance on the one side and is highly cost efficient and environmentally friendly on the other side. All alternatives for the track area tested and investigated so far lead to lower safety levels, negative impacts on the operational performance due to difficulties with integrating the time schedules for treatments into the tight railway schedules, are about ten or more times as expensive as herbicide treatments, are much more energy intensive and often also have negative impacts on the environment.

Nevertheless, the railways are searching for alternatives. New methods and technologies are investigated and new development for existing technologies as e.g. thermal and electrical methods are thoroughly evaluated.

A topic of increasing importance for railways is the control of invasive alien species (ias like invasive plants or fungi) since they have the potential to damage constructions and facilities, can overgrow signals and operational devices, boost maintenance efforts, threaten biodiversity and can constitute health risks e.g. due to their allergenic potential. The typical treatment consists of manual cutting, herbicides are only used as an exception in special cases. Since ias dispersal is increasing and manual treatment is cost and labor intensive, railways also look for alternative treatment methods such as biological control and e.g. start to include ias-management into the tenders of construction works.

2. General Principles of Vegetation Control

2.1. REGULATORY AND LEGISLATION FRAMEWORK FOR WEED CONTROL AND MANAGEMENT

Vegetation control for unsealed surfaces, sealed surfaces and track areas on the premises of railway companies is governed by legislation and regulation on different levels:

1. European level
2. National level
3. Federal level (if applicable)
4. Regional and Local level

All applicable legislation and regulation is derived from four obligations for railway companies, the obligation of

1. Safe and reliable railway operation
2. Preventing the endangerment of customers and personnel
3. Protecting the environment
4. Preventing negative impacts on neighbouring property

Vegetation control for railways generally governed by the Precautionary Principle. This principle is one of the fundamental principles of the European Union governing policies related to the environment, health and food safety. The **characteristic feature of the precautionary principle is risk prevention in the face of scientific uncertainty**. The precautionary principle aims to prevent harm before a hazard has come into existence. The precautionary principle is detailed in Article 191 of the Treaty on the Functioning of the European Union.

The precautionary principle is related to three specific principles:

- the fullest possible scientific evaluation, the determination, as far as possible, of the degree of scientific uncertainty;
- a risk evaluation and an evaluation of the potential consequences of inaction;
- participation of all interested parties in the study of precautionary measures, once the results of the scientific evaluation and/or the risk evaluation are available.

The environmental performance of railway companies regarding integrated vegetation control and management can be improved significantly by implementing the precautionary principle within the framework of risk assessment and management (a) risk evaluation, (b) risk management and (c) risk communication.

Within the context of integrated vegetation management of railways a great variety of methods and technologies is applied – constructional, mechanical, biological, chemical, thermal and electrical. Within this spectrum, the chemical methods which are based on the application of herbicides are the ones which have a tight legislative and regulative framework.

On European level, applicable legislation is defined by directive 2009/128/EC of the European Parliament and of the Council of 21st October 2009 **"Establishing a framework for Community action to achieve the sustainable use of pesticides"**. This Directive sets out a framework to achieve a sustainable use of pesticides by reducing the risks and impacts of pesticide use on human health and the environment and promoting the use of integrated pest management and of alternative approaches or techniques, such as non-chemical alternatives to pesticides. The Directive stipulates that these provisions do not prevent Member States from applying the precautionary principle in restricting or prohibiting the use of pesticides in specific circumstances. The directive requests the Member States of the European Union to introduce National Action Plans while setting quantitative objectives, measures and timelines to reduce risks for human health and environment (Article 4 of the Sustainable Use Directive). The Member States had to submit their respective National Action Plans to the EU Commission and the other Member States of the EU by end of 2012.

On national level, the legislation and regulation framework for vegetation control is defined by

- **National railway legislation focusing at safe and reliable operation of railway services**
- **National action plans for sustainable use of pesticides** with regards to directive 2009/128/EC
- **National Civil Codes** defining obligations to prevent negative impacts on people and property of third parties
- **National environmental protection laws** defining obligations with respect to the protection of soil, water, air, forests, biodiversity, nature in general as well as national nature preserves.

On local (and federal) **level**, the legislation and regulation framework for vegetation control is defined by

- **Local (or federal) environmental regulation** with respect to the protection of soil, water, air, forests, biodiversity, as well as local conservation areas.

2.2. MANAGEMENT PROCESS FOR VEGETATION CONTROL

An important success factor for an efficient vegetation control is the establishment of a management process for vegetation control covering 5 phases:

1. **Inspection** of status quo of vegetation growth on the different surfaces and structures
2. **Assessment** of the status of vegetation growth and selection of adequate vegetation control measures by experts
3. **Planning and application** of the selected vegetation control measures
4. **Evaluation** of the success of the vegetation control measures by qualified personnel
5. **Documentation and communication** of performed vegetation control measures.

Inspection

The first phase of the management cycle – inspection – aims at determining the status quo of vegetation growth on the different types of surfaces by qualified personnel as basis for the assessment.

Assessment

The second phase covers the detailed assessment of the status of vegetation growth by internal or external experts comprising (1) the identification of the need for vegetation control measures, (2) the selection of the appropriate vegetation control measures taking into account all relevant legal, technical and operational requirements and aspects (3) Incorporation of all preventive measures or direct treatments performed before for the respective area. This can include the determination of appropriate preventive measure for the future in order to avoid or minimize direct treatment.

Planning & application

The vegetation control measures determined in phase 2 are planned and implemented in phase 3. If measures based on herbicide use have been selected, applications are submitted to the relevant authorities in order to receive the required permits. These applications have to justify the need for herbicide use and have to conclusively establish the lack of viable alternatives. Vegetation control based on herbicide treatments have to be carried out by qualified and certified personnel. The qualification comprises knowledge with regard to responsible handling of herbicides as well as knowledge with regard to the appropriate application techniques. This personnel has to fully understand and respect all requirements and obligations arising from EU directive 2009/128/EC and the respective national action plan for the sustainable use of pesticides. The railway companies are responsible for guaranteeing high quality standards for the application of herbicides on their premises. This can either be ensured by constant qualification of own personnel or by long-term agreements with experienced contractors where the compliance with high quality standards is an integrated part of the contracts. Furthermore, it requires regular quality monitoring in both cases. The responsible handling of herbicides comprises not only the treatments and application techniques as such, but also the limitation of the amount of herbicides to the absolutely necessary level as well as professional cleaning of equipment and disposal of residual amounts.

Evaluation

Phase 4 – evaluation – covers the rating of impact and especially success of the treatment and the formal approval of the achieved results by experts. The personnel responsible for the evaluation possess the required knowledge and experiences for the legal, technical and operational aspects of vegetation control and are qualified on a regular basis. This includes acquiring knowledge about the current status of development of active substances, technologies and applications methods as well as good and best practices.

Documentation and communication

The final phase consists of the detailed documentation of all implemented vegetation control measures (type, size and location of treated area, amount of active substances, application technology, used resources) and their respective results and impacts as the basis for

- Evaluation of the mid- and long-term results and impact of vegetation control
- Reporting and documentation of herbicide use
- Establishing the benefit of vegetation control and justifying the need for vegetation control
- Communication to external and internal stakeholders.

3. Guideline for Vegetation Management on unsealed Surfaces

3.1. CHARACTERIZATION OF UNSEALED SURFACES

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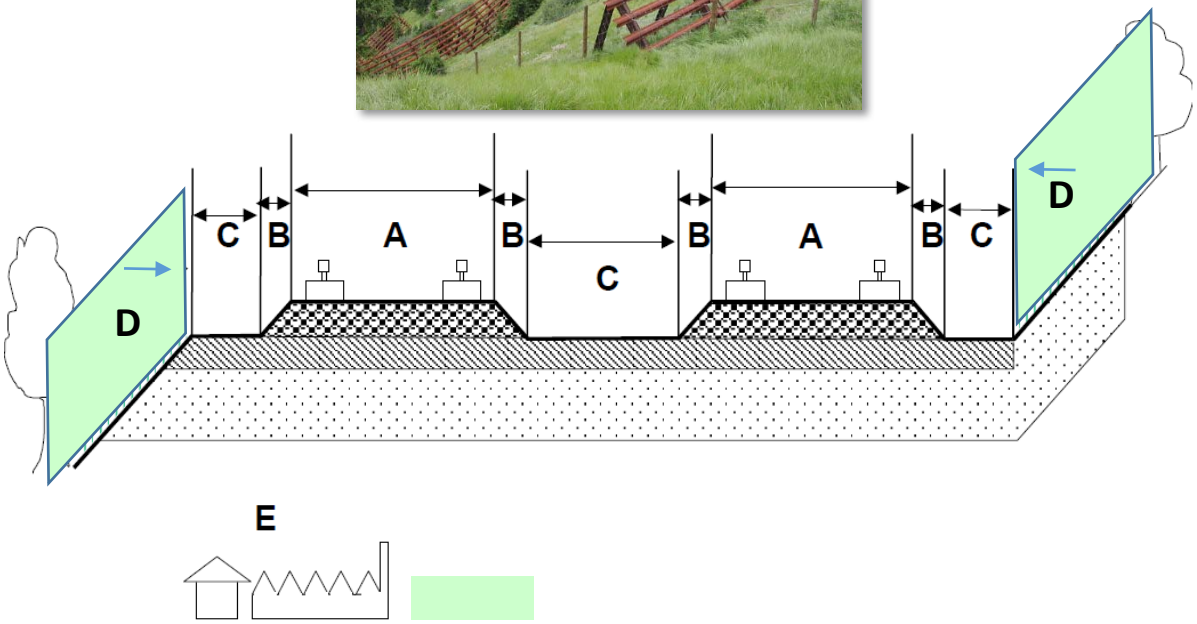

Figure 1: Areas of Application for Vegetation Control Methods on unsealed surfaces – Areas D and unsealed parts of areas E

The unsealed surfaces relevant for vegetation control comprise the embankments (Area D in figure 1) and the unsealed areas outside the tracks and not directly linked with the tracks (unsealed part of Area E). Examples are embankments, unsealed paths, areas around substations, unsealed areas around railway stations, forest land, meadows, unsealed fallow land.

3.2. SPECIFIC NEEDS AND REQUIREMENTS FOR VEGETATION CONTROL MEASURES FOR UNSEALED SURFACES

Vegetation on unsealed surfaces can have positive and negative impacts. Positive impacts are connected with the stabilization of surfaces and especially the prevention of soil erosion caused by vegetation growth, negative impacts are connected with potential hazards for railway operation and safety of people. Needs and requirements for vegetation control on unsealed surfaces are depending heavily on the concreate type and use of the area concerned as well as on its location and exposition. This results in specific operational and technical requirements. The main focus for vegetation control regarding the positive impact of vegetation growth is to maintain vital, healthy and robust vegetation with high biodiversity on all unsealed areas where vegetation growth is desired.

The need for vegetation control for unsealed surfaces arises from the obligation of safe and reliable railway operation and the obligation of preventing the endangerment of customers and personnel as well as negative impacts on neighbouring property. With respect to these three obligations, the negative impacts of vegetation on unsealed surfaces and the resulting requirements for vegetation control can be divided into five categories (a) operational safety & reliability and technical performance, (b) structural safety and integrity of buildings and facilities (c) occupational safety and safety of third parties and (d) safety of neighbouring property:

(a) Operational safety & reliability and technical performance
- **Risk of accidents and injury and/or reduced operational performance and disruptions caused by**
  - **trees falling on tracks and overhead lines**
  - **malfunctioning of electrical equipment** due to plants growing too close to trackside equipment and facilities
  - **restricted visibility of signals** caused by high growing plants close to the track.
- Requirements: Maintain minimum distances to track area, equipment and facilities and keep healthy plant populations.

(b) Structural safety and integrity of buildings and facilities
- **Damage to buildings and structures and reduced integrity due to vegetation impacting parts of the drainage system**; requirement: Prevent growth of vegetation in and close to the drainage system.

(c) Occupational safety and safety of third parties
- **Risk of injury on unsealed paths** due to low branches and roots; requirement: Prevent growth of roots and low branches on paths.

- **Health risks for personnel and third parties due to pest infestation** (e.g. oak egger), requirement: measures for pest control.

(d) Safety of neighbouring property

- **Damage to neighbouring property** caused by falling vegetation, vegetation impacting drainage, pests and invasive species propagating from unsealed surfaces (railway property).

3.3. VEGETATION CONTROL MEASURES (WITH REFERENCE TO EU-DIRECTIVE 2009/128/EG APPENDIX III)

Preventive measures

Regarding the positive impacts of vegetation growth on unsealed surfaces such as embankments the main focus of prevention is to allow and **maintain a vital, healthy and robust vegetation** on these surfaces. A key point in this respect is the development and maintenance of locally suitable and sustainable vegetation populations.

Regarding the negative impacts of vegetation growth on unsealed surfaces (see chapter 2.2) the main focus of prevention is on **continuous monitoring of the status quo of vegetation growth** and the **assessment of its impact** by qualified personnel.

Treatments

In accordance with the precautionary principle, **vegetation control on unsealed surfaces should be generally based on non-chemical methods**. These comprise of mowing and mulching for weeds, herbs and shrubs and cutting for trees and tree-like shrubs.

The only **exception** from this principle **is the chemical treatment of certain pests or invasive neophytes if alternative methods are not successful**. These exceptions **require special permits** issued by the relevant authorities and have to be carried out by experienced and qualified personnel. Based on the **assessment of type and intensity of infestation** and using **decision support** provided e.g. by internal directives and guidelines, appropriate chemicals for treatment and methods of application are selected and communicated to the authorities. It is important that **the chemical treatment is limited to the absolutely necessary level**. If repeated application is needed, an **appropriate resistance management** has to be implemented. **A detailed documentation of all vegetation control measures based on herbicides** (time & location, active substances, dosage, applied technology etc.) **is mandatory**.

4. Guideline for Vegetation Control on sealed Surfaces

4.1. CHARACTERIZATION OF SEALED SURFACES

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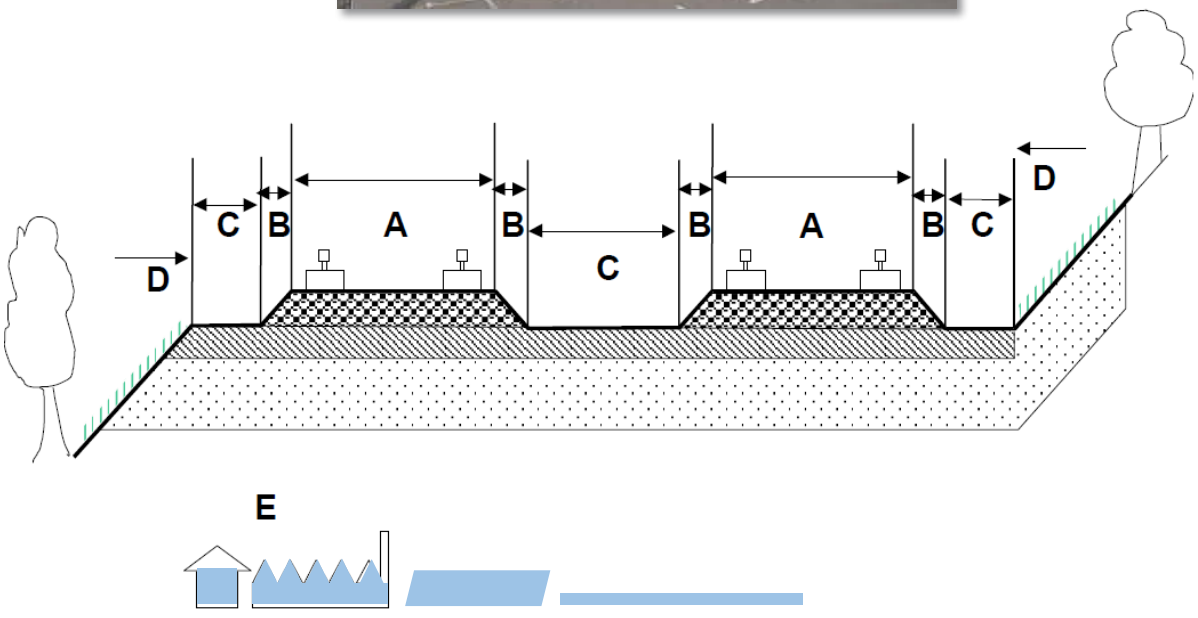

Figure 2: Areas of Application for Vegetation Control Methods on sealed surfaces – Areas E

Sealed surfaces relevant for vegetation control comprise the sealed areas outside the tracks and not directly linked with the tracks (sealed part of Area E in figure 2). Examples are sealed streets, paths and driveways, loading areas, storage areas, parking lots, station platforms.

4.2. SPECIFIC NEEDS AND REQUIREMENTS FOR VEGETATION CONTROL MEASURES FOR SEALED SURFACES

The need for vegetation control for sealed surfaces arises from the obligation of safe and reliable railway operation and the obligation of preventing the endangerment of customers and personnel. With regard to these two obligations, the impacts of vegetation on sealed surfaces and the resulting requirements for vegetation control can be divided into four categories (a) operational safety and reliability, (b) transport safety (c) occupational safety (d) structural safety and integrity of buildings:

(a) Operational safety and reliability

- **Reduced operational performance and disruptions due to reduced stability of support structures** caused by degraded or damaged drainage systems causing restrictions and instabilities for operation; requirements: Prevent and restrict vegetation growth in drainage systems and close to drainage systems.

(b) Transport safety

- **Reduced transport safety of sealed areas** such as paths, access roads, parking areas, loading areas due to degraded and tilted surfaces caused by vegetation growth; requirement: Prevent or restrict plant growth in joints and cracks.

(c) Occupational safety

- **Risk of injury on sealed service paths** due to low branches and roots; requirement: Prevent growth of roots and low branches on paths.

(d) Structural safety and integrity of buildings

- **Damage to buildings and structures and reduced integrity due to vegetation impacting the drainage system**, requirement: Prevent growth of vegetation in and close to the drainage system.
- **Damage to buildings and structures and reduced integrity due to vegetation growing in joints and cracks**, requirement: Prevent growth of vegetation in joints and cracks.

4.3. PLANT PROTECTION MEASURES (WITH REFERENCE TO EU-DIRECTIVE 2009/128/EG APPENDIX III)

Preventive Measures

The most important focus for prevention is to **avoid or at least significantly limit vegetation growth due to appropriate design and construction**. This can be achieved e.g. by complete sealing of a surface, which implies other negative impacts, e.g. on water run-off, microclimate, soil-degradation, etc. and should therefore be assessed carefully. Other important preventive measures are the **regular cleaning of surfaces** and especially cracks and joints as well as **preventing the colonization from neighbouring unsealed surfaces** by regular mowing and mulching of these areas in combination with **continuous monitoring** of the status of vegetation growth and the **assessment of its impact**.

Treatments

In accordance with the precautionary principle, **vegetation control on sealed surfaces such as paths, roads, platforms is generally based on non-chemical methods**. Mechanical as well as thermal methods should be applied on a regular basis and in the early stages of vegetation growth in order to minimize effort and impact. Usually this is done within the framework of standard cleaning and maintenance work. The infestation and impact assessment should be performed by qualified personnel.

For **vegetation control on sealed surfaces such support structures and buildings non-chemical methods are also the first priority**. The concrete measures for vegetation control are based on the technical requirements of the structures and buildings. Only if non chemical methods are not successful and the stability and integrity of structures and buildings is endangered with possible consequences for safe and reliable operation, **chemical treatments can be envisaged for single specific cases**. These **exceptions require special permits** issued by the relevant authorities and have to be carried out by experienced and qualified personnel. Based on the **assessment of type and intensity of infestation** and using **decision support** provided e.g. by internal directives and guidelines, appropriate chemicals for treatment and methods of application are selected and communicated to the authorities. It is important that the **chemical treatment is limited to the absolutely necessary level**. If repeated application is needed, an **appropriate resistance management** has to be implemented. **A detailed documentation of all vegetation control measures based on herbicides** (time & location, active substances, dosage, applied technology etc.) **is mandatory**.

5. Guideline for Vegetation Control on Railway Tracks

5.1. CHARACTERIZATION OF RAILWAY TRACKS

Photocredits: SNCF

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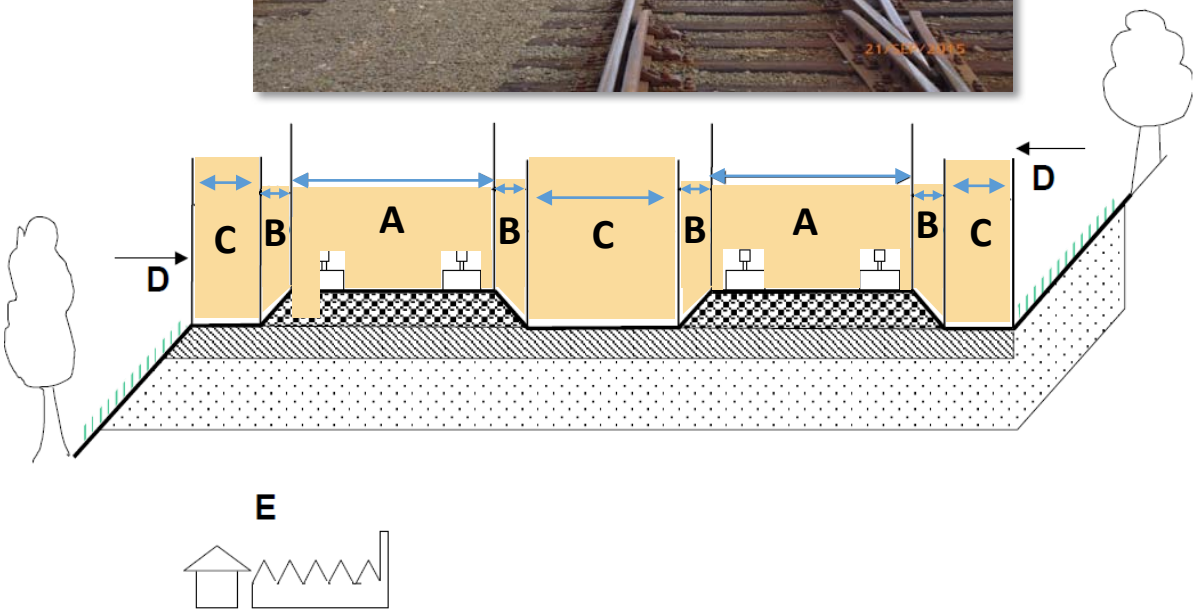

Figure 3: Areas of Application for Vegetation Control Methods – Railway Tracks (Areas A, B and C)

The railway tracks comprise the ballast bed being the part of the track-bed made of ballast or gravel including embedded sleepers and rails (Area A in figure 3), the ballast shoulder being the part of the track-bed covering the slopes on both sides of the ballast bed (Area B in figure 3) – or in the case of a slab track being a concrete track-bed construction (Area A in figure 3). Additionally it comprises the transition area which is the part of the track abutting the slope on both sides of the ballast bed and includes walking path for maintenance reasons/inspection and walk ways and areas between two tracks in case of double and more tracks (Area C in figure 3).

5.2. SPECIFIC NEEDS AND REQUIREMENTS FOR VEGETATION CONTROL MEASURES FOR RAILWAY TRACKS

The need for vegetation control for the track area arises from the obligation of safe and reliable railway operation. The impacts of vegetation on the track area with relevance for the safe and reliable operation and the resulting requirements for vegetation control can be divided into three categories (a) operational safety and reliability, (b) operational and technical performance (c) economic performance:

(a) Operational safety and reliability

Risks of accidents and safety risks due to

- **Restricted visibility of signals** due to high growing plants – safety risk; requirement: limit the plant growth (height) on ballast, ballast shoulder and in transition area
- **Reduction of traction** (longer breaking distances = safety risk, less traction, secondary damage on tracks and wheels), requirement: sustain high quality of traction by ensuring minimum vegetation growth in ballast and on ballast shoulder
- **Malfunctioning of signalling equipment** caused by vegetation too close to equipment – safety risk; requirement: maintain required minimum distances between plants and electrical equipment
- **Shortcuts of electrical trackside equipment** due to vegetation too close to equipment, safety risk; requirement: maintain required minimum distances between plants and electrical equipment
- **Restricted access to emergency and rescue routes** due to excessive plant growth on pathways, requirement: keep the emergency and escape routes always accessible and safely usable.
- **Restricted access and usability of service paths** for maintenance and inspection due to excessive plant growth, requirement: keep the service pathways always accessible and safely usable

(b) Operational and technical performance

Reduced operational performance and disruptions due to

- **Degradation of track quality and stability** by softening of the sub-construction caused by formation of humus, requirement: Keep formation of humus in the track area to a minimum

- **Malfunctioning of electrical trackside equipment** due to vegetation too close to equipment causing operational problems; requirement: maintain required minimum distances between plants and electrical equipment
- **Frost damage of track area and destabilization** caused by increased humidity stored in humus; requirement: Keep formation of humus in the track area to a minimum

(c) Economic performance

- **Reduced lifetime of track construction** due to changed physical properties of the ballast (e.g. lower elasticity) caused by plant growth and humus formation and resulting reduced resilience to dynamic forces, requirement: Keep plant growth and formation of humus in the track area to a minimum.
- **Reduced operational speeds due to track area degradation** caused by vegetation resulting in delays, overall reduction of performance and productivity and operational losses; requirement: Keep plant growth and formation of humus in the track area to a minimum.
- **Increased maintenance effort and costs for track area** due to degradation of track area caused by vegetation; requirement: Preventive vegetation control measures performed on a regular basis.
- **Increased effort, costs and frequency for ballast cleaning** caused by plant growth and humus formation in the ballast, requirement: Preventive vegetation control measures performed on a regular basis.

5.3. PLANT PROTECTION MEASURES (WITH REFERENCE TO EU-DIRECTIVE 2009/128/EG APPENDIX III)

Preventive Measures

Ballast bed and slab track are hostile environments and therefore difficult to be colonized by plants. An important focus for prevention is the **avoidance or restriction of colonization from neighbouring unsealed and sealed surfaces** by regular mowing and mulching of weeds and shrubs and cutting of trees and tree-like shrubs in these areas in combination with **continuous monitoring** of the status of vegetation growth and the **assessment of its impact**.

Treatments

The infestation and impact assessment is performed by qualified personnel. **Main infestation criterion is the degree of vegetation cover** and at certain threshold values vegetation control measures are activated.

In accordance with the precautionary principle, **non-chemical vegetation control measures should be the first priority for the track area**. But since **currently there is no cost efficient alternative to chemical measures**, herbicide use is the commonly practiced method of vegetation control for the track area and non-chemical methods are only used to a very limited degree and only for sections of track with specific requirements. At the actual state of technology development and implementation, **vegetation control with herbicides using spraying trains is more than 10 times more cost efficient than non-chemical alternatives**.

On the basis of the detected degree of vegetation cover and composition of plant populations, the **appropriate chemicals** (herbicides/active substances) **are selected** and their dosage and the optimum time of application are decided by experienced professionals certified for herbicide-based vegetation control. Since the track area is treated on an annual basis, an **adequate resistance management** has to be implemented taking into account the spectrum of licenced herbicides available. The **dosage of application has to be limited to the absolutely necessary level**. This can be reached e.g. by **adjusting the amount of herbicides applied to the concrete level of vegetation growth**. Currently these adjustments are either done manually (on view) – by the operators of spraying equipment aboard the spraying trains or automatically based on plant detection. **Automatic plant detection coupled with dosage adjustment for spraying trains has a potential** for the further reduction of herbicide use in the future. Another consequence of the limitation of herbicide use to the absolutely necessary level, the frequency is **restricted to one** or – for problem zones – to maximum two **treatments per year**.

The most efficient and therefore most common method for the application of herbicides for the track area is the use of spraying trains. **Drift of herbicides into adjacent areas is minimized** by special design of the injectors producing big and heavy enough droplets, by limiting the operational speed of the trains (usually to 50 km/h), addition of wetting agents and by avoiding the application if strong cross winds are present.

A detailed documentation of all vegetation control measures based on herbicides (time & location, active substances, dosage, applied technology etc.) **is mandatory**.

An inventory of track **areas with special protection obligations** has to be updated annually and handed over to the railway company unit responsible for vegetation control or the certified external company contracted for this purpose. Special protection requirements are usually based on either (ground) water protection or general nature conservation legislation.

6. Outlook

The following future trends for vegetation control for railways can be identified:

- Railway's strategies and concepts for vegetation control are becoming more holistic with a stronger integration of different methods and technologies for vegetation control.
- Herbicide use will still be the dominant method for the railway track area in the near future but the importance of alternative methods for track – especially thermal ones – is increasing since the part of the networks where herbicide use is restricted or forbidden (currently about 13%) is rising due to tighter legislation and regulations in the future.
- Although the railways have already significantly reduced their usage of herbicides over the last 20 years – the current annual amount of active substances applied by railways is about 400 t corresponding to less than 0.5% of the overall annual herbicide market in Europe – the amount will be further reduced. Main focus here is the implementation technologies which allow the adjustment of dosages according to the actual status of vegetation growth.
- Railway's reporting and documentation of herbicide application will be more and more based on dedicated databases and GIS systems. These systems also allow a transparent communication of herbicide use.
- For sealed surfaces and unsealed surfaces outside the track area mechanical methods for vegetation control are already the most important ones. The majority of railway companies has already stopped or at least significantly restricted herbicide use in these areas and in a mid-term perspective herbicide use will be phased out by the remaining ones.
- Railways are increasing their efforts to search for alternatives to herbicide use in the track area. Existing methods and technologies are improved and re-evaluated and new methods as e.g. the usage of high electric fields are investigated.
- Railways are investing a lot into Research and development projects in order to get alternatives on the market.
- Railways are intensifying knowledge exchange and especially the exchange of good and best practices for integrated vegetation management.
- Railways are taking vegetation management into account from the very beginning, in terms of design and construction when infrastructure facilities or lines are built or renovated.

State of the Art of Vegetation Control

PART B

Final version

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Content

0. Introduction

There is a broad spectrum of technologies and measures used for vegetation control and management in railways – namely constructional measures, (which can mainly be applied for new track or reconstruction projects), chemical, biological, mechanical, thermal and electrical methods.

The most widespread and cost-efficient measure of vegetation control for railways – especially for the track area - is the application of herbicides. At the current state of development and automation levels, alternative measures cannot compete economically and performance-wise with herbicides.

It should be pointed out that the use of herbicides in the railway sector differs significantly from the use in agriculture. Whereas in agriculture herbicides are always used to within the context of food production – to control and destroy unwanted plants growing close to crop – railways use herbicides for the sole purpose of safe and efficient operation by keeping tracks and other operational areas free of weeds. This results in far lower levels of risk and potential exposition for human beings. The impact of herbicides used by European railways is furthermore put into perspective by the fact that agriculture is by far the main user of herbicides (>95%) whereas railways use less than 1% of the total amount of herbicides sold annually in Europe.

Although herbicide use within the private sector can be both food related (crop protection) and non-food related (weed control for functional or esthetical reason), the risk and exposition level for human beings is also far higher than for railway applications. Railways have strict rules and procedures for the use of herbicides aiming at minimizing health and environmental risks. Only sufficiently trained and qualified personnel is allowed to handle herbicides. The rules comprise the dictum that herbicide use has to be kept to the necessary minimum needed for safe and reliable operation of tracks, the compliance with strict limits for dosages and explicit reporting procedures.

There is growing concern about the environmental impacts of herbicide use e.g. on ground water, other problems concern the increasing risk of herbicide resistance in weeds and changing plant populations with continuous herbicide use.

Other restrictions for the application of herbicides for weed control and management arise from the fact that the use of herbicides is ruled by national legislation and regulation. In many EU countries the use of herbicides is limited to only one or very few active substances (e.g. Glyphosate, Flazasulfuron and Diflufenican) and to a certain maximum dosage of herbicides per track length or area. There is also a growing number of areas where the use of herbicides is banned (e.g. ground water protection zones) and tighter legislation and regulation are to be expected in the future.

Recently, increasing political pressure on herbicide use in Europe has led to an extension of the license of Glyphosate of only 5 years. That means that according to European legislation Glyphosate can be used until December 2022 but a prolongation of the license is highly uncertain and – looking at the political pressure and actions taken in some European countries – even unlikely.

As for these alternative measures and technologies for weed control and management - mainly biological, mechanical, thermal and electrical measures, it has to be stated that despite the great variety of applicable technologies most of them are currently either far from being applicable under the very specific conditions in railway tracks, too slow or too cost intensive (or expensive). Therefore, they are today mainly used in a supplementary way or in areas where herbicide use is forbidden by law (e.g. water catchment areas). Constructional measures such as lateral and vertical plant barriers, porous concrete bars or slab track can be highly efficient in terms of long-term weed control, but they are only applicable for newly built track or reconstruction projects.

Looking at the problems and restrictions of herbicide use and at the limitations of the alternative technologies and measures it becomes obvious that new strategies for vegetation management and control have to be developed by railway companies. These strategies have to focus on two options: the development of improved strategies for herbicide use (e.g. selective application of herbicides and adjustable dosage in dependence of automatically detected actual vegetation growth) and environmentally optimized herbicides for the next few years and the rapid development and implementation of the most promising alternative (non-herbicide based) methods in the mid- and long-term perspective.

The main objectives of the Herbie project and this report are to

- Present the current state of the art of vegetation control and management at European railway companies (Final Report Part A)
- Provide up-to date guidelines for vegetation control and management of railways (Final Report Part B)
- Assess a wide range of current and upcoming methods for vegetation control with regard to technical, economic, environmental and social performance; Identify the most promising upcoming and future methods for integrated vegetation control (Final Report Part C),
- Provide an outlook on the future perspectives of chemical and non- chemical methods of weed control for railways and define the outline of a roadmap for this important area (Final Report Part C)

1. State of the Art of Vegetation Control in European Railways

1.1. HERBIE SURVEY FOR STATE OF THE ART OF VEGETATION CONTROL

Within the framework of the Herbie project, a detailed survey on the state of the art of vegetation control and management of European Railways has been performed in 2017. The survey is more detailed and has a better coverage than the first survey performed in 2012. The feedback to the Herbie survey was very good: 15 European railway companies have sent detailed filled out questionnaires.

Railway Networks in Europe			**2015**		
No	**Country**	Network	Total Track	Survey	
		line km	**track km**	**2017**	2012
1	Austria	4.846	9.646		
2	Belgium	3.605	8.476		
3	Bulgaria	4.019	6.474	-	-
4	Czech Republic	9.444	15.443		
5	Denmark	2.560	3.670		-
6	Germany	33.332	60.795		
7	Estonia	1.207	1.290	-	-
8	Espania	15.385	21.122		-
9	Finland	5.923	8.483		
10	France	29.921	61.000		
11	Great Britain	15.799	31.117		
12	Croatia	2.604	3.968	-	-
13	Hungary	7.387	12.622	-	-
14	Ireland	1458	1502	-	-
15	Italy	16.724	24.286		
16	Lithuania	1.877	3.564	-	-
17	Luxembourg	275	621	-	-
18	Latvia	1.860	3.171	-	-
19	Netherlands	3.223	5.205		
20	Norway	4.209	4.465		
21	Poland	18.510	36.218		
22	Portugal	2.546	3.621	-	-
23	Romania	10.770	19.868	-	-
24	Sweden	9.716	14.090		
25	Slovenia	1.209	1.209	-	-
26	Slovakia	3.626	4.643	-	-
27	Switzerland	3.172	7.779		
		215.207	**374.348**		

Table 1 : Feedback to the surveys of state of the art of vegetation control - Herbie 2017 and UIC 2012 surveys (color code: green - covered in the 2017 Herbie survey, pink – covered in the 2012 UIC survey; track data: UIC statistics 2013 and 2014 with updates from the Herbie survey 2017)

The coverage of the Herbie 2017 survey and the UIC survey 2012 is illustrated in the following figure:

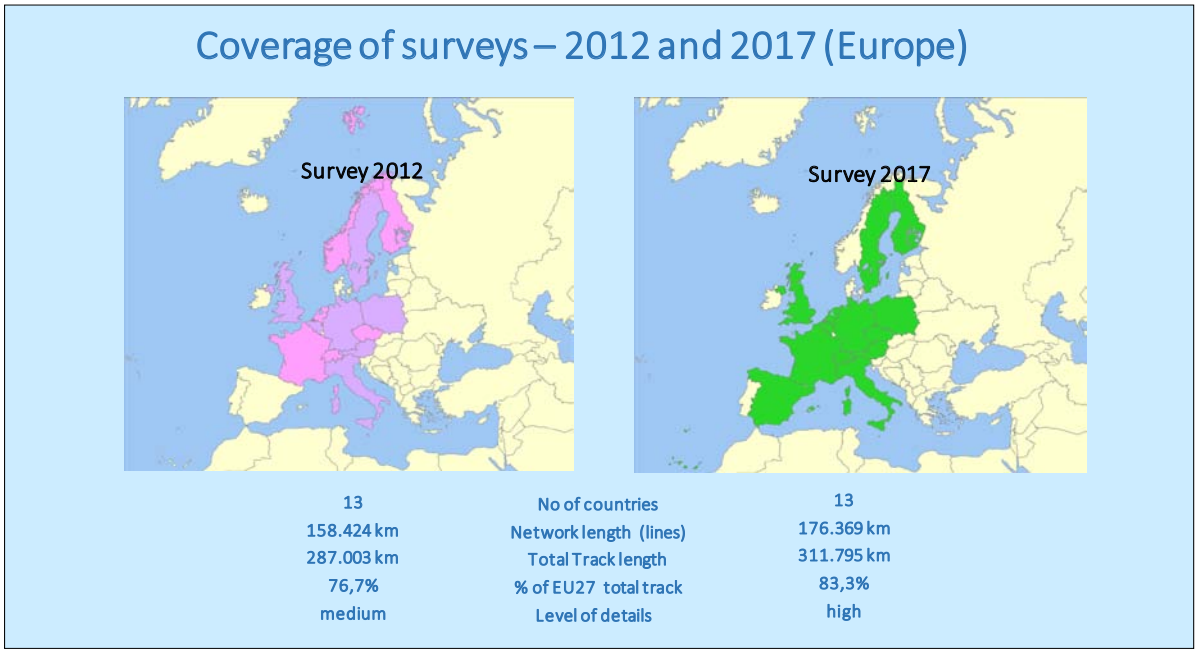

Figure 1 : Coverage of the Herbie Survey 2017 and the UIC survey 2012 on the state of the art of vegetation control and management.

The survey covers all three area types relevant for railways: track area, sealed surfaces and unsealed surfaces with a strong focus on the track area. The results of the survey are presented in the following chapter.

1.2. CURRENT STATE OF VEGETATION CONTROL IN EUROPEAN RAILWAYS

The vast majority of railway tracks (over 95% of the tracks covered by the survey) are annually treated with measures of vegetation control and the total costs spent p.a. for these treatments amounts to 125 million €. The most important single method is the application of Herbicides – more than 90% of the railway tracks covered by the survey are treated with Herbicides. Only 4 % of the tracks are treated mechanically and only 1% have very low needs for treatment because of constructive measures.

Railway Network		
Total length of network (km of lines) covered by survey	176.445	
Total track length (km) covered by survey	311.795	
% or km of network length treated annually with weed control measures	95,7%	
Treatments		
Length of network treated by different methods		
Length of network treated by constructive measures (km)	2.493	1%
Length of network treated by herbicides (track km)	282.637	91%
Length of network treated by mechanical methods (km)	12.213	4%
Length of network were herbicide use is restricted		
Length of network where herbicide use is restricted (km)	26.960	15%
Length of network where herbicide use is forbidden (km)	11.850	7%
Total costs for vegetation control for the track area		
Please give total costs p.a. for vegetation control of track area (including equipment, personnel, safety)	125 Mio €	

Table 2. Overview of current status of vegetation control of European railways from Herbie survey 2017.

Looking in detail at the use of herbicide-based methods the following facts can be stated:

- The most important and universally used active substance of the herbicides is Glyphosate, followed by Flazasulfuron and Diflufenican
- The number of annual treatments varies from country to country. Some countries restrict the applications to once per year while others treat the track area two times per year
- Automatic plant detection is a current state of the art method to reduce the amounts of herbicides needed for the track area. The widespread use of this advanced technology is an essential advantage compared to the status quo of herbicide use in the agricultural sector)
- The total costs for herbicide application for the track area (including herbicides, personnel, equipment and safety measures) are 85 million € p.a.

Herbicides (Track Area)			
Active Substances	Glyphosate (15)		
	Flazasulfuron (6)		
	Diflufenican (6), div (x1, x2)		
Frequency of herbicide treatment	1x: 6	1 to 2x: 3	2x: 6
Herbicides (Track Area, cont.)			
Total amount of active substances in t p.a. for track area	415 t		
Total costs p.a. for herbicide use for track area (equipment, personnel, herbicides, safety)	ca. 85 Mio €		
Measures to reduce herbicide use for the track area	automatic plant detection (8)		
Your average cost range per track km for herbicdes	equipment, herbicides, personnel, safety		
Cost range per track km for spraying trains	40-500 €/ km		
Cost range per track km for spraying with small equipment	50-1.000 €/km		
Cost range per track km for backpack spraying	50-1.000 €/km		

Table 3 : Overview over the current status of herbicide-based vegetation control of railway track area.

The amount of active substances needed and the costs per track km vary between the different railway companies. The following two figures illustrate this fact.

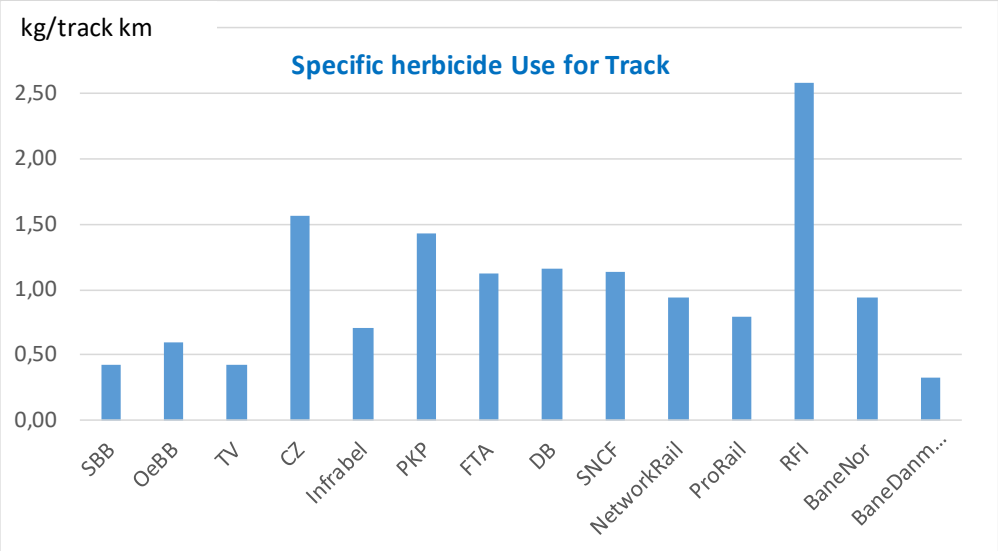

Figure 2: Specific herbicide use in kg of active substance per track km for European railways

As it can be seen from the figure 2, the average specific herbicide use is about 1 kg of active substances per treated track km. It varies for different railway companies varies by up to a factor of 6. This clearly shows that there is still room for improvement in terms of efficient Herbicide use for the railway track area. The most relevant factors influencing the specific herbicide use are: number of applications per year, applied technology, different herbicide products in use, national and company regulations and standards. Note: The term “treated track km” p.a. does not mean that every km of the reported track length is actually treated with herbicides. In the case of the spraying train with automatic plant detection, for a substantial part of the track there is no actual application of herbicides since the nozzles are closed if there is no or inly marginal plant growth detected. Nevertheless, the whole track length covered by the spraying train counts as treated track km.

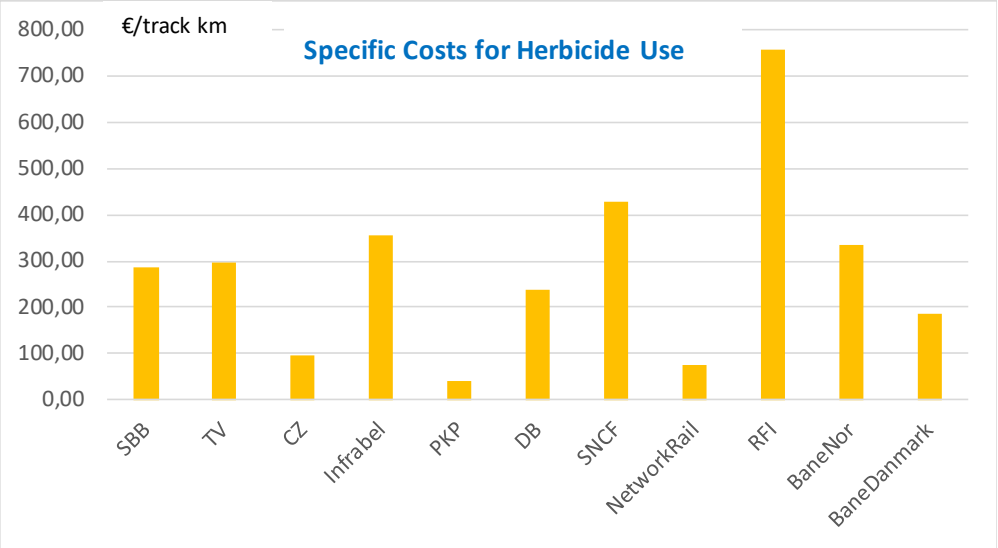

Figure 3: Specific costs for herbicide use in € per track km for European railways

The specific costs for Herbicide use for the track area also vary significantly between different railway companies. The most relevant influencing factors are here the level of labor costs, the amount of herbicides used, applied technology, different herbicide products in use, as well as national and company regulations and standards.

The share of the network treated regularly with herbicides also differs between the companies:

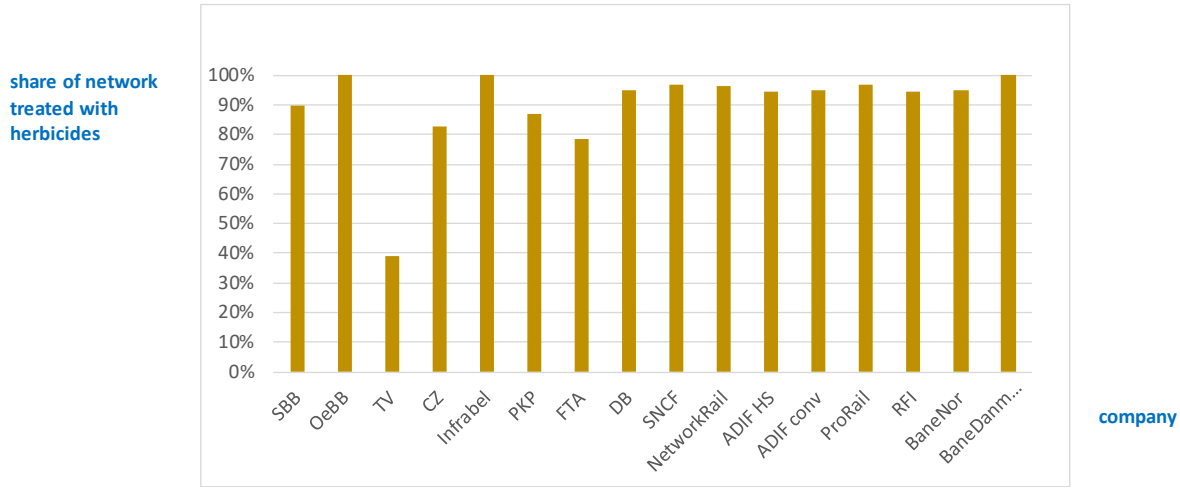

Figure 4: Share of railway network (% of track km) treated annually with herbicides for European railways

Figure 4 clearly shows that all companies treat the greatest part of their track network with herbicides. The share of network treated varies between 80% and 100%. Note: In Sweden a substantial part of the network is treated only once every 2 years, so the average share of the network treated annually is about 60%.

1.3. COUNTRY PROFILES FOR VEGETATION CONTROL AND MANAGEMENT

Country profiles for the state of vegetation control of railways have been created from the feedback of the Herbie survey. An overview of these country profiles is given in the following figure, more details are available in the corresponding annex.

			Network	Track length	Part of network	Areas treated with herbicides			Herbicide use	
ID Nr	Country	Infra-Manager	line km	track km	treated with herbicides	track	unsealed	sealed	volume (active)	costs
1	Switzerland	SBB	3.172	7.779	90%				**2-3t**	2-2,5 Mio €
2	Austria	OeBB	4.846	9.646	100%				**4,7 t**	no data
3	Sweden	TV	9.716	14.090	39%				**2,3 t**	4,2 Mio €
4	Czech Republic	SŽDC	9.444	15.443	83%				**20 t**	1,46 Mio €
5	Belgium	Infrabel	3.605	8.476	100%				**6,0 t**	3 Mio €
6	Poland	PKP	18.510	36.216	87%				**45 t**	0,64 Mio €
7	Finland	FTA	5.923	8.483	79%			no data	**5,6 t**	no data
8	Germany	DB	33.332	60.795	95%				**67 t**	14,4 Mio €
9	France	SNCF	29.921	61.000	97%				**67 t**	26,2 Mio €
10	UK	Networkrail	15.799	31.117	96%				**28 t**	2,3 Mio €
11	Spain	ADIF	15.385	21.122	95%			no data	no data	no data
13	The Netherlands	ProRail	3.223	5.205	97%				no data	no data
14	Italy	RFI	16.724	24.286	95%				**60 t**	18,4 Mio €
15	Norway	JBV	4.209	4.465	95			no data	3 t	1.5 Mio €
16	Denmark	BANE	2.560	3.670	100%				**1,2 t**	0,68 Mio €

Table 4: Overview over the country profiles for railway vegetation control and management. (Color code for the treatment with herbicides: green: herbicides are widely used, no restrictions; orange: herbicide use restricted, only allowed for special cases; red: herbicide use forbidden.)

As it can be seen from the table 4, all railways covered by the survey use herbicide-based methods for the track area since this is currently the most effective and cost-efficient method of vegetation control. For unsealed surfaces such as embankments, unsealed paths, areas around substations, unsealed areas around railway stations, forest land and meadows the use of herbicides is already forbidden in two countries (Germany and Finland) and in 6 other countries herbicides can be only used as an exception and for certain hot-spots. For sealed surfaces the majority of railway companies is already using alternatives to herbicides for vegetation control - in 8 countries the use of herbicides is already banned. It is to be expected that the use of herbicides will further be restricted and diminished for sealed and unsealed surfaces and will finally be totally phased out for these two types of areas.

2. Appendix 1: Country profiles for vegetation control and management of railways

Within the framework of the Herbie Survey 2017 the following railway companies have provided consistent data for the country profiles by answering the Herbie questionnaire:

Country	Company
Austria	ÖBB Infrastruktur AG
Belgium	Infrabel
Czech Republic	Ceske Drahy
Denmark	Banedanmark
Finland	FTA
France	SNCF
Germany	Deutsche Bahn
Italy	RFI
Netherlands	Prorail
Norway	Jernbaneverket
Poland	PKP
Spain	ADIF
Switzerland	SBB
Sweden	Trafikverket
United Kingdom	NetworkRail

Based on these questionnaires form the Herbie Survey, 15 country profiles for vegetation control and management of railways have been elaborated. These profiles are shown in the following tables.

2.1. COUNTRY PROFILE: AUSTRIA – ÖBB-INFRASTRUKTUR AG

UIC Project HERBIE - County Profiles - Austria			
Country	Austria		
Infrastructure Manager	ÖBB Infrastruktur AG		
Total length of network (line km)	4.846		
Herbicide use	track	unsealed	sealed
Alternative methods of vegetation control	track	unsealed	sealed
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	9.646		
Part of network treated annually with weed control measures	100%		
Treatments	Constructive measures, Herbicides, Thermal methods (heat)		
Length of track treated by different methods	herbicides: 81%, constructional: few km, mechanical 19%		
Length of track where herbicide use is restricted/forbidden (km)	512 (forbidden)		
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)	no data		
Herbicide Use	Glyphosate, Flazasulfon		
Frequency of herbicides treatment p.a. for track area	1x		
Total amount of active substances in t used p.a. for track area	4,7t		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	no data		
Measures to reduce herbicide use	Automatic vegetation detection; no application on sites which will be subject to construction works in the following year, constructive measures on new or rebuild tracks		
Management, Documentation, Research			
Documentation for the use of herbicides	Paper report		
Guidelines or regimes for the use of herbicides	Internal (company) guidelines, External guidelines and management cycle for vegetation control		
Research focus	New Herbicides with in-use active substances, New active substances, Plant detection technique, Constructional technique, Mechanical technique, Thermal technique, Biological technique		
Pilot projects:	Herbicide reduction programm together with an NGO, spraying train and small equipment		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows…)*			
Treatments	Constructive measures, Herbicides, Thermal method, Biological methods (competing plants), Mechanical methods		
Length of embankments treated by different methods	100% (no herbicides used on embankments)		
Unsealed surface outside embenkments treated by different methods	no data		
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)	no data		
Documentation, Research			
Documentation for the use of herbicides	Paper report		
Research focus	New Herbicides with in-use active substances, New active substances, Plant detection technique, Constructional technique, Thermal technique, Biological technique		
Pilot projects:	Wave - hot water treatment, water-cutting, grazing with goats and sheep (cows), bioengineering, railcompatible forestry, foil-cover of invasive plant stands, horticulture-urban gardening, use of biomass		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	Chemical and mechanical treatments. No details available: vegetation control is done by external service providers and handled with frame contracts		
Measures to reduce herbicide use	only selective weed control, where needed (no holohedral spraying)		

Use of vegetation control measures	widly used	only special cases	not used / forbidden

2.2. COUNTRY PROFILE: BELGIUM – INFRABEL

UIC Project HERBIE - County Profiles - Belgium			
Country	Belgium		
Infrastructure Manager	Infrabel		
Total length of network (line km)	3.605		
Herbicide use	track	unsealed	sealed
Alternative methods of vegetation control	track	unsealed	sealed
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	6515 km (main tracks) + 1961 km (other tracks) = **8 476 km in total**		
Part of network treated annually with weed control measures	100%		
Treatments	Herbicides		
Length of track treated by different methods	herbicides: 100% *		
Length of track where herbicide use is restricted/forbidden (km)	about 500 km with restrictions		
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)	3 Mio EUR for one year		
Herbicide Use	Glyphosate, Flazasulfuron, Triclopyr, 2,4-D, Diflufenican		
Frequency of herbicides treatment p.a. for track area	2x		
Total amount of active substances in t used p.a. for track area	6 tons		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	3 Mio EUR for one year		
Measures to reduce herbicide use	Automatic vegetation detection on main tracks		
Management, Documentation, Research			
Documentation for the use of herbicides	GIS system		
Guidelines or regimes for the use of herbicides	Internal (company) guidelines, External guidelines and management cycle for vegetation control		
Research focus	Constructional, Mechanical, Thermal techniques		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows…)*			
Treatments	Herbicides, Mechanical methods (cutting, mowing…)		
Length of embankments treated by different methods	Length not known - In relation to the 6500 km of main track		
Unsealed surface outside embankments treated by different methods	150 ha treated by herbicides + Surface not known treated by mechanical methods		
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)	12,1 Mio €		
Herbicide Use	Glyphosate, Flazasulfuron, Triclopyr, 2,4 D, Diflufenican		
Frequency of herbicides treatment p.a. for unsealed surfaces except embankments	1 X		
Total amount of active substances used p.a. for unsealed surfaces in t	500 kg		
Total costs p.a. for herbicide use for for unsealed surfaces including embankments (equipment, personnel, herbicides, safety)	100 000 €		
Measures to reduce herbicide use for unsealed surfaces	0 % of chemical treatment targeted		
Documentation, Research			
Documentation for the use of herbicides	paper reports		
Research focus	Mechanical technique		
Pilot project:	test alternatives		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	Mechanical methods (cutting, mowing…)		
Area treated by different measures	alternative methods: almost 100%		

* without taking into account tracks which don't require a treatment like tunnels, bridges, …

Use of vegetation control measures	widly used	only special cases	not used / forbidden

2.3. COUNTRY PROFILE: CZECH REPUBLIC – CZESKE DRAHY

UIC Project HERBIE - County Profiles - Czech Republic			
Country	Czech Republic		
Infrastructure Manager	SŽDC		
Total length of network (line km)	9.444		
Herbicide use	track	unsealed	sealed
Alternative methods of vegetation control	track	unsealed	sealed
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	15.443		
Part of network treated annually with weed control measures	98%		
Treatments	Herbicides, Mechanical methods (cutting, mowing…)		
Length of track treated by different methods	herbicides: 83%, mechanical: 16%		
Length of track where herbicide use is restricted/forbidden (km)	737 km (restricted), 270 km (forbidden)		
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)	6,3 Mio EUR		
Herbicide Use	Glyphosate, MCPA		
Frequency of herbicides treatment p.a. for track area	2x		
Total amount of active substances in t used p.a. for track area	20 t		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	1,46 Mio EUR		
Measures to reduce herbicide use	Reduction of max amount per track km, Automatic vegetation detection (a part of weedspraying devices)		
Management, Documentation, Research			
Documentation for the use of herbicides	Paper reports, database, GPS data		
Guidelines or regimes for the use of herbicides	internal (company) guidlines and management cycle for vegetation control		
Research focus	New Herbicides with in-use active substances, New active substances, Plant detection technique		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows…)*			
Treatments	Herbicides, Mechanical methods (cutting, mowing…)		
Length of embankments treated by different methods	17% (herbicides use is forbidden for 165 km)		
Unsealed surface outside embenkments treated by different methods	mechanical: 387 ha, herbicides: 1203 ha		
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)	2,24 Mio EUR		
Herbicide Use	Glyphosate, MCPA		
Frequency of herbicides treatment p.a. for unsealed surface except embankments	1x, 2x		
Total amount of active substances used p.a. for p.a. for unsealed surfaces in t	without evidence		
Total costs p.a. for herbicide use for unsealed surfaces including equipment, personnel, herbicides, safety	0,7 Mio EUR		
Measures to reduce herbicide use	Reduction of max amount per area, selective spraying		
Documentation, Research			
Documentation for the use of herbicides	Paper reports		
Research focus	New Herbicides with in-use active substances, New active substances, Plant detection technique, Constructional technique		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	Herbicides, Mechanical methods: mulching, torf …		
Herbicide Use	Glyphosate		
Frequency of herbicides treatment p.a. for sealed surface	1x, 2x		
Measures to reduce herbicide use	selective spraying		
Systematic treatment of sealed surface areas by herbicides	platform		

Use of vegetation control measures	widly used	only special cases	not used / forbidden

2.4. COUNTRY PROFILE: DENMARK – BANE DENMARK

UIC Project HERBIE - County Profiles - Denmark			
Country	Denmark		
Infrastructure Manager	BANE Denmark		
Total length of network (line km)	2.560		
Herbicide use	track	unsealed	sealed
Alternative methods of vegetation control	track	unsealed	sealed
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	3.670		
Part of network treated annually with weed control measures	100%		
Treatments	Herbicides		
Length of track treated by different methods			
Length of track where herbicide use is restricted/forbidden (km)	60 km forbidden		
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)	0,68 Mio EUR		
Herbicide Use	Glyphosate		
Frequency of herbicides treatment p.a. for track area	1x		
Total amount of active substances in t used p.a. for track area	1,2 t		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	0,68 Mio EUR		
Measures to reduce herbicide use	Automatic vegetation detection		
Management, Documentation, Research			
Documentation for the use of herbicides	GPS data for reports + database, Geo-localization of the treatment		
Guidelines or regimes for the use of herbicides	internal (company) guidlines		
Research focus	Test new treatment for problem plants (middle problems with Equisetum, Fallopia, Heracleum); Constructional technique (summarize effect af ballast-cleaning and spraying)		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows...)*			
Treatments	Mechanical methods (cutting, mowing...), Herbicides only for problem plants		
Length of embankments treated by different methods	3.670		
Unsealed surface outside embenkments treated by different methods	0		
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)	no data		
Herbicide Use	Glyphosate		
Frequency of herbicides treatment p.a. for unsealed surface except embankments	2x		
Total amount of active substances used p.a. for p.a. for unsealed surfaces in t	no data		
Total costs p.a. for herbicide use for unsealed surfaces including equipment, personnel, herbicides, safety			
Measures to reduce herbicide use	no spraying on unsealed areas		
Documentation, Research			
Documentation for the use of herbicides			
Research focus	Mechanical technique		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	Mechanical methods (cutting, mowing...)		
Herbicide Use	herbicides are forbidden in platform and pathways areas (about 75 ha)		
Systematic treatment of sealed surface areas by herbicides	no		
Use of vegetation control measures	widly used	only special cases	not used / forbidden

2.5. COUNTRY PROFILE: FINLAND – FTA

UIC Project HERBIE - County Profiles - Finland			
Country	Finland		
Infrastructure Manager	FTA		
Total length of network (line km)	5.923		
Herbicide use	track	unsealed	sealed (no data)
Alternative methods of vegetation control	track	unsealed	sealed (no data)
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	8.483		
Part of network treated annually with weed control measures	79%		
Treatments	Herbicides, Mechanical methods (cutting, mowing…)		
Length of track treated by different methods	herbicides: 59%, mechanical: 20%		
Length of track where herbicide use is restricted/forbidden (km)	all ground water areas		
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)	no data		
Herbicide Use	Glyphosate, Diflufenican, Pelargon acid, Maleic hydrazide		
Frequency of herbicides treatment p.a. for track area	1x		
Total amount of active substances in t used p.a. for track area	5,6 t		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	no data		
Measures to reduce herbicide use	Herbicides are forbidden on ground water areas		
Management, Documentation; Research			
Documentation for the use of herbicides	Paper reports		
Guidelines or regimes for the use of herbicides	Internal (company) guidelines, External guidelines and management cycle for vegetation control		
Research focus	no data		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows…)*			
Treatments	Mechanical methods (cutting, mowing…)		
Length of embankments treated by different methods			
Unsealed surface outside embenkments treated by different methods			
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)			
Documentation, Research	no data		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	no data		

Use of vegetation control measures	widly used	only special cases	not used / forbidden

2.6. COUNTRY PROFILE: FRANCE – SNCF

UIC Project HERBIE - County Profiles - France			
Country	France		
Infrastructure Manager	Société nationale des chemins de fer français - SNCF		
Total length of network (line km)	29.921		
Herbicide use	track	unsealed	sealed
Alternative methods of vegetation control	track	unsealed	sealed
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	61.000		
Part of network treated annually with weed control measures	97%		
Treatments	Constructive measures, Herbicides, Mechanical methods (cutting, mowing…)		
Length of track treated by different methods	herbicides: 97%, mechanical: up to 3 %		
Length of track where herbicide use is restricted/forbidden (km)	1000 forbidden		
Total costs p.a. for vegetation control of track area (including equipment, personnel, safety)	28,7 Mio EUR		
Herbicide Use	Glyphosate,Flazasulfuron, Diflufenican, Triclopyr, Aminopyralid, MCPA		
Frequency of herbicides treatment p.a. for track area	1x		
Total amount of active substances in t used p.a. for track area	ca. 67 t		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	26,2Mio EUR		
Measures to reduce herbicide use	no treatment on new track		
Mangement, Documentation, Research	GPS data for reports + database, GIS system		
Documentation for the use of herbicides	Paper reports, database, GIS system		
Guidelines or regimes for the use of herbicides	internal (company) guidlines and management cycle for vegetation control		
Research focus	New Herbicides with in-use active substances, Plant detection technique, Constructional technique, Mechanical technique		
Pilot project	Alternatives évaluation (ie issues addressed)		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows…)*			
Treatments	Herbicides, Mechanical methods (cutting, mowing, mulching, torf …)		
Length of embankments treated by different methods	mechanical: 20%, herbicides used occasionnally		
Unsealed surface outside embenkments treated by different methods	marginal		
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)	100 Mio EUR		
Documentation, Research			
Documentation for the use of herbicides	Database reporting		
Research focus	strengthening expertise: organisation of vegetation management; innovative outsourcing		
Pilot project	main issue: multi-year program, combination of methods		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	Herbicides, Thermal methods: Heat, Biological methods (competing plants), Mechanical methods (cutting, mowing…)		
Area treated by different measures	Stations: total forbidden use of Herbicides since 2017		

Use of vegetation control measures	widly used	only special cases	not used / forbidden

2.7. COUNTRY PROFILE: GERMANY – DEUTSCHE BAHN

UIC Project HERBIE - County Profiles - Germany			
Country	Germany		
Infrastructure Manager	Deutsche Bahn AG		
Total length of network (line km)	33.332		
Herbicide use	track	unsealed	sealed
Alternative methods of vegetation control	track	unsealed	sealed
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	60.795		
Part of network treated annually with weed control measures	93%		
Treatments	Herbicides, Constructional		
Length of track treated by different methods	herbicides: 93%, constructional: 4%		
Length of track where herbicide use is restricted/forbidden (km)	8.025		
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)	14,4 Mio EUR		
Herbicide Use	Glyphosate, Flazasulfuron, Flumioxazine		
Frequency of herbicides treatment p.a. for track area	1x		
Total amount of active substances in t used p.a. for track area	67		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	14,4 Mio EUR		
Measures to reduce herbicide use	Reduction of max amount per track km , partly automatic vegetation detection		
Mangement, Documentation, Research			
Documentation for the use of herbicides	Paper reports, GPS data for reports + database, GIS system		
Guidelines or regimes for the use of herbicides	internal guidlines and management cycle for vegetation control		
Testing new methods	Geo localization of treatment and restricted areas		
Research focus	New Herbicides and new active substances, Plant detection technique, Biological technique		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows...)*			
Treatments	Mechanical methods (cutting, mowing, mulching, torf ...)		
Length of embankments treated by different methods	mechanical: 90%, herbicides 0%		
Unsealed surface outside embankments treated by different methods	mechanical: 700 km2, herbicides: 0		
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)	70 Mio. EUR in the vegetation prevention		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	Constructive measures, Thermal methods (steam, heat) , Mechanical methods (cutting, mowing...)		
Area treated by different measures	alternative methods: 100%, herbicides: 0%		

Use of vegetation control measures	widly used	only special cases	not used / forbidden

2.8. COUNTRY PROFILE: ITALY – RFI

UIC Project HERBIE - County Profiles - Italy			
Country	Italy		
Infrastructure Manager	RFI-Rete Ferroviaria Italiana		
Total length of network (line km)	16750		
Herbicide use	track	unsealed	sealed
Alternative methods of vegetation control	track	unsealed	sealed
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	24.286		
Part of network treated annually with weed control measures	100%		
Treatments	Herbicides, Mechanical methods (cutting, mowing…)		
Length of track treated by different methods	herbicides: 95%		
Length of track where herbicide use is restricted/forbidden (km)	N.D.		
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)	35,0 Mio EUR		
Herbicide Use	Glyphosate		
Frequency of herbicides treatment p.a. for track area	2x		
Total amount of active substances in t used p.a. for track area	60 t		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	18,4 Mio €., average costs range: 300-500 €/km (spraying trains/small equipment); up to 50 €/km (backpack)		
Measures to reduce herbicide use	RFI complies with new Italian regulation (Feb 2017) focusing at integrating minimum environmental criteria (CAM**) & limits into ITT* concerning herbicides use on tracks and roads & promoting of non-herbicide alternatives***		
Management, Documentation, Research			
Documentation for the use of herbicides	GPS data for reports + database		
Guidelines or regimes for the use of herbicides	Company guidlines & compliances with new Italian regulation/guidelines (Feb 2017)		
Research focus	no		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows…)*			
Treatments	Herbicides, Mechanical methods (cutting, mowing…)		
Length of embankments treated by different methods			
Unsealed surface outside embenkments treated by different methods	mechanical: 1654 ha, herbicides: 2600 ha		
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)	15,0 Mio EUR		
Herbicide Use	Glyphosate		
Frequency of herbicides treatment p.a. for unsealed surface except embankments	1x, 2x		
Total amount of active substances used p.a. for p.a. for unsealed surfaces in t	26 t		
Total costs p.a. for herbicide use for unsealed surfaces including equipment, personnel, herbicides, safety	n.d., only average costs: 1200,00 € per treatment		
Measures to reduce herbicide use	no		
Documentation, Research			
Documentation for the use of herbicides	GPS data for reports + database (information included: dosage of herbicides used, km of track treated, amount of water used, GPS system for restrictef areas)		
Research focus	no		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	Mechanical methods (cutting, mowing…)		
Area treated by different measures	alternative methods: 100%, herbicides: 0%		

*ITT = Invitation to Tender

** Minimum environmental criteria - CAM: Mandatory basic criteria (e.g. authorizatoin of herbicides for rail, classification & labelling…) & rewarding criteria for ITT (higher ranking of alternative technologies & higher efficiency)

*** Herbicides can only be used if the "non-convenience" of other measures for vegetation control is demonstrated; by means of cost-benefit studies, impact mitigation measures, assessment of hydrology, the specific environment, etc..

Use of vegetation control measures	widly used	only special cases	not used / forbidden

2.9. COUNTRY PROFILE: NETHERLANDS – PRORAIL

UIC Project HERBIE - County Profiles - The Netherland			
Country	The Netherland		
Infrastructure Manager	ProRail		
Total length of network (line km)	3.223		
Herbicide use	track	unsealed (only for problem plant)	sealed
Alternative methods of vegetation control	track	unsealed	sealed
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	5.205		
Part of network treated annually with weed control measures	100%		
Treatments	Herbicides, Brushing		
Length of track treated by different methods	herbicides: 97%, mechanical: 3%		
Length of track where herbicide use is restricted/forbidden (km)	161 restricted/forbidden		
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)	Unknown part of each seperate maintenance contract		
Herbicide Use	Glyphosate, MCPA, Triclopyr, Flumioxazin, Glyfosinate ammonium, (Acetic Acid as bioherbicide)		
Frequency of herbicides treatment p.a. for track area	2x		
Total amount of active substances in t used p.a. for track area	unknown		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	unknown part of each seperate maintenance contract		
Measures to reduce herbicide use	Anti-vegetationmats, mowing . Investigation about more useable alternatives		
Management, Documentation, Research			
Documentation for the use of herbicides	Paper reports, Geo-localization of the treatment		
Guidelines or regimes for the use of herbicides	In accordance with the law		
Research focus	different alternative methods		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows...)*			
Treatments	Thermal methods: (heat), Brushing, Herbicides (Glyphosate only for problem plants)		
Length of embankments treated by different methods			
Unsealed surface outside embenkments treated by different methods			
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)			
Documentation, Research			
Documentation for the use of herbicides	no data		
Research focus	no		
Weed / Vegetation Control Outside Track - Sealed Surfaces *(areas not directly linked with track with sealed surfaces)*			
Treatments	Covering		
Area treated by different measures	alternative methods: 100%, herbicides: 0%		
	Use of vegetation control measures	widly used	only special cases / not used / forbidden

2.10. COUNTRY PROFILE: NORWAY – BANE NOR

UIC Project HERBIE - County Profiles - Norway			
Country	Norvay		
Infrastructure Manager	Bane NOR (JBV- Jernbaneverket)		
Total length of network (line km)	4.285		
Herbicide use	track	unsealed	no data
Alternative methods of vegetation control	track	unsealed	no data
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	4.673		
Part of network treated annually with weed control measures	95%		
Treatments	Herbicides, Mechanical methods (cutting, mowing...)		
Length of track treated by different methods	herbicides: 95%, mechanical: ?		
Length of track where herbicide use is restricted/forbidden (km)	200 km (restricted), 5 km (forbidden)		
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)	ca. 1.5 Mio EUR		
Herbicide Use	Glyphosate, Fluroxypyr 5 %		
Frequency of herbicides treatment p.a. for track area	1x		
Total amount of active substances in t used p.a. for track area	4000 liters (about 3 t)		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	ca. 1.5 Mio EUR		
Measures to reduce herbicide use	Automatic vegetation detection		
Management, Documentation, Research			
Documentation for the use of herbicides	Paper reports, GPS data for reports + database, GIS system		
Guidelines or regimes for the use of herbicides	internal (company) guidlines		
Research focus	Plant detection technique, Mechanical technique		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows...)*			
Treatments	Herbicides, Mechanical methods (cutting, mowing...), Mechanical methods: mulching, torf ...		
Length of embankments treated by different methods	4285 ha		
Unsealed surface outside embenkments treated by different methods	herbicides: 80 ha		
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)	Including in costs Part A		
Herbicide Use	Glyphosate,		
Frequency of herbicides treatment p.a. for unsealed surface except embankments	1x		
Total amount of active substances used p.a. for p.a. for unsealed surfaces in t	Including in amounts Part A		
Total costs p.a. for herbicide use for unsealed surfaces including equipment, personnel, herbicides, safety	Including in amounts Part A		
Measures to reduce herbicide use	Automatic vegetation detection		
Documentation, Research			
Documentation for the use of herbicides	GPS data for reports + database		
Research focus	Plant detection technique		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	Part C not relevant for Bane NOR Infrastructure		

Use of vegetation control measures	widly used	only special cases	not used / forbidden

2.11. COUNTRY PROFILE: POLAND – PKP

UIC Project HERBIE - County Profiles - Poland			
Country	Poland		
Infrastructure Manager	PKP		
Total length of network (line km)	18.510		
Herbicide use	track	unsealed	sealed
Alternative methods of vegetation control	track	unsealed	sealed
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	36.218		
Part of network treated annually with weed control measures	98%		
Treatments	Herbicides, Mechanical methods (cutting, mowing…)		
Length of track treated by different methods	herbicides: 87%, mechanical: 13%		
Length of track where herbicide use is restricted/forbidden (km)	0		
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)	1,424 Mio EUR		
Herbicide Use	Glyphosate		
Frequency of herbicides treatment p.a. for track area	1x, 2x		
Total amount of active substances in t used p.a. for track area	ca. 45 t		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	1,424 Mio EUR		
Measures to reduce herbicide use	no		
Management, Documentation, Research			
Documentation for the use of herbicides	Paper reports		
Guidelines or regimes for the use of herbicides	Internal (company) guidelines, External guidelines		
Research focus	New Herbicides with in-use active substances, New active substances		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows…)*			
Treatments	Herbicides, Mechanical methods (cutting, mowing…)		
Length of embankments treated by different methods			
Unsealed surface outside embenkments treated by different methods			
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)			
Documentation, Research			
Documentation for the use of herbicides	Paper reports		
Research focus	New Herbicides with in-use active substances, New active substances		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	Mechanical methods (cutting, mowing…)		
Area treated by different measures	alternative methods: 100%, herbicides: 0%		

Use of vegetation control measures	widly used	only special cases	not used / forbidden

2.12. COUNTRY PROFILE: SPAIN – ADIF

UIC Project HERBIE - County Profiles - Spain			
Country	Spain		
Infrastructure Manager	ADIF Conventional		
Total length of network (line km)	13.015		
Herbicide use	track	unsealed	no data
Alternative methods of vegetation control	track ?	unsealed	no data
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	16.382		
Part of network treated annually with weed control measures	no data		
Treatments	Herbicides, Mechanical methods (cutting, mowing…)		
Length of track treated by different methods	no data		
Length of track where herbicide use is restricted/forbidden (km)			
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)			
Herbicide Use	Glyphosate, Flumioxazine, Triclopyr		
Frequency of herbicides treatment p.a. for track area	no data		
Total amount of active substances in t used p.a. for track area			
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety			
Measures to reduce herbicide use			
Management, Documentation, Research			
Documentation for the use of herbicides	Paper reports, database (amount of water used, dosage of herbicides used, km of track treated)		
Guidelines or regimes for the use of herbicides	No specific data. But management cycle for vegetation control		
Research focus	no		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows…)*			
Treatments	Herbicides, Mechanical methods (cutting, mowing…)		
Length of embankments treated by different methods	95%		
Unsealed surface outside embenkments treated by different methods	no data		
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)	no data		
Herbicide Use	Glyphosate, Flumioxazine		
Frequency of herbicides treatment p.a. for unsealed surface except embankments	no data		
Total amount of active substances used p.a. for p.a. for unsealed surfaces in t			
Total costs p.a. for herbicide use for unsealed surfaces including equipment, personnel, herbicides, safety			
Measures to reduce herbicide use			
Documentation, Research			
Documentation for the use of herbicides	no data		
Research focus	no data		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	no data		
Herbicide Use	no data		

Use of vegetation control measures	widly used	only special cases	not used / forbidden

2.13. COUNTRY PROFILE: SWEDEN – TRAFIKVERKET

UIC Project HERBIE - County Profiles - Sweden			
Country	Sweden		
Infrastructure Manager	Trafikverket (Swedish Transport Administration)		
Total length of network (line km)	9.716		
Herbicide use	track	unsealed	sealed
Alternative methods of vegetation control	track	unsealed	sealed
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	14.090		
Part of network treated annually with weed control measures	significantly less than 100% p.a.		
Treatments	Herbicides & locally also mechanical methods*		
Length of track treated by different methods	herbicides: 39% *		
Length of track where herbicide use is restricted/forbidden (km)	12361 (restricted), 1888 (=13,4% forbidden, water protection)		
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)	4,2 Mio EUR *		
Herbicide Use	Glyphosat		
Frequency of herbicides treatment p.a. for track area	1x, 2x		
Total amount of active substances in t used p.a. for track area	2,3 t (dosage 1,8 kg /ha)		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	4,2 Mio EUR		
Measures to reduce herbicide use	Automatic vegetation detection		
Management, Documentation, Research			
Documentation for the use of herbicides	GPS data for reports + database		
Guidelines or regimes for the use of herbicides	Internal guidelines and management cycle for vegetation control		
Research focus	Efficacy & environmental performance of new actives & alternative methods		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows…)*			
Treatments	Mechanical methods (cutting, mowing…)		
Length of embankments treated by different methods	mechanical: 59%, herbicides 0%		
Unsealed surface outside embenkments treated by different methods			
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)	7 Mio EUR		
Herbicide Use	Glyphosate (only for problem plants)		
Frequency of herbicides treatment p.a. for unsealed surfaces	1x		
Total amount of active substances in t used p.a. for unsealed surfaces	no data		
Total costs p.a. for herbicide use for unsealed surfaces including equipment, personnel, herbicides, safety	no data		
Measures to reduce herbicide use	selective spraying		
Documentation, Research			
Documentation for the use of herbicides	reports		
Research focus	no		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	Thermal methods: heat, Mechanical methods (cutting, mowing…)		
Area treated by different measures	alternative methods: 100%, herbicides: 0%		

Use of vegetation control measures	widly used	only special cases	not used / forbidden

* Note: The one systematically used method of vegetation control for the track area is based on appliction of herbicides by spraying train. For this method of treatment, the track length covered (39%) and the costs (4,2 milion €) are reported and documented on national level. In addition, mechanical methods are used locally, but overall track length covered and costs are not reported on an aggreggated level.

2.14. COUNTRY PROFILE: SWITZERLAND – SBB

UIC Project HERBIE - County Profiles -Switzerland			
Country	Switzerland		
Infrastructure Manager	SBB - Schweizerische Bundesbahnen		
Total length of network (line km)	3.172		
Herbicide use	track	unsealed (only for problem plants)	sealed
Alternative methods of vegetation control	track	unsealed	sealed
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	7.779		
Part of network treated annually with weed control measures	90%		
Treatments	Herbicides, Mechanical		
Length of track treated by different methods	herbicides: 90%		
Length of track where herbicide use is restricted/forbidden (km)	125 km restricted, 70 km forbidden		
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)	2,3 -2,7 Mio EUR		
Herbicide Use	Glyphosate		
Frequency of herbicides treatment p.a. for track area	1x, 2x		
Total amount of active substances in t used p.a. for track area	2-3 t		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	2-2,5 Mio EUR		
Measures to reduce herbicide use	manual vegetation detection		
Mangement, Documentation, Research			
Documentation for the use of herbicides	Paper reports		
Guidelines or regimes for the use of herbicides	internal (company) guidlines, external guidelines		
Research focus	New Herbicides with in use active substances, Plant detection technique		
Pilot project	chemical vegetation control with small trains and automatic vegetations detection, new herbicides		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows...)*			
Treatments	Mechanical methods (cutting, mowing, mulching, torf ...)		
Length of embankments treated by different methods	mechanical: 95%, herbicides generally forbidden (exceprion only for invasive neophytes and other problem plants)		
Unsealed surface outside embenkments treated by different methods			
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)	ca 11-12 Mio EUR		
Herbicide Use	Glyphosate, Triclopyr		
Frequency of herbicides treatment p.a. for unsealed surface except embankments	1x		
Total amount of active substances used p.a. for p.a. for unsealed surfaces in t	around 0,1 t		
Total costs p.a. for herbicide use for unsealed surfaces including equipment, personnel, herbicides, safety	around 90.000 - 140.000 EUR		
Measures to reduce herbicide use	selective spraying		
Documentation, Research			
Documentation for the use of herbicides	GPS data for reports, database (including dosage of herbicides used, km of track treated, methods)		
Research focus	no		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	Mechanical methods (cutting, mowing...)		
Area treated by different measures	alternative methods: 100%, herbicides: 0%		

Use of vegetation control measures	widly used	only special cases	not used / forbidden

2.15. COUNTRY PROFILE: UNITED KINGDOM – NETWORKRAIL

UIC Project HERBIE - County Profiles - United Kingdom			
Country	UK		
Infrastructure Manager	Networkrail		
Total length of network (line km)	15.799		
Herbicide use	track	unsealed	sealed
Alternative methods of vegetation control	track	unsealed	sealed
Vegetiation Control for Track Area *(ballast bed + ballast shoulder + transition area)*			
Railway Network			
Total length of track (track km)	31.117		
Part of network treated annually with weed control measures	96%		
Treatments	Herbicides, Mechanical methods: mulching, torf ..., Hand Pulling, Brush Cutting.		
Length of track treated by different methods	herbicides: 96%. Mechnical methods are used in combination with chemical		
Length of track where herbicide use is restricted/forbidden (km)	5050 km (restricted); 240 km (forbidden)		
Total costs p.a. for vegetation control track area (including equipment, personnel, herbicides, safety)	8,6 Mio EUR		
Herbicide Use	Glyphosate, Flazasulfuron, Diflufenican, 2-4, D		
Frequency of herbicides treatment p.a. for track area	2x		
Total amount of active substances in t used p.a. for track area	ca. 28 t		
Total costs p.a. for herbicide use for track area including equipment, personnel, herbicides, safety	2,3 Mio EUR		
Measures to reduce herbicide use	Automatic vegetation detection		
Mangement, Documentation, Research			
Documentation for the use of herbicides	GPS data for reports + database		
Guidelines or regimes for the use of herbicides	Internal (company) guidelines, External guidelines and management cycle for vegetation control		
Research focus	New Herbicides with in-use active substances, New active substances, Plant detection technique, Mechanical technique, Biological technique		
Pilot project	Low drift and adjuvant technology		
Vegetation Control Outside Track - Unsealed Surfaces: *embankments & areas outside embarkments (unsealed paths, forest, meadows...)*			
Treatments	Herbicides , Biological methods (competing plants), Mechanical methods (cutting, mowing...)		
Length of embankments treated by different methods	herbicides: 80%, mechanical methods: 16%		
Systematic treatment of parts of the embankment by herbicides	2 m		
Total costs for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)	within 8,6 Mio EUR		
Herbicide Use	(Triclopyr Aminopyralid)		
Frequency of herbicides treatment p.a. for (parts of) embankments und for unsealed surfaces except embankments	1x		
Total amount of active substances in t used p.a. for unsealed surfaces	1,5 t		
Total costs p.a. for herbicide use for unsealed surfaces including equipment, personnel, herbicides, safety	Chemical cost 0,4 Mio EUR		
Measures to reduce herbicide use	Reduction of max amount per area, selective spraying, other		
Documentation, Research			
Documentation for the use of herbicides	GPS data for reports + database		
Research focus	New active substances,. Pilot Project: Hedging technique project		
Vegetation Control Outside Track - Sealed Surfaces: *areas not directly linked with tracks (streets, paths, driveways, loading zones, station platforms)*			
Treatments	Limited. Reactive treatement techniques liely to be chemical or mechanical. Many sealed surfaces actually managed by Train Operators rather than Network Rail		
Measures to reduce the amount of herbicides for sealed surfaces	selective spraying		

Use of vegetation control measures	widly used	only special cases	not used / forbidden

3. Appendix 2: Questionnaire for the Herbie Survey on vegetation control and management of railways 2017

Questionnaire for UIC Project HERBIE- 2017	
Contact Details	
Name	
e-mail adress	
phone number	
Part A	
Weed/Vegetiation Control for Track Area	*Track Area: Area A ballast bed + Area B ballast shoulder + Area C transition area with path ways*
Railway Network	
Total length of track network (km)	
% or km of network length treated annually with weed control measures	
Treatments	
What method of weed control do you apply within the track?	
please select, multiple selections possible	
If other, please describe method of treatment	
Length of network treated by different methods	
Length of network treated by constructive measures (km)	
Length of network treated by herbicides (km)	
Length of network treated by mechanical methods (km)	
Length of network treated by biological methods (km)	
Length of network were herbicide use is restricted	
Length of network where herbicide use is restricted (km)	
Length of network where herbicide use is forbidden (km)	
Total costs for vegetation control for the track area	
Please give total costs p.a. for vegetation control of track area (including equipment, personnel, safety)	
Typical Stakeholder actions regarding your vegetation control?	
Operational disruptions caused by vegetation	
What is the share of operational disruptions caused by vegetation in %	
What is total costs p.a. for these disruptions caused by vegetation?	-
What are typical stakeholder demands concerning vegetation control?	

Herbicides	
If using herbicides, which active substances do you use?	
please select, multiple selections are possible	
please select, multiple selections are possible	
If other active substance, please specify	
Details for Herbicide Treatments: Frequency, Amount and Costs	
How often do you typically apply herbicides p.a. in the track area?	
What is the total amount of active substances in t used p.a. for track area?	
What are the total costs p.a. for herbicide use for the track area including equipment, personnel, herbicides, safety?	
Do you apply measures to reduce herbicide use for the track area?	
please select, multiple selections are possible	
If other measure, please specify	
Your average cost range per km for applying herbicdes in the track area? (equipment, herbicides, personnel, safety)	
Cost range per track km for spraying trains	please select
Cost range per track km for spraying with small equipment	please select
Cost range per track km for backpack spraying	please select
Documentation	
How do you document the use of herbicides for the track area?	
please select, multiple selections are possible	
Which information is included in the documentation?	
please select, multiple selections are possible	
If testing new methods, please specify	
Problem Plants	
How do you handle so called problem plants (not to be treated/difficult to	
If other of testing yes, please specify the problem plants	
Management	
Do you have specific guidelines or regimes for the use of herbicides?	
Do you or do your contractors follow the management cycle for vegetation control?	
please select, multiple selections are possible	
Research	
Does your railway company carry out investigations concerning vegetation control measures for the track area?	
What issues are addressed - please select (multiple choice possible)	
If "other", please specify the investigated methods	
Do you have pilot projects for vegetation control in the track area?	
If yes, please describe these pilot projects (name of project, technology and method used, contact persons)	

Part B	
Weed / Vegetation Control Outside Track - Unsealed Surfaces	Area D - embankments, Area E - areas not directly linked with track with unsealed surfaces e.g. around substations, other pathways ...
Treatments	
How do you treat weeds on embankments and other unsealed surfaces ?	
please select, multiple selections possible	
If other, please describe method of treatment	
Length of network / size of area treated by different measures	Embankments only!
Length of network (embankments) treated by constructive measures (km)	
Length of network (embankments) treated by herbicides (km)	
Length of network (embankments) treated by mechanical methods (km)	
Length of network (embankments) treated by biological methods (km)	
* alternatively or complementary *	
Embankment area treated by herbicides (ha)	
Embankment area treated by mechanical methods (ha)	
Embankment area treated by biological methods (ha)	
Do you systematically treat parts of the embankment by herbicides?	
If yes, what is width of the part of the embankment which is treated by herbicides (in m)?	
Area of unsealed surfaces treated by different measures	Unsealed surfaces except embankments
Unsealed surface area except embankments treated by herbicides (ha)	
Unsealed surface area treated by mechanical methods (ha)	
Total costs for vegetation control for unsealed surfaces	
Please give the total costs p.a. for vegetation control for unsealed surfaces including embankments (equipment, personnel, safety)	
Herbicides	
If using herbicides, which active substances do you use?	
please select, multiple selections are possible	
If "other", please describe treatment	
Details for Herbicide Treatments: Frequency, Amount and Costs	
How often do you typically apply herbicides p.a. for (parts of) embankments?	
How often do you typically apply herbicides p.a. for unsealed surfaces except embankments?	
Total amount of active substances of herbicides used p.a. for unsealed surfaces in t?	
What are the total costs p.a. for herbicide use for unsealed surfaces including embankments (equipment, personnel, herbicides, safety)?	
Do you apply measures to reduce the amount of herbicides for unsealed surfaces?	
please select, multiple selections are possible	
If other", please specify"	
Length of network / area with restrictions for herbicide use	
Length of network (embankments) where use of herbicides is forbidden (km)	
Unsealed surfaces except embankments where use of herbicides is forbidden (ha)	
What is the average cost range per ha for applying herbicdes for unsealed surfaces ? (per treatment)	

Documentation	
How do you document the use of herbicides for unsealed surfaces?	
please select, multiple selections are possible	
Which information is included in the documentation?	
please select, multiple selections are possible	
If other information, please specify	
Problem Plants	
How do you handle so called problem plants (not to be treated/difficult to treat)?	
If yes, please specify the problem plants	
Research	
Does your railway company carry out investigations concerning vegetation control methods for unsealed surfaces outside track?	
What issues are addressed - please select (multiple choice possible)	
If "other", please specify the investigated methods	
Do you have pilot projects for vegetation control for areas with unsealed surfaces including embankmnts?	
If yes, please give details of the projects (name of project, technology and method used, contact persons)	

Part C	
Weed / Vegetation Control Outside Track - Sealed Surfaces	Area E - areas not directly linked with track with sealed surfaces e.g. station platforms, paved pathways and roads, parking lots
Treatments	
How do you treat weeds on sealed surfaces ?	
please select, multiple selections possible	
If "other", please describe treatment	
Area treated by different measures - sealed surfaces only!	
Sealed surface area treated by herbicides (ha)	
Sealed surface area treated by mechanical methods (ha)	
Sealed surface area treated by biological methods (ha)	
Do you systematically treat sealed surface areas by herbicides?	
If yes, which types of sealed surfaces are treated by herbicides?	
If "other", please describe type of sealed surface	
Sealed surface areas with restrictions for herbicide use	
Types of sealed surface areas where use of herbicides is forbidden	
Sealed surface areas where use of herbicides is forbidden (ha)	
Total costs for vegetation control for sealed surfaces	
Please give the total costs p.a. for sealed surfaces (equipment, personnel, safety)	
Herbicides	
If using herbicides, which active substances do you use?	
please select, multiple selections are possible	
If "other", please describe treatment	
Details for Herbicide Treatments: Frequency, Amount and Costs	
How often do you typically apply herbicides p.a. for sealed surfaces?	please select
What is the total amount of active substances of herbicides used p.a. for sealed surfaces in t?	
What are the total costs in € p.a. for herbicide use for sealed surfaces (including equipment, personnel, herbicides, safety)?	
Do you apply measures to reduce the amount of herbicides for sealed surfaces?	
please select, multiple selections are possible	
If other", please specify"	
Thank you very much for your valuable input!	

Assessment and Recommendations

PART C

Final version

Submitted to UIC – International Union of Railways, Paris, France,
Fundamental Values Department, Sustainable Development Unit by
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Content

1. Assessment of methods for vegetation control for railway track area

1.1. INTRODUCTION

Railways have to manage different types of areas – unsealed surfaces such as embankments, protective forests, meadows; sealed surfaces such as roads, pathways, station platforms and track area as a special case - with their specific needs and requirements for vegetation control. Recently European railways have agreed upon a comprehensive guideline for a systematic and responsible integrated vegetation management of the different types of areas (see “Herbie project – Final Report part A – UIC Guideline for Integrated Vegetation Management”). The current status of vegetation control at European railways is documented in “Herbie Project – Final Report Part B– State of The Art of Vegetation Control”.

The focus of this assessment report is on methods for vegetation control of the railway track area where permanent vegetation growth cannot be tolerated since it can destabilize the ballast and rails, significantly decrease the visibility of signals and block pathways for maintenance and emergency evacuation and thus jeopardize the safe and reliant performance of railway systems.

The most widespread and cost-efficient measure of vegetation control for the railways track area is the application of herbicides. At current state of development and automation levels, alternative measures cannot compete economically and performance-wise with herbicides. But the growing pressure from policy makers, legislation and other stakeholders leads to increasing restrictions for the use of herbicides for vegetation control and intensifies the search for viable alternatives. According to current European legislation, the main herbicide used for vegetation control and management of railways – Glyphosate - can only be used until December 2022. A prolongation of the Glyphosate license is highly uncertain and – regarding current political activities and pressure in some European countries – seems even unlikely.

At this point it is important to stress that the European market share of chemical herbicides used for vegetation control by railways is about 0,5 %. Which means that 99% of the market share is held by agricultural sectors. In contrast to agriculture, railways are not using these herbicides in the process of food-production but to keep a transport-infrastructure functional and safe. Due to the insignificant market share, the big players of chemical industry will never develop railway specific herbicides. Therefore, the railway sector will always be depending on herbicides, which have been developed for agricultural uses in the first place and are approved for the railway sector in a second step of the registration.

If herbicide-based methods for vegetation control of the railway track area would be substituted in the mid to long-term perspective by alternative methods, the most promising candidates with sufficient performance have to be identified, assessed and – in due time – further developed. It should be noted although this assessment report focuses on the railway

track area, the search for efficient alternative methods of vegetation control is also relevant for some areas outside track (e.g. power stations, small paths to technical boxes not accessible by public roads etc.) which are rather difficult to manage with conventional methods such as mowing and are in many European countries still treated with herbicides.

The following chapters provide an objective basis for this process by documenting the assessment of the wide spectrum of currently known methods for weed control of the railway track area (including documentation of the applied methodology and the assessment results).

1.2. METHODOLOGY – THE ASSESSMENT PROCESS

1.2.1. Principles

A multidimensional socio-economic and ecological assessment of different vegetation control methods (with and without herbicides) is carried out in order to

- Identify the sustainability performance of different methods
- Rank methods according to their performance
- Identify the methods with the highest performances and development potentials

Regarding the great variety of applicable technologies and methods for weed control ranging from chemical and biological to physical methods like mechanical, thermal and electrical ones and having in mind that many of those options have currently only a very limited application range or are far away from economic efficiency. Therefore, the multi-dimensional assessment will be performed in two stages:

- Stage 1 consists of a screening of the currently known methods with the aim of selecting the most relevant methods with regards to cost efficiency and operational performance,
- Stage 2 comprises the detailed assessment of the methods selected in stage 1 by means of a full set of economic, technical, environmental and social performance indicators.

This process is illustrated in the following figure:

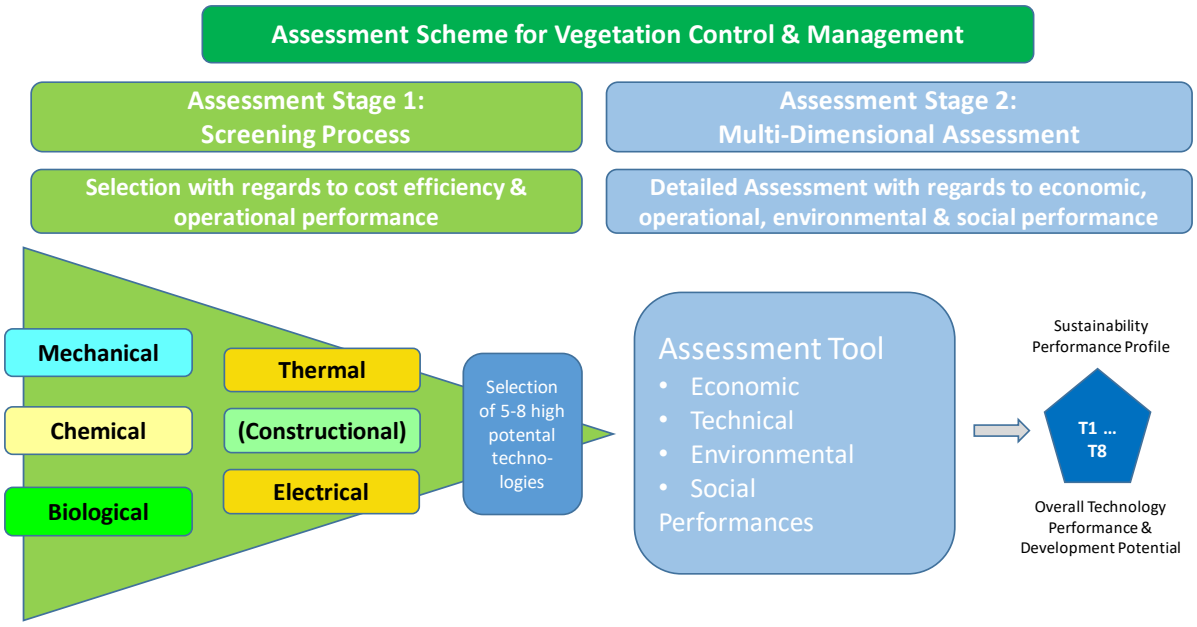


Figure 1: Two Stage multi-dimensional Assessment Methodology

1.2.2. Multi-dimensional Assessment tool

The multi-dimensional Assessment tool developed for the Herbie-Project allows a balanced assessment of the economic, social and environmental performance of different methods of vegetation control. An overview over the assessment dimensions and criteria is shown in the following figure:

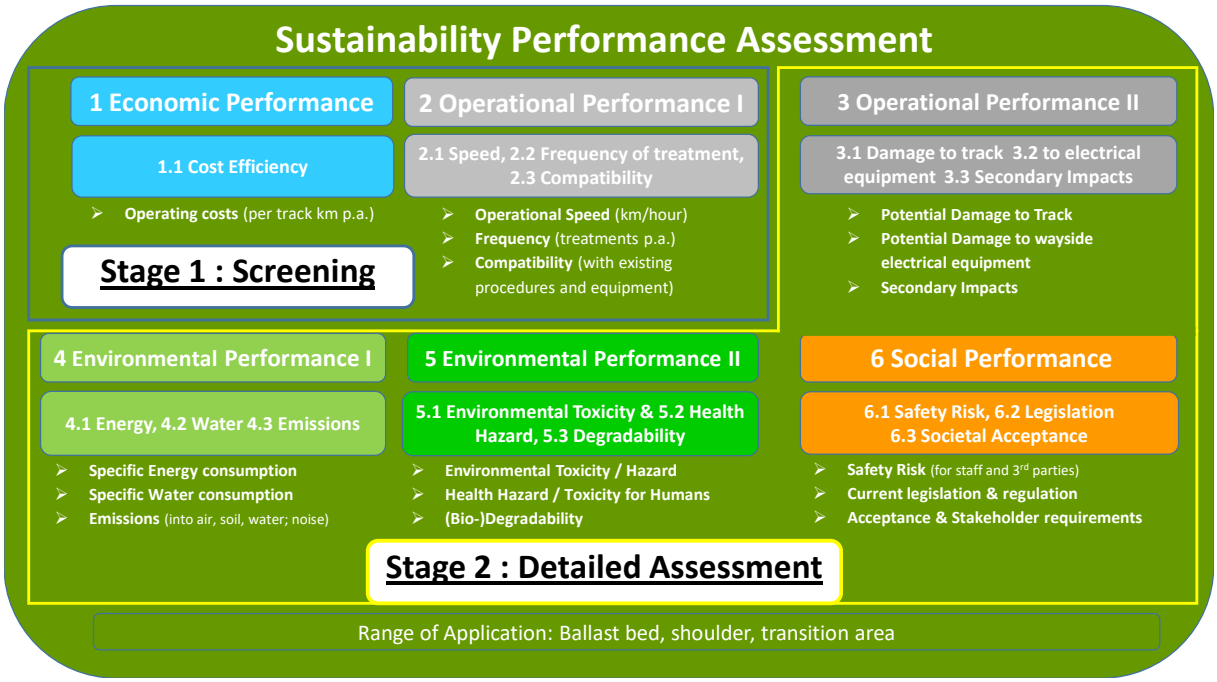


Figure 2: Socio-economic, operational and environmental assessment of methods for vegetation control

1.2.3. Assessment Stage 1: Screening Process with regards to economic performance (cost efficiency) & operational performance (speed, frequency, compatibility)

The screening process is used for a pre-selection of relevant methods of vegetation control for the railway track area in a way that those methods which do not have sufficient potential to substitute conventional methods (especially herbicide-based methods) at least in the mid-term perspective are filtered out. This is achieved by using a combined scoring of economic performance (cost efficiency) and three aspects of the operational performance (operational speed, required annual frequency of treatment and compatibility with existing processes of weed control) since these aspects are crucial for performance and for substitution purposes.

a) Economic performance

The main aspect of the economic performance is cost efficiency – defined as full costs (including equipment, substances, personnel and safety measures) per km of single track p.a.

b) Operational Performance I

The main aspects of the operational performance relevant for the pre-selection are operational speed (in km/h for treating the track area), frequency of treatment (i.e. number of treatments per year needed for a given method to archive the required standard of weed control for the track area : weed-free or very low level of growth for the ballast, defined low coverage rate of the area beside the tracks etc.) and compatibility of the method with existing processes and regimes for vegetation control since these three parameters define performance as well as the effort and resources needed to operate the respective method of weed control.

c) Threshold

Only those methods of vegetation control reaching a combined assessment result of 4 or higher for the combined scoring of cost efficiency and operational performance (excluding damage) are selected for further detailed assessment and investigation. Methods with a combined scoring result below 4 are considered as having not a sufficient performance to become a viable candidate for substituting the highly efficient herbicide-based methods of vegetation control in a mid- or long-term perspective.

d) Exclusion of constructional methods

Since an important focus of the assessment process and tool is on the combined economic and technical performance of the different methods including cost efficiency and operational performance of daily operation, this framework is not adequate to evaluate constructional methods. These methods have therefore to be treated separately and were not the focus of this study, because they have also other objectives than vegetation control. In addition they are typically implemented once in a timeframe of 20 years or more and the criterion of operational speed does not apply. Nevertheless, it should be highlighted that constructional methods have a high impact on costs and efficiency of vegetation control over many years and should therefore be carefully considered when building or renewing track. All other methods of vegetation control can be assessed by the above described tool.

1.2.4. Assessment Stage 2. In-Depth Multidimensional Assessment of the pre-selected Methods

Stage 2 of the Assessment – the in-depth assessment of the selected methods - is then carried out using all dimensions of the sustainability performance and applying the full assessment tool based on the criteria and parameters as illustrated in figure 2.

a) Operational Performance II

In addition to the operational aspects covered above in part I (operational speed, frequency of treatment and compatibility with existing processes for weed control), potential damage to track and electrical equipment as well as potential secondary impacts are covered in the second part (e.g. appearance of resistant plants, long term destabilization of tracks, destruction of drainage) since the corresponding risk and performance levels influence heavily the usability of the different methods in daily operation and the resources required for maintenance issues.

b) Environmental Performance I

For the environmental performance I of the different methods for weed control, 3 important aspects are covered: specific energy consumption (energy use per track km), specific water consumption (water use per track km) and specific emissions (emissions into air, water and soil per km of treated track).

c) Environmental Performance II

Environmental performance II covers two aspects of toxicity – environmental hazard due to toxicity and health hazard as well as the degree of bio-degradability. Environmental and health hazard are defined here according to the Globally Harmonized System of Classification and Labeling of Chemicals – GHS. Bio-degradability is defined according to REACH criteria.

d) Social Performance

Safety risk, legislation & regulation and societal acceptance are the three main aspects of social performance defining the risk and acceptance levels for the different methods of weed control. Safety risk covers the impact of weed control methods on safety of railway staff as well as 3rd parties. Legislation and regulation focuses on the current legal and regulatory framework and related legislative barriers for the different methods of weed control. Societal acceptance comprises both general acceptance of a method of weed control as well as requirements defined by relevant stakeholder groups thus both addressing barriers and obstacles for implementation and operation.

1.3. THE SCREENING PROCESS (COMBINED ECONOMIC & OPERATIONAL PERFORMANCE I)

1.3.1. Identified methods for weed control

Currently there are 36 methods identified for weed control ranging from constructional, biological and mechanical to chemical, thermal and electrical methods (see Figure 3).

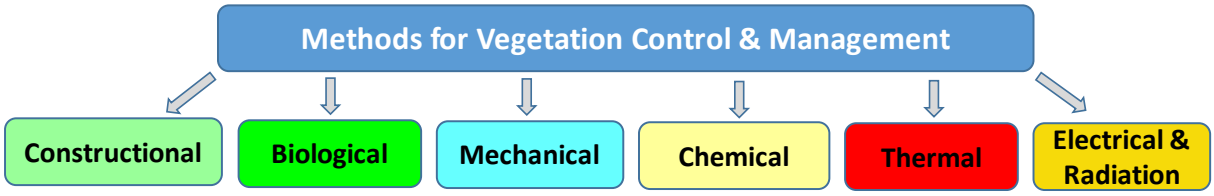


Figure 3: Classification of methods for vegetation control

A good overview can be found in the final report of the UIC Vegetation Control Project (UIC, 2003). The classification developed in this project will be followed with some modifications: Thermal and electrical methods are seen here as to be separate categories and mowing is moved to the category “mechanical” instead of “biological” methods.

Although research and development for technologies and methods of weed control has not been very dynamic over the last 16 years after publication of the UIC report, some methods have been developed further and very few new methods are under development. These updates are integrated into the Herbie project leading to some additions in the overview table. Characteristics and performance values have to be updated for selected technologies documented in the Herbie fact sheets and are taken into account for the multi-dimensional assessment.

The updated overview over the different methods of weed control provides a solid basis for the screening process as the first stage of the assessment:

	A) Constructional		B) Biological		C) Mechanical		D) Chemical		E) Thermal		F) Electrical & Radiation
M1	Lateral plant barriers	M8	Greening	M11	Mowing	M18	Conventional Herbicides with Backpack spraying	M23	Burning/ Flaming	M29	Electro-weeding with Small equipment
M2	Thin vertical plant barriers	M9	Selective embankment maintenance	M13	Ballast cleaning	M19	Conventional Herbicides with Spraying train	M24	Infrared radiation	M30	Microwaves
M3	Plant-inhibiting design of transition area	M10	Biological Weed control	M14	Ballast replacement	M20	Conventional Herbicides with Road-Rail vehicle	M25	Wet steaming with small equipment	M31	Laser cutting
M4	Porous concrete barriers	M12	Mulching	M15	Mechanical weeding	M21	Conv. Herbicides with Spraying train + plant detection	M26	Hot water with Small equipment	M32	UV light
M5	Amount and kind of ballast	M33	Alleophatic Plants	M16	Manual weeding	M22	Conventional Herbicides with Weed wiping	M27	Hot air		
M6	Plant barriers beneath track			M17	Brushing	M35	Organic acids with Small equipment	M28	Freezing		
M7	Slab track					M36	Conventional Herbicides with Small Equipment	M34	Hot foam		

Table 1: Overview and classification of methods for vegetation control (based on UIC Vegetation Control Project, UIC 2003, updated with current information)
Light Yellow = not suitable for track area, Light Violet = excluded due to lack of reliable data

The classification scheme of UIC 2003 (see 4.1 Appendix Part A) has been further developed in Herbie. The full text of the UIC Study on Vegetation Control 2003 is to find on the UIC website https://uic.org/sustainable-land-use.

There are two additions to the list of methods covered (M35-Small equipment with Organic acids and the M36 Small Equipment with conventional Herbicides) and there is a better approach for labeling the methods: Whereas in UIC 2003 there were mainly techniques of vegetation control addressed, in Herbie the labels for the most relevant methods for the track area contain a combination of the vegetation control method/technique (use of conventional herbicides, hot water, electric fields…) and the method of application (e.g. with spraying train, road-rail vehicle, small equipment etc.). This new labeling has the advantage that highly relevant assessment criteria such as cost, efficiency or operational speed can now be quantified much more precisely.

Small equipment is used here for small motorized machinery such as small and medium sized tractors or grass mowers which are equipped with applicators for vegetation management. The operational speed of this machinery depends very much on the motorization itself but also on the area of application. Whereas speeds up to 20 km/h can be reached on paved

roads and pathways. Speeds between 3 to max. 10 km/h are typical for off-road situations.

The assessment is focused on methods for weed control for the track area. Therefore methods, which can only be used for either sealed or unsealed surfaces outside the track area or a limited part of the track area are excluded from further investigation (marked light yellow in table1). An example for a method with only limited applicability for the track area is mowing since it can only be used for the transition area and not for the ballast bed and shoulder. Usually it is used for embankments and unsealed surfaces outside the track area.

Methods which have not yet been sufficiently tested or without reliable data on relevant aspects of the economic performance have also been singled out (marked light violet in table 1). Since plant detection is today state of the art for spraying trains with herbicides, the two methods M19 and M21 can be considered the same. Since the focus of this study is not on preventive measures the constructional methods are not evaluated.

The organic acids (M35, e.g. pelargonic acid) are herbicides like Glyphosate, Flazasulfuron e.g. are subsumed as chemical method even though they are not a technology like the spraying train etc. Actually, these active substances are discussed very intensively as alternatives to the conventional herbicides and should not be forgotten.

The term organic acids is used in this report not in the broad sense of organic compounds with acidic characteristics but in the narrower sense of such compounds which at the same time can be found in nature, like e.g. pelargonic and acetic acid. They can be either obtained from plants or produced synthetically. This meaning of organic acids used sets them apart from the purely synthetic ones such as Glyphosate. Another difference between organic acids which can be found in nature and purely synthetic relevant for railway use is the different risk classification.

More details about the methods of vegetation control relevant for the railway track area can be found in the technology fact sheets in annex C.

1.3.2. Rating of the screening criteria

Now the screening process is performed using one economic parameter cost efficiency combined with the three parameters of operational performance I - operational speed, frequency of treatment and compatibility.

Cost efficiency and operational performance I are rated equally. While cost efficiency is a single factor with 100%, the operational performance I is divided into three factors:

- 40% for operational speed
- 40% for frequency and
- 20% for compatibility.

Since the operating costs for the same method of vegetation control vary significantly from country to country and depend on many factors, a definition of absolute values (€ per track km) for the assessment does not make sense. Therefore, in order to reach comparable results, the operating costs are expressed in relative terms. The current standard method is the spraying train with herbicides (STH). This is the most widely used and cost-efficient method of weed control for the track area and at the same time the one with the best operational performance. Therefore it is defined as the reference method (=baseline). Operating costs for the other methods are thus expressed as multiples of the current standard.

The scales and values for the different assessment parameters are given in table 2:

1. Economic Performance		
Parameter	**value**	**points**
1.1. Cost efficiency / Specific operating costs* (per km of single track - all costs including treatment, equipment, traction, safety…	same as STH	5
	1,2-2x STH	4
	3x-4x STH	3
	5x-10x STH	2
	10x-20x STH	1
	>20x STH	0

*in relative terms, reference = spraying train with herbicide (STH)

2. Operational Performance I		
Parameter	**value**	**points**
2.1. Operational speed*	> 80% of STH (>=40 km/h)	5
	40%-80% of STH (20 to 40 km/h)	4
	20%-40% of STH (10 - 20 km/h)	3
	10%-20% of STH (5 - 10 km/h)	2
	2%-10% of STH (1 - 5 km/h)	1
	< 2% of STH (< 1 km/h)	0
2.2. Frequency of treatment	significantly less than 1x p.a.**	5
	1 - 1,3 x p.a. (as often as STH)	4
	2 x p.a.	3
	3 - 6 x p.a.	2
	7 and more x p.a.	1
2.3. Compatibility	Fully compatible with existing practice	5
	slight adaptations needed	4
	moderated adaptations needed	3
	large adaptations needed	2
	incompatible with existing practice	1

*in relative terms, reference = spraying train with herbicide (STH)
** treatment is only performed every few years - e.g. one per 5….10 years as for ballast cleaning etc.

Table 2: Scales and values for the parameters of the economic performance & operational performance I

Note: Frequency of treatment for spraying train with herbicides is typically 1-1,3 times p.a. In some countries there is only 1 campaign for the spraying train (in spring to summer) covering the network. In other countries there are two annual campaigns– a spring campaign covering a large part of the network and an autumn campaign where only certain hot spots of vegetation growth are covered – leading in average to a cumulated value of 1,3 times p.a. for both campaigns.

1.3.3. Screening results and pre-selection of methods

The following chapter gives an overview over the results of the screening process in terms of a combined rating for economic performance (cost efficiency) and operational performance I (speed, frequency and compatibility). Applying the methodology described in chapter 1.2.3 and using the weighting factors introduced in the previous chapter 1.3.2 yields the following screening scores (S-Scores):

	D) Chemical	S-Score
M18	Conventional Herbicides with Backpack Spraying	7,40
M20	Conventional Herbicides with Road-Rail-Vehicle	8,40
M21	Conventional Herbicides with Spraying Train & plant detection	9,60
M35	Organic Acids with Small Equipment	5,60
M36	Conventional Herbicides with Small Equipment	6,40

	C) Mechanical	E-Score
M13	Ballast cleaning	2,20
M14	Ballast replacement	2,20
M15	Mechanical weeding	3,80
M16	Manual weeding	3,80
M17	Brushing	3,00

	F) Electrical & Radiation	S-Score
M29	Electroweeding with Small Equipment	5,00
M30	Microwaves	3,40

	E) Thermal	S-Score
M23	Burning/Flaming	3,60
M24	Infrared	3,20
M25	Wet Steam with Small Equipment	4,20
M26	Hot Water with Small Equipment	4,60
M27	Hot air	3,80

Table 3: Results of the Screening process: Screening Scores(S-Scores) for the combined economic & operational performance I (cost efficiency & operational speed + frequency of treatment + compatibility) for different methods of weed control.

These results of table 3 were calculated using the parameters and weight factors described above. For the purpose of a better traceability of these results, an example calculation can be found in annex B.

The complete table with the details and results of the screening process of the different methods can be found in table4.

Screening score = score for combined economic performance and operational performance I = cost efficiency * 100% + speed * 40% + frequency of treatment * 40% + compatibility * 20%

No of Method	Method	Operating Costs	Operating Speed	Frequency of treatment	Compatibility (Processes)	Screening Score (S-Score)
		Score / 100%	Score / 40%	Score / 40%	Score / 20%	
Mechanical methods						
M13	Ballast Cleaning	0 / 0	0 / 0	5 / 2.0	1 / 0.2	2.2
M14	Ballast Replacement	0 / 0	0 / 0	5 / 2.0	1 / 0.2	2.2
M15	Mechanical Weeding with Small Equipment	1 / 1	1 / 0.4	3 / 1.2	2 / 0.4	3.0
M16	Manual Weeding	1 / 1	1 / 0.4	3 / 1.2	2 / 0.4	3.0
M17	Brushing with Small Equipment	1 / 1	1 / 0.4	3 / 1.2	2 / 0.4	3.0
Chemical methods						
M18	Conventional Herbicides with Backpack Spraying	5 / 5	1 / 0.4	4 / 1.6	2 / 0.4	7.4
M20	Conventional Herbicides with Road-Rail vehicle	4 / 4	5 / 2.0	4 / 1.6	4 / 0.8	8.4
M21	Conventional Herbicides with Spraying Train	5 / 5	5 / 2.0	4 / 1.6	5 / 1.0	9.6
M22	Conventional Herbicides with Weed Wiping	1 / 1	1 / 0.4	4 / 1.6	2 / 0.4	3.4
M35	Organic Acids with Small Equipment	3 / 3	3 / 1.2	3 / 1.2	3 / 0.6	6.0
M36	Conventional Herbicides with Small Equipment	3 / 3	3 / 1.2	4 / 1.6	3 / 0.6	6.4
Electrical & Radiation Methods						
M29	Electroweeding with Small Equipment	2/2	2 / 0.8	4 / 1.6	3 / 0.6	5
M30	Microwaves	1/1	1 / 0.4	4 / 1.6	2 / 0.4	3,4

Thermal Methods						
M23	Burning/Flaming with Small Equipment	2 / 2	2 / 2	1 / 0.4	2 / 0.4	3.6
M24	Infrared Radiation with Special Train	1 / 1	1 / 0.4	3 / 1.2	3 / 0.6	3.2
M25	Wet steaming with Small Equipment	2 / 2	2 / 0.8	2 / 0.8	3 / 0.6	4.2
M26	Hot water with Small Equipment	2 / 2	2 / 0.8	3 / 1.2	3 / 0.6	4.6
M27	Hot air with Small Equipment	2 / 2	1 / 0.4	2 / 0.8	3 / 0.6	3.8

Table 4: Detailed results of the Screening process: Weighted scores for the combined economic & operational performance I (cost efficiency & operational speed + frequency of treatment + compatibility) for different methods of weed control

Note: The very good economic performances score for backpack spraying is based on data from Switzerland only. In Switzerland, backpack spraying with conventional herbicides is the basic method which is used on a large scale (for the whole network). Thus, the very good economic performance of backpack spraying in Switzerland is based on widespread use and a very high level of optimization. Processes are smooth & the service is rather cheap (per track km). In other countries, backpack spraying is only used as an additional method of vegetation control for much smaller areas or lengths of track. Since this kind of service is not highly standardized and optimized, it is much more expensive.

A) The specific situation of organic acids

Although organic acids could be used with different motorized methods of application (spraying train, road-rail vehicle, small equipment), they are assessed here only in combination with small equipment since the solutions with higher operational speed and better performance (spraying train and road rail vehicle) are not yet implemented – neither commercially nor as pilot projects. Current projects and activities focus on pelargonic (also known as nonanoic acid) acid, but in the future also other organic acids could be investigated.

There is an active ongoing discussion about the use of pelargonic acid for either substituting or complementing Glyphosate and the first results coming out of pilot projects are already indicating it`s limits.

One of the main restricting issues here is the required high quantities of organic acid (e.g. pelargonic acid) plus water per hectare which still prevents the usage of spraying trains or road-rail vehicles with comparable equipment. Another significant barrier for the application of e.g. pelargonic acid in the railway sector is due to the fact that this substance is so far not approved and certified for use for the railway track area. Non-motorized methods of application such as backpack spraying and manual weed wiping do not have to be assessed separately in combination with organic acids since the very low operational speed combined with the rather high specific cost make them not suitable for hundreds or thousands of kilometers of railway track.

It should also be mentioned that pelargonic acid is – in contrast to Glyphosate - not a systemic herbicide. It basically impacts all parts of a plant growing above ground. Therefore,

plants are not fully destroyed by applying pelargonic acid and regrowth occurs. Results from first pilot projects on railways indicate that at least 3 to 4 treatments per year may be necessary for the same level of vegetation control, as it is the case for systemic herbicides. One substantial drawback that has been reported from Austrian field-tests is that pelargonic acid has a nauseous odor, which can be a problem when using it in railway stations or close to settlements. Recent reports from Bayer Crop Science suggest that the results of treatment of large areas as e.g. railway tracks with pelargonic acid can be improved by combining pelargonic acid with a pre-emergent herbicide such as Diflufenican (pers. communication). Nevertheless, in that case, it is a mixture of conventional herbicides and organic acids.

B) Spraying train as a reference

As can be seen in table 3, the screening results expressed as combined rating for economic performance (cost efficiency) and operational performance I (speed, frequency and compatibility) for different methods of weed control vary widely. The highest score (9.6 out of 10) has – as to be expected - the spraying train with herbicides and state of the art plant detection system. The lowest scores (2.2 out of 10) have the two mechanical methods related to ballast cleaning and ballast renewal because of their very low operational speed and the immensely high costs per track km.

It is necessary to define a threshold value for the combined economic performance, which has to be reached in order to be selected for the second stage of the assessment process. With regard to the high importance of the assessment criteria cost efficiency and operational performance there should be acceptable values in relation to the reference method – the spraying train with herbicides. Hence a threshold value of 4 was set, because it allows different alternative methods to pass the first stage. At the same time it cuts off those methods with a performance too low to be viable candidates to substitute herbicide-based treatments in the future.

One should also keep in mind that the assessed methods and technologies have a different status of maturity. It ranges from fully matured technologies already commercially used for the track area like spraying trains with conventional herbicides to technologies which are commercially available only for urban purposes or even smaller areas. The latter ones may have still an interesting development potential and with appropriate Research and Development efforts, an increase of the general performance can be expected. If the research and adaptation measures explicitly address the application context and specific conditions or the railway track area, the related performance increases could be substantial.

As the result of the first stage of the assessment ("Screening"), the following methods of weed control have been selected for stage 2 the detailed assessment:

	D) Chemical	S-Score
M18	Conventional Herbicides with Backpack Spraying	7,40
M20	Conventional Herbicides with Road-Rail-Vehicle	8,40
M21	Conventional Herbicides with Spraying Train & plant detection	9,60
M35	Organic Acids with Small Equipment	5,60
M36	Conventional Herbicides with Small Equipment	6,40

	E) Thermal	S-Score
M25	Wet Steam with Small Equipment	4,20
M26	Hot Water with Small Equipment	4,60
	F) Electrical & Radiation	S-Score
M29	Electroweeding with Small Equipment	5,00

Table 5: Selected methods of weed control for detailed assessment after completion of the screening process (S-Score = screening score)

As it can be seen in table 5, all together eight methods of weed control have been selected for stage 2 the detailed assessment. They comprise five herbicide-based methods (M18, M20, M21, M35 and M36) and three non-chemical methods (M25, M26 and M29).

It seems surprising, that mowing as the most widely used mechanical method for railways and today's standard fallback option if conventional herbicides cannot be used, did not even enter the screening procedure. But as it has been already mentioned above, only methods which could be used on all parts of the track area – ballast bed, ballast shoulder and transition area – have been taken into account. Mowing is clearly not applicable for the ballast bed (see also point 1.3.1).

In addition to these essential limitation, the combined economic and operational performance of mowing is very poor because of a very low cost efficiency (mowing is approximately 10-15 times more costly than conventional herbicides with spraying train), a high required number of treatments per year as well as a low operational speed (typically 1-3 km/h).

1.4. ASSESSMENT STAGE 2: DETAILED MULTI-DIMENSIONAL ASSESSMENT

1.4.1. Introduction

The second stage of the assessment consists of a detailed multi-dimensional assessment of the selected methods for weed control taking into account all three dimensions of the sustainability performance – the economic, environmental and social. It is carried out by the application of the Herbie Assessment tool (see also Chapter 1.2).

1.4.2. Weighting factors

Beside a detailed table, a graphical representation of the sustainability performance profile based on the assessment tool is produced for each method selected in stage 1 – the screening.

The Economic performance (cost efficiency) & operational performance I (speed, frequency, compatibility) have already been assessed during the screening process (see table 4).

The next steps are the assessment of the operational performance II (potential damage and secondary impacts) as well as the environmental and social performance.

Sustainability Performance Assessment				
1. Economic Performance	**1.1.** Cost efficiency (points for specific costs per track km in relation to Spraying train with conv. herbicides)			total score economic performance
single score	5			
weighting factor	100%			5.00
2. Operational Performance I	**2.1.** Operational Speed (points for speed level)	**2.2.** Frequency (points for required treatments p.a.)	**2.3.** Compatibility (points for required adaptations)	total score operational performance I
single score	3	3	3	
weighting factors	40%	40%	20%	3.00

Screening Score = Combined score for economic performance and operational performance I				8.00
3. Operational Performance II	**3.1. Damage to track parts** (points for damage level)	**3.2. Damage to electrical equipment** (points for damage level)	**3.3. Secondary Impacts** (points for impact level)	total score operational performance II
single score	3	3	3	
weighting factors	40%	35%	25%	3.00
4. Environmental Performance I	**4.1. Energy Consumption** (points for energy efficiency)	**4.2. Water Consumption** (points for water efficiency)	**4.3. Emissions** (points for emission level into air. water. soil)	total score environmental performance I
single score	4	4	4	
weighting factors	55%	30%	15%	4.00
5. Environmental Performance II	**5.1. Environmental Hazard** (points for hazard level)	**5.2. Health Hazard** (points for hazard level)	**5.3. Degradability** (points level of degradability)	total score environmental performance II
single score	3	4	3	
weighting factors	40%	40%	20%	3.40
6. Social Performance	**6.1. Safety Risk** (points for risk level)	**6.2. Legislation & Regulation** (points for legislative barriers)	**6.3. Acceptance** (points for level of societal acceptance)	total score social performance I
single score	2	2	4	
weighting factors	30%	40%	30%	2.60

Table 6: Multidimensional assessment tool for stage two with the weighting of the different parameters

The weighting factors for this assessment tool have been jointly developed by the experts of the SLU Expert Group (Sustainable Land-use Expert Group of UIC) within the framework of a consultation process with multiple feedback loops integration relevant knowledge from internal and external sources. The final version of the weighting factors has been agreed upon at the SLU meeting in September 2018.

1.4.3. Scales and values of the scoring system

The parameters of the assessment and their respective scales and values are shown in the following tables. More details about the parameters can be found in chapter 1.2.4 on the methodology of the multi-dimensional assessment. The settings for the economic performance are already described for stage 1 (“Screening” – see table 2).

a) Settings for the operational performance II

3. Operational Performance II		
Parameter	**value**	**points**
3.1. Damage to track	small risk of damage	5
	moderate risk of damage	3
	high risk of damage	1
3.2. Damage to electrical equipment	small risk of damage	5
	moderate risk of damage	3
	high risk of damage	1
3.3. Secondary Impacts	small	5
	moderate	3
	high	1

Table 7: Scales and values for the parameters of the operational performance II (potential damage to track and electrical equipment and secondary impacts)

Since the parameters for operational performance II (potential damage and secondary impacts) are much more difficult to quantify and have to be assessed mostly on a qualitative basis, the scales of the scoring system on table 7 have been reduced here from 5 (1-5) to 3 values (1;3;5).

b) Environmental performance I and II

Tables 8 and 9 include the parameters, scales and values for the environmental performance. Environmental performance I comprises specific energy and water consumption as well as emissions into air, water and soil:

4. Environmental Performance I		
Parameter	**value**	**points**
4.1. Energy Consumption*	lower than STH	5
	same as STH	4
	2x-3x consumption of STH	3
	4x-6x consumption of STH	2
	>=7x consumption of STH	1
4.2. Water Consumption	no water consumption	5
	low water consumption (up to 100 l/ha)	4
	medium consumption STH (100-500 l/ha)	3
	high water consumption (500-2.000 l/ha)	2
	very high water consumption (>2.000 l/ha)	1
4.3. Emissions (into air, water, soil; noise)	no emissions	5
	moderate emissions	3
	high emissions	1

*in relative terms, reference = spraying train with herbicides (STH)

Table 8: Scales and values for the parameters of the environmental performance I (energy consumption, water consumption and emissions into air, soil and water.

As can be seen in table 8, the specific energy consumption is defined in relative terms with the energy consumption of the reference method - spraying train with herbicides – is defined as 1, whereas the specific water consumption (water use per ha) is defined in absolute values. As for the operational performance II, the number of values for the parameter emissions into soil, water and air has been reduced to 3 (1;3;5) since the assessment has to be performed here qualitatively.

Environmental performance II comprises environmental and health hazard as well as and bio-degradability (table 9). For the environmental and health hazards there are only 4 values available since the criteria are directly derived from the CLP classification of hazardous substances. For bio-degradability there are again 5 values since these can be directly derived from OECD/REACH criteria for bio-degradability.

5. Environmental Performance II		
Parameter	**value**	**points**
5.1. Environmental Hazard	not harmful	5
	harmful	3
	toxic	2
	very toxic	1
5.2. Health Hazard	not harmful	5
	harmful	3
	toxic	2
	fatal	1
5.3. Bio-Degradability	readily biodegradable - high	5
	readily biodegradable - average	4
	moderately biodegradable	3
	persistent (P)	2
	very persistent (vP)	1

Table 9: Scales and values for the parameters of the environmental performance II (environmental hazard, health hazard and bio-degradability.)

Environmental hazard (5.1) and health hazard (5.2) are defined according to the criteria and classification system of the Regulation (EC) No 1272/2008 on classification, labeling and packaging of substances and mixtures – the so-called CLP Regulation (https://echa.europa.eu/documents/10162/23036412/clp_en.pdf)

According to this regulation, the properties toxic, harmful etc. are attributed to the concentrated active substance. It should be noted that in terms of environmental hazards, CLP only covers the hazards for aquatic environments.

c) Social performance

Since some parameters are much more difficult to quantify and have to be assessed mostly on a qualitative basis, the scales of the scoring system have been reduced to 3 values instead of 5 in table 10. This reduction has been chosen for the three parameters of the social performance – safety risk, current legislation & regulation and acceptance and stakeholder requirements:

6. Social Performance		
Parameter	**value**	**points**
6.1. Safety Risk (staff & 3rd parties)	low safety risk	5
	moderate safety risk	3
	high safety risk	1
6.2. Current legislation & regulation	no restrictions & barriers	5
	moderate restrictions & barriers	3
	high restrictions and barriers	1
6.3. Acceptance & Stakeholder requirements	high acceptance, some requirements	5
	moderate acceptance & requirements	3
	low acceptance, high requirements	1

Table 10: Scales and values for the parameters of the social performance (safety risk, current legislation & regulation and acceptance and stakeholder requirements)

1.4.4. Results of the Sustainability Performance Assessment – Stage 2

As already mentioned before, the assessed methods and technologies have different levels of maturity and commercialization, especially with respect to the application for the railway track area.

Therefore, two different assessment groups are formed:

- **Group A:** comprises all selected methods which are already fully matured and commercially used for the track area:

Methods commercially used for track area		S-Score
M18	Conventional Herbicides with Backpack Spraying	7,40
M20	Conventional Herbicides with Road-Rail-Vehicle	8,40
M21	Conventional Herbicides with Spraying Train & plant detection	9,60
M36	Conventional Herbicides with Small Equipment	6,40

Table 11: Methods commercially used for track area

- **Group B:** comprises all selected methods resp. active substances which are currently commercially used outside track area (e.g. for urban services or in agriculture), with small equipment and which have a high development potential for railway track area. So far these methods have not been officially approved by authorities for the use in the railway sector.

Methods with high potential for track area		S-Score
M25	Wet Steam with Small Equipment	4,20
M26	Hot Water with Small Equipment	4,80
M29	Electroweeding with Small Equipment	5,00
M35	Organic Acids with Small Equipment	6,00

Table 12: Methods with high potential for track area

The application of the multi-dimensional Assessment Tool to the selected methods for weed control produces the following detailed Assessment Results (tables 12 and 13) and Sustainability Performance Profiles (fig 4-11):

			Conventional Herbicides with			
			Spaying Train	Road-Rail Vehicle	Small Equipment	Backpack Spraying
			M21	M20	M36	M18
1.1	Operating Costs	100%	5 / 5.0	4 / 4.0	3 / 3.0	5 / 5.0
	Score economic Performance		**5,00**	**4,00**	**3,00**	**5,00**
2.1	Operating. Speed	40%	5 /2.0	5 /2.0	3 / 1.2	1 / 0.4
2.2	Frequency of treatment	40%	4 / 1.6	4 / 1.6	4 / 1.6	4 / 1.6
2.3	Compatibility (Processes)	20%	5 /1.0	4 / 0.8	3 / 0.6	2 / 0.4
	Score operational performance I		**4,60**	**4,40**	**3,40**	**2,40**
3.1	Damage risk for track	40%	5 /2.0	5 /2.0	5 /2.0	5 /2.0
3.2	Damage risk electrical equipment	35%	5 / 1.75	5 / 1.75	5 / 1.75	5 / 1.75
3.3	Secondary Impacts	25%	3 / 0.75	3 / 0.75	3 / 0.75	3 / 0.75
	Score operational performance II		**4,50**	**4,50**	**4,50**	**4,50**
4.1	Energy consumption	55%	4 / 2.2	4 / 2.2	4 / 2.2	5 / 2.75
4.2	Water consumption	30%	3 / 0.9	3 / 0.9	3 / 0.9	3 / 0.9
4.3	Emissions	15%	3 / 0.45	3 / 0.45	3 / 0.45	3 / 0.45
	Score environmental performance I		**3,55**	**3,55**	**3,00**	**4,10**
5.1	Environmental hazard	40%	2 / 0.8	2 / 0.8	2 / 0.8	2 / 0.8
5.2	Health hazard	40%	2 / 0.8	2 / 0.8	2 / 0.8	2 / 0.8
5.3	Bio-Degradability	20%	3 / 0.6	3 / 0.6	3 / 0.6	3 / 0.6
	Score environmental performance II		**2,60**	**2,60**	**2,60**	**2,60**
6.1	Safety risk	30%	3 / 0.9	3 / 0.9	3 / 0.9	3 / 0.9
6.2	Legislation & regulation	40%	1 / 0.4	1 / 0.4	1 / 0.4	1 / 0.4
6.3	Acceptance	30%	1 / 0.3	1 / 0.3	1 / 0.3	1 / 0.3
	Score social performance		**1,60**	**1,60**	**1,60**	**1,60**

Table 13: Detailed results of the multi-dimensional assessment: Weighted scores for all 6 assessment dimensions (economic performance, operational performance / and //, environmental performance I and II, social performance) for Group A – Methods of weed control commercially used for the track area.

			Organic Acids	Wet Steaming	Hot Water	Electro-Weeding
			Small Equipment	Small Equipment	Small Equipment	Small Equipment
			M35	M25	M26	M29
1.1	Operating Costs	100%	3	2	2	2
	Score economic Performance		**3,00**	**2,00**	**2,00**	**2,00**
2.1	Operating Speed	40%	2,00	2,00	2,00	2,00
2.2	Frequency of treatment	40%	3,00	2,00	3,00	4,00
2.3	Compatibility (Processes)	20%	3,00	3,00	3,00	3,00
	Score operational performance I		**2,60**	**2,20**	**2,60**	**3,00**
3.1	Damage risk for track	40%	5,00	3,00	3,00	5,00
3.2	Damage risk electrical equipment	35%	5,00	3,00	3,00	5,00
3.3	Secondary Impacts	25%	3,00	3,00	3,00	5,00
	Score operational performance II		**4,50**	**3,00**	**3,00**	**5,00**
4.1	Energy consumption	55%	4,00	3,00	2,00	3,00
4.2	Water consumption	30%	2,00	2,00	2,00	5,00
4.3	Emissions	15%	3,00	3,00	3,00	3,00
	Score environmental performance I		**3,25**	**2,70**	**2,15**	**3,60**
5.1	Environmental hazard	40%	3,00	5,00	5,00	5,00
5.2	Health hazard	40%	3,00	3,00	3,00	5,00
5.3	Degradability	20%	5,00	5,00	5,00	5,00
	Score environmental performance II		**3,40**	**4,20**	**4,20**	**5,00**
6.1	Safety risk	30%	3,00	3,00	3,00	3,00
6.2	Legislation & regulation	40%	3,00	5,00	5,00	5,00
6.3	Acceptance	30%	3,00	5,00	5,00	5,00
	Score social performance		**3,00**	**4,40**	**4,40**	**4,40**

Table 13: Detailed results of the multi-dimensional assessment: Weighted scores for all 6 assessment dimensions (economic performance, operational performance / and //, environmental performance I and II, social performance) for Group B – Methods of weed control with high potential for the track area.

1.4.5. Sustainability performance of methods of vegetation control commercially used for the track area

The next four figures represent the sustainability performance of Group A which comprises all selected methods which are already fully matured and commercially used for the track area with use of conventional herbicides:

a) Conventional Herbicides with Spraying Train

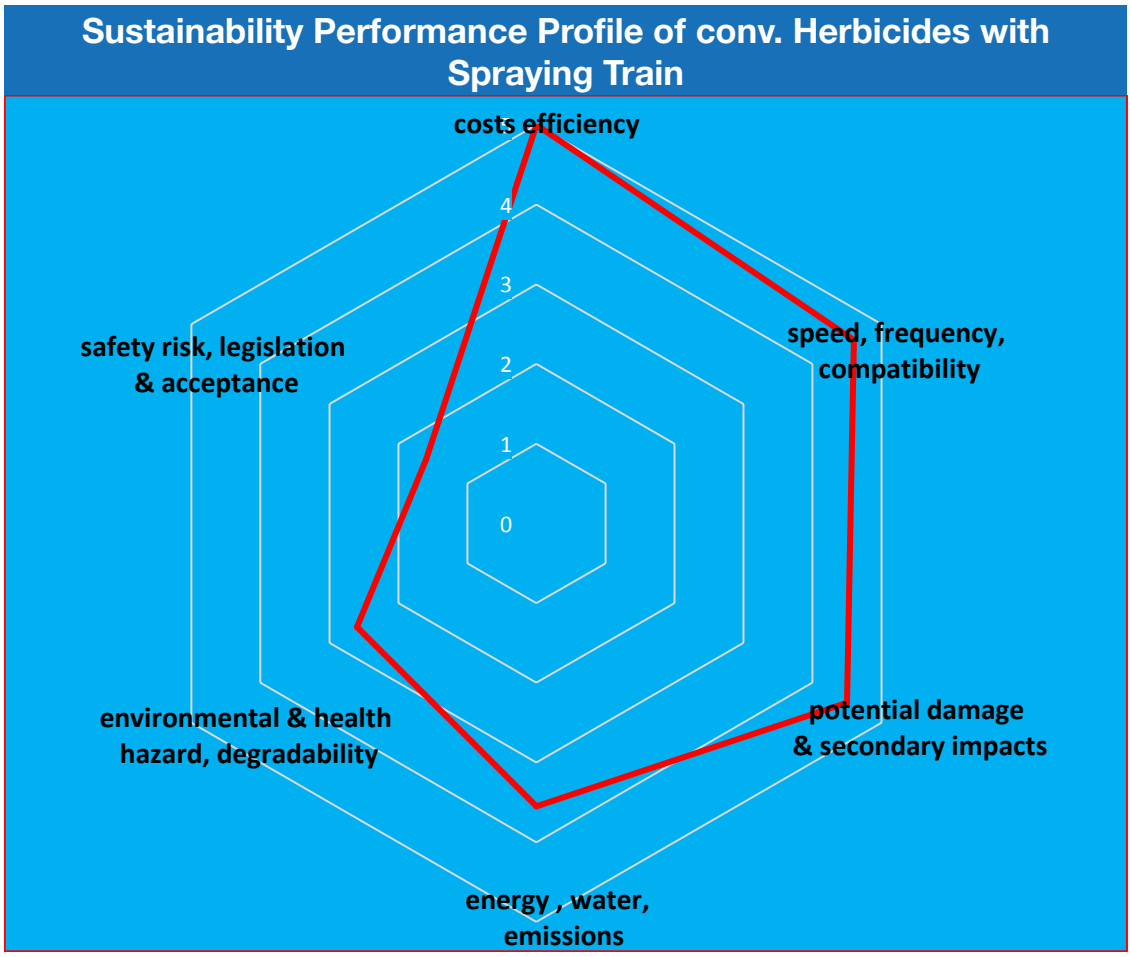


Figure 4: Sustainability Performance Profile for the reference method – Conventional herbicides applied by spraying train with automatic plant detection

The Sustainability Performance Profile for the reference method –conventional herbicides (mainly based on the use of the herbicide Glyphosate) applied with state-of-the-art spraying trains with automatic plant detection – shows an excellent combined economic and operational performance with a score 5 out of 5 for cost efficiency, 4.6 for operational performance I (speed, frequency of treatment, compatibility) and 4.5 for operational performance II. The score for the first part of the environmental performance (energy, water and emissions) is also good (3.55). More problematic is the value for the second part of the environmental performance (environmental and health hazard, bio-degradability (2.6). But clearly the greatest problem of this method is the low value (1.6) for the social performance (safety risk, legislation and acceptance). While the score for safety risk is still ok, both variables have the lowest possible scores: (1) for current legislation and regulation and acceptance and stakeholder requirements. The current intense political debate about Glyphosate clearly shows that today's reference method in combination with the active ingredient Glyphosate is far away from being future

proof and makes an intensified search for viable replacements resp. new active substances necessary. This is also reflected in the intense discussions about the prolongation of the Glyphosate license at the end of 2017, the negotiated compromise of a five year prolongation and the growing political pressure for this issue.

The three other methods for vegetation control based on conventional herbicide use (assessment results here are based on Glyphosate as the most wide-spread active substance) show similar Sustainability Performance Profiles with some modifications for the economic and operational performance due to the fact that the most influencing parameter is the public opinion concerning the use of herbicides:

b) Conventional Herbicides with Road-Rail-Vehicles

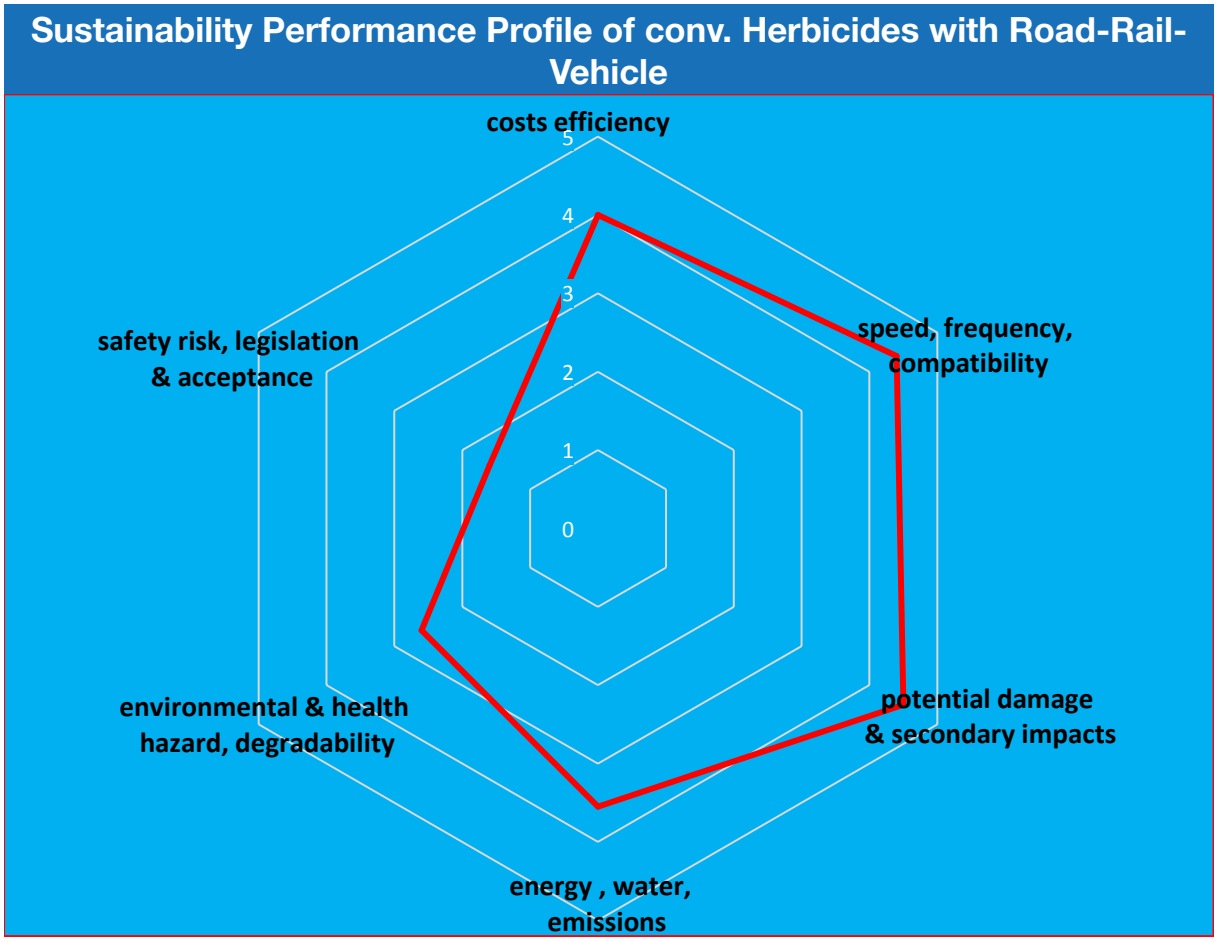


Figure 5: Sustainability Performance Profile for the road-rail vehicles for the application of conventional herbicides.

Road-rail vehicles have higher costs and a lower process compatibility than spraying trains. Therefore, the scores for cost efficiency is 4 and for the operational performance I (speed, frequency and compatibility) 4.4. All other values are unchanged compared with the data of spraying train with conventional herbicides. A substantial improvement potential could be realized, if road-rail vehicles would also be equipped with automatic plant detection systems, increasing the cost efficiency and reducing the amount of herbicides used. Currently there is some R&D-work done to achieve this. Of course the method faces the same problems as the spraying train with herbicides (mainly based on the use of Glyphosate), but this improvement should also be relevant for other active substances or methods. The more target-oriented a method can be designed, the better.

c) Conventional Herbicides with Small Equipment

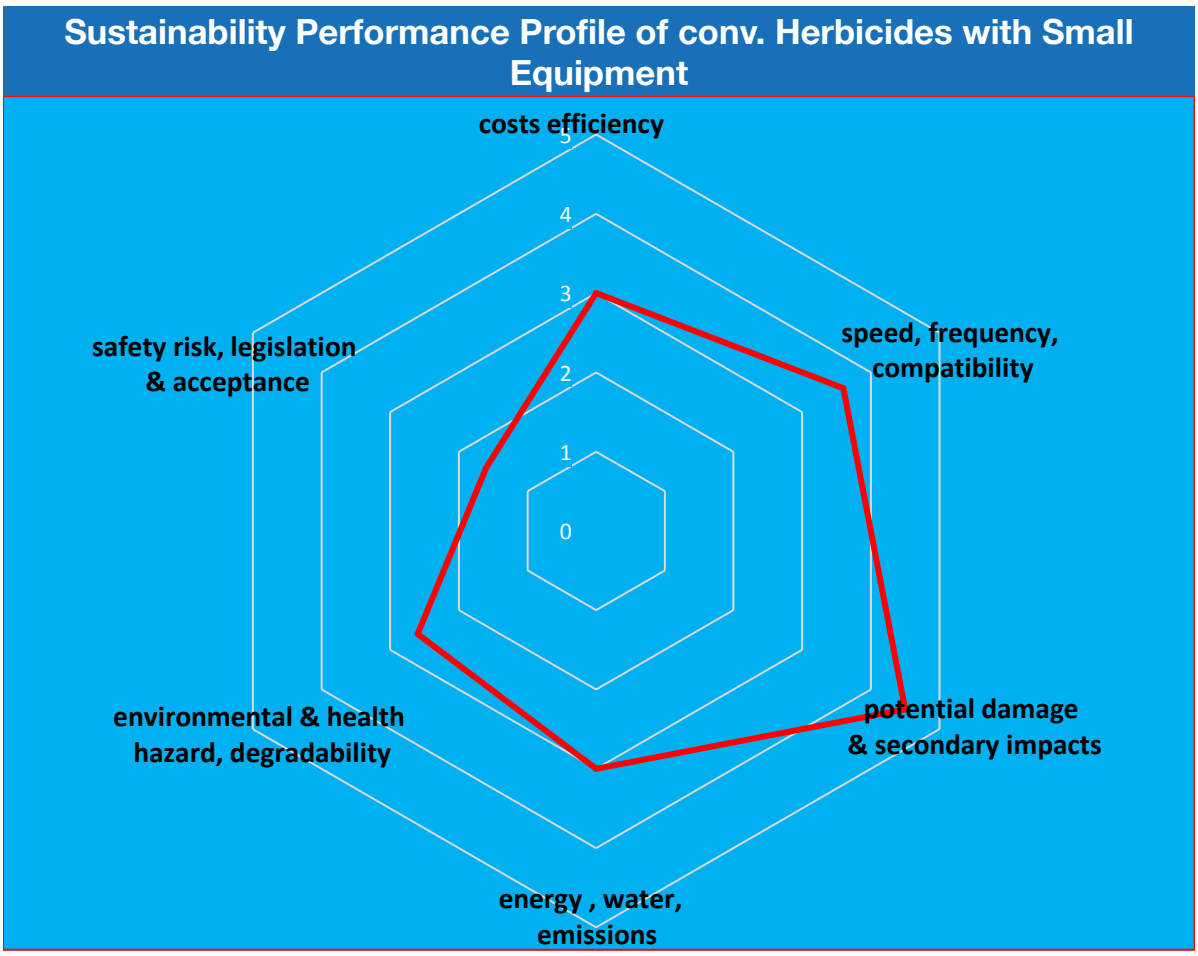


Figure 6: Sustainability Performance Profile for using small equipment for the application of conventional herbicides.

Using small equipment for the application of conventional herbicides lowers the operational speed even further down to 10 to 20 km/h, and cost-efficiency is typically lower by a factor of 2 with respect to road-rail-vehicles. The improvement potential of this method is related to the same issue as for road-rail vehicles. Automatic detection systems would be a huge improvement.

d) Conventional Herbicides with Backpack spraying

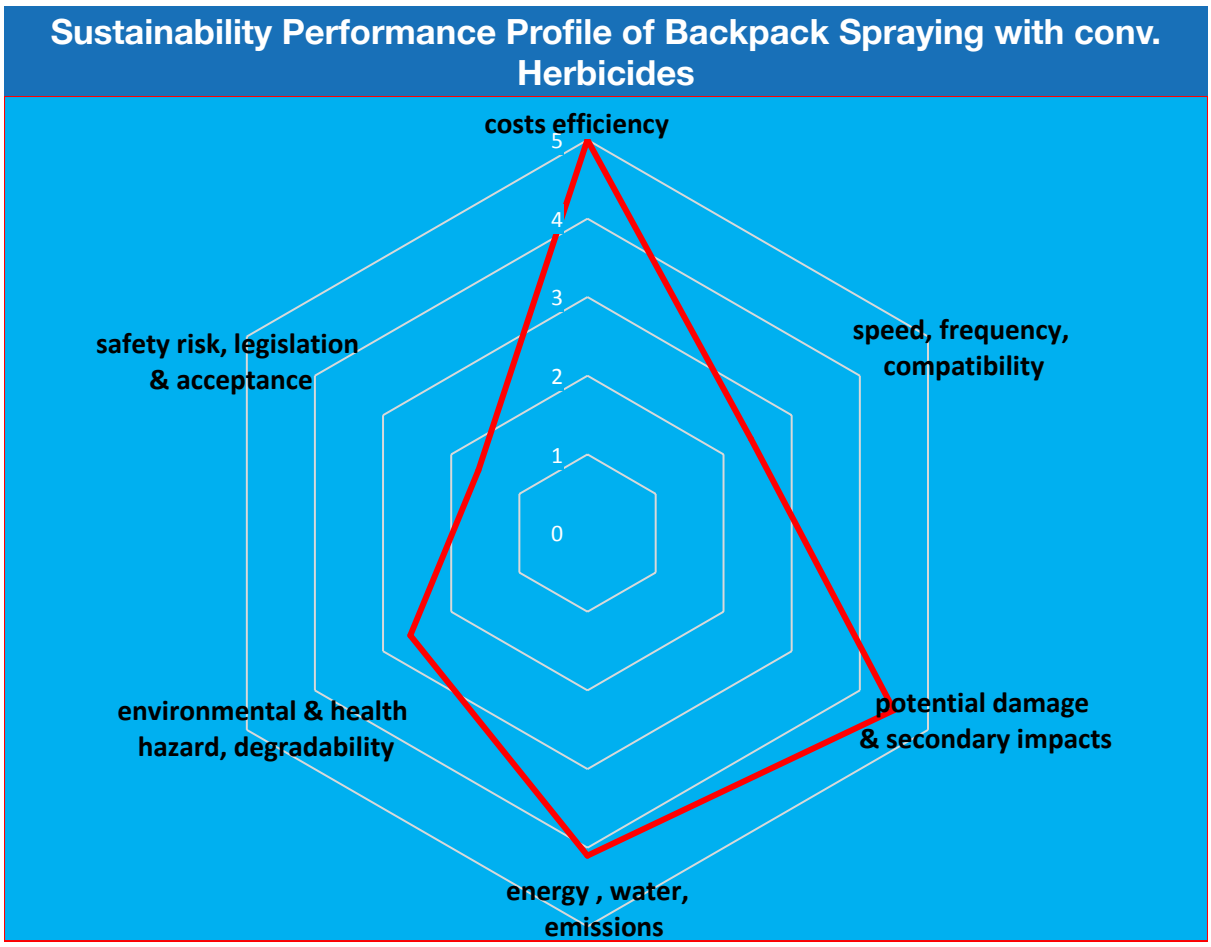


Figure 7: Sustainability Performance Profile for the backpack spraying of conventional herbicides.

Backpack spraying of herbicides has a significantly lower operational speed compared to spraying trains and road-rail vehicles. But the cost efficiency can be as high as the one of the spraying train as the SBB example shows. There is very little improvement potential for this method and the problems are the same as for all other methods based on the use of conventional herbicides (mainly based on the use of the herbicide Glyphosate).

1.4.6. Sustainability performance of methods of weed control with high developing potential for the track area

The next four figures represent the sustainability performance of the selected alternative methods of weed control with high developing potential for the track area (group B) – one chemical, one electrical and two thermal methods.

It has to be kept in mind that the sustainability performance for these methods is based on the current performance outside railways – typically in an urban context or in organic agriculture. It does not reflect the improvements which can be expected with sufficient research & development and adaptation efforts. This is especially true for cost performance and operational speed. Due to the status of the alternative technologies discussed here which are currently only used with small equipment and low degree of automation, the corresponding costs are still relatively high and operational speeds comparatively low. With increasing automation and use of special rolling stock both parameters could be improved considerably. In the final chapter of this report the issue of future development and performance potential will be discussed in more detail.

The alternative chemical method resp. active substance is the application of organic acids.

a) Organic Acids with Small Equipment

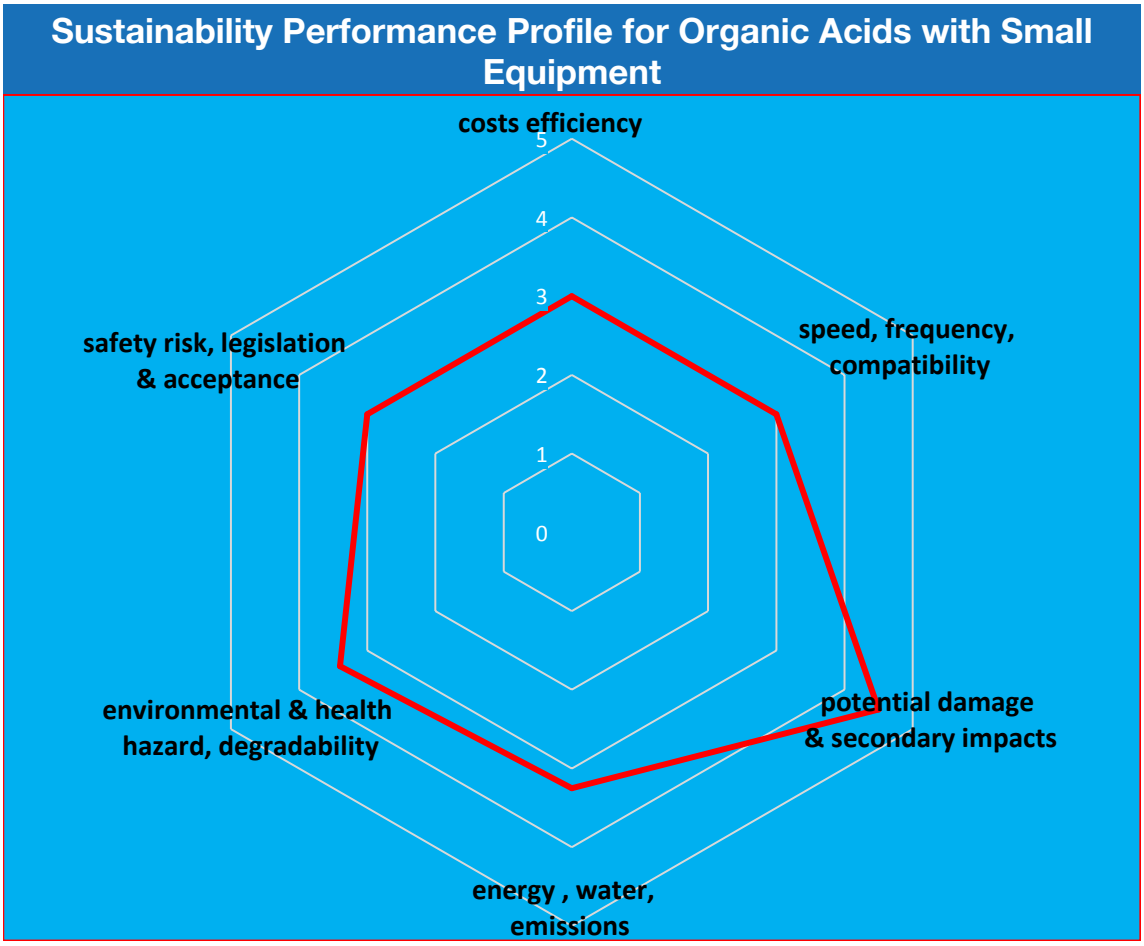


Figure 8: Sustainability Performance Profile for Organic Acids.

It has to be pointed out that organic acids are not a new method or technology but an alternative herbicide resp. active substance. Currently there is no pelargonic acid product available, which has already been approved for the railway-sector. Basically, organic acids could be applied with the same methods as conventional herbicides. But since the amount of ready mixture of organic acids and water to be applied per ha is much higher than for conventional herbicides, organic acids are still not ready to be applied with spraying trains or road-rail vehicles. This current restriction to either small equipment or backpack spraying is the reason that the speed is still restricted to about 10 km/h but future improvements in this area are very likely.

Despite this restriction the combined economic and operational performance is still good (6.0). The costs are higher (by an estimated factor of 3 to 5 because of the high amount of organic herbicides and water required and the current restriction to methods with low degree of automation) in comparison to methods based on conventional herbicides. The frequency of application is increased compared to the one for conventional herbicides since pelargonic acid mainly destroys the leaves and not the roots (non-systemic herbicide). The first pilot projects indicate that 3-4 applications p.a. are needed to achieve the same level of vegetation control as for conventional herbicides. Compatibility with existing processes and equipment for chemical weed control is very high.

The potential damage to track and electrical equipment is considered to be higher as for the reference method since the amount of water to be sprayed onto the tracks would be much higher and the solution is known as corrosive as well – hence the rating 3 (moderate risk of damage).

This method of weed control is not yet adapted to and commercially available for the railway track area. Nevertheless, recent information and new pilot projects suggest that the current barriers - high amount of organic acids and water required per hectare, restricting the methods of application to small equipment and backpack spraying and resulting in higher costs and lower operational speed – could be overcome.

The environmental performance 2 - environmental and health hazard & degradability - is better (3.4) than the one for methods based on conventional herbicides (score 2.6) and especially the higher score for the social performance - safety risk, current legislation and regulation & acceptance - score 3.0 combined with the improvement potential for cost performance and operational speed make this option very interesting and promising for the future.

The two thermal alternatives are hot water and wet (saturated) steam:

b) Hot Water

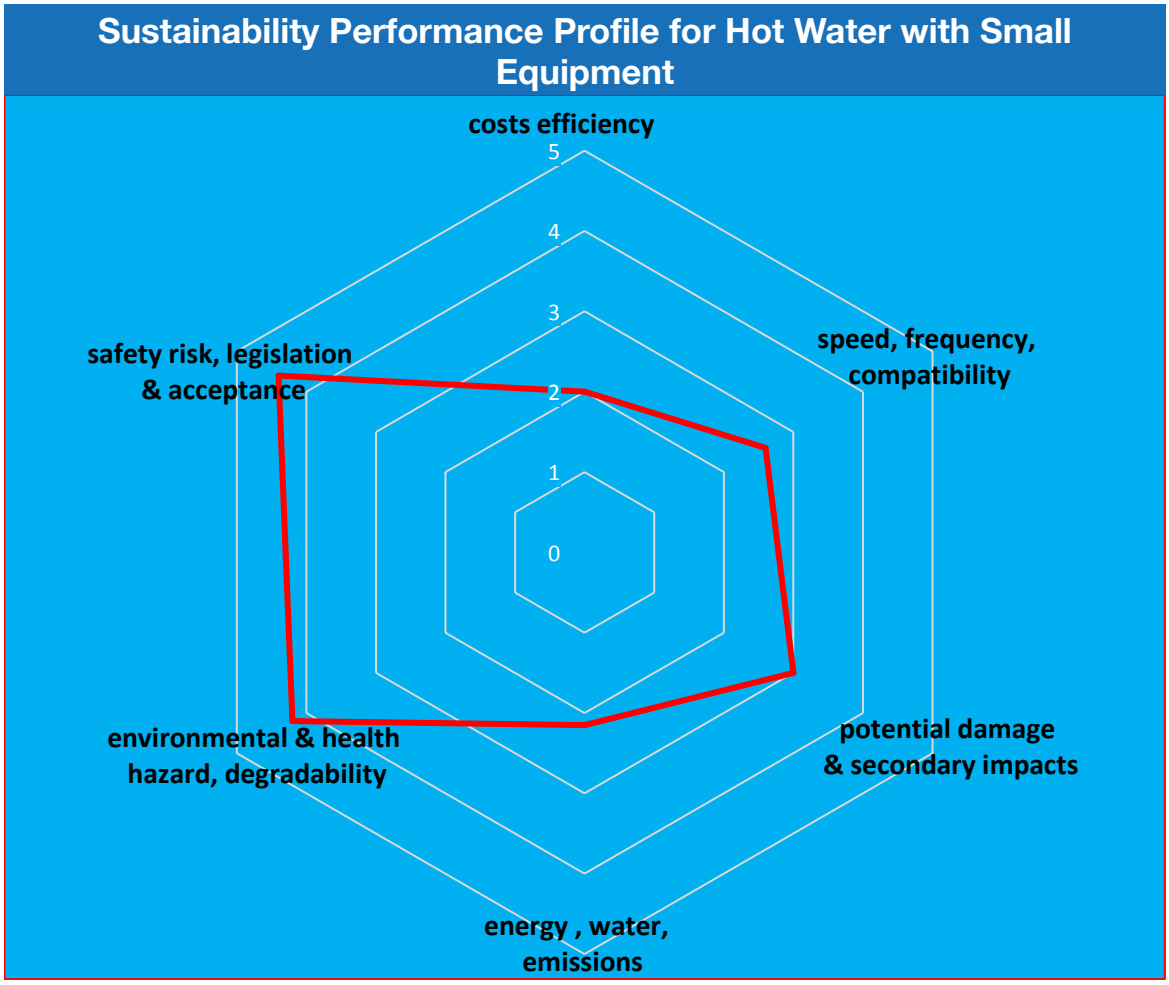


Figure 9: Sustainability Performance Profile for the application of hot water.

c) Wet Steam

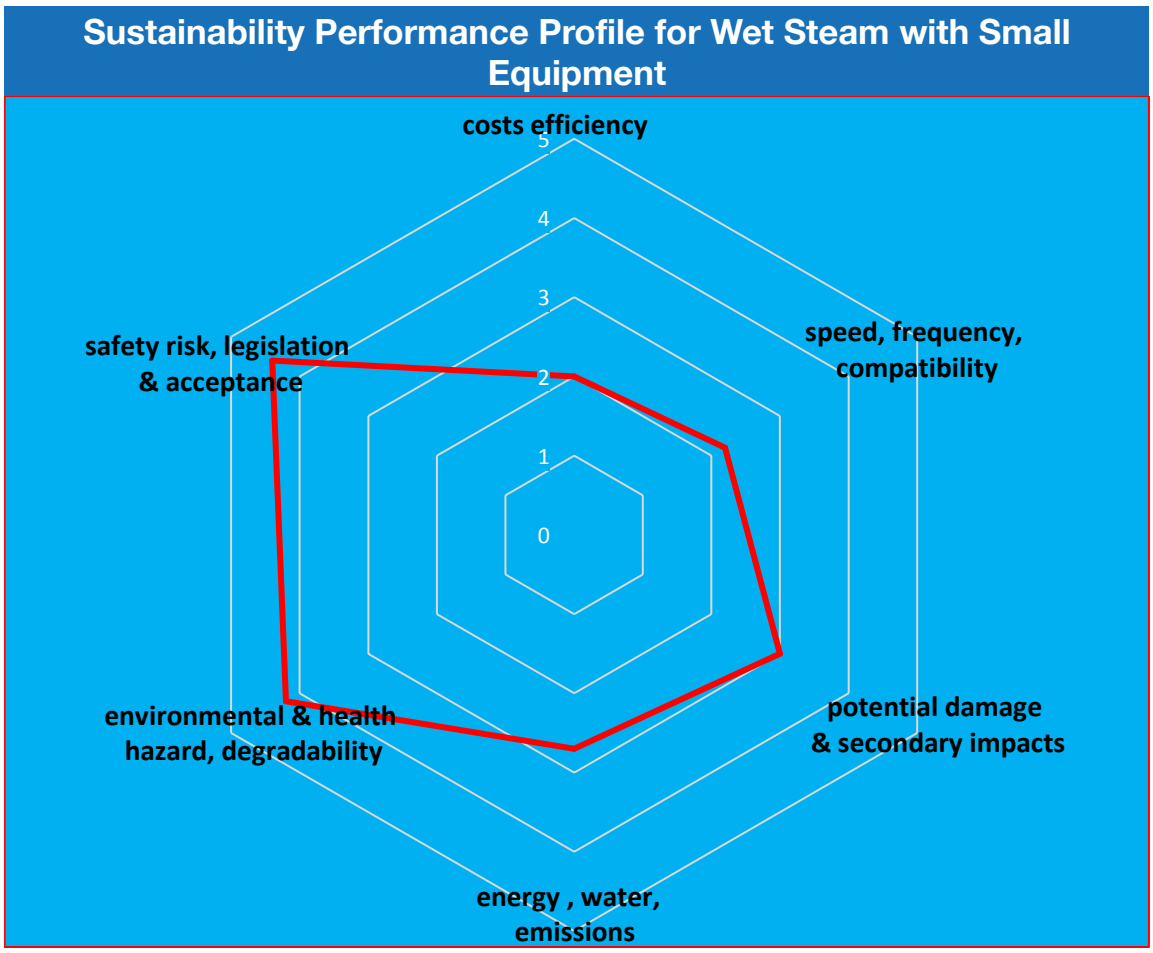


Figure 10: Sustainability Performance Profile for Spraying with wet (saturated) steam.

Both methods – hot water and wet steam - are not yet commercially available for the use in track areas and are not yet automated enough to be used on train carriers. But they are already widely used in the urban environment with different sizes of vehicles. The costs are currently higher than those for the spraying train with herbicides (factor 3-5) and the operational performance is lower due to lower speeds (between 5-10 km/h) and higher frequencies of application, but there seems to be still an interesting development potential. Another difference is the energy consumption, which is considerably higher than for the spraying train with herbicides.

From today's perspective, the hot water method looks more promising since the frequency of application is lower with 3-4 treatments per year as compared to 5-6 treatments per year for the wet steam method and the improvement potential for the operational speed seems to be higher as well.

The very good score for the environmental performance 2 (environmental & health hazard and degradability (4.2 as compared to 2.6 for all herbicide-based methods) and the high score for social performance (safety, legislation & regulation and acceptance – 4.4 as compared to only 1.6 for all methods based on conventional herbicides) combined with the improvement potential for cost and operational speed make both methods very interesting candidates for a long-term substitution of herbicide-based methods. The potential damage to track and electrical equipment is rated higher (3 – moderate risk of damage) as for the reference method since at the current state of technology development large amounts of very hot water and saturated steam would have to be applied to the tracks which could stimulate corrosion and also jeopardize wayside electric equipment.

The last selected alternative method is electro weeding. The performance profile is given in figure 11:

d) Electro-Weeding

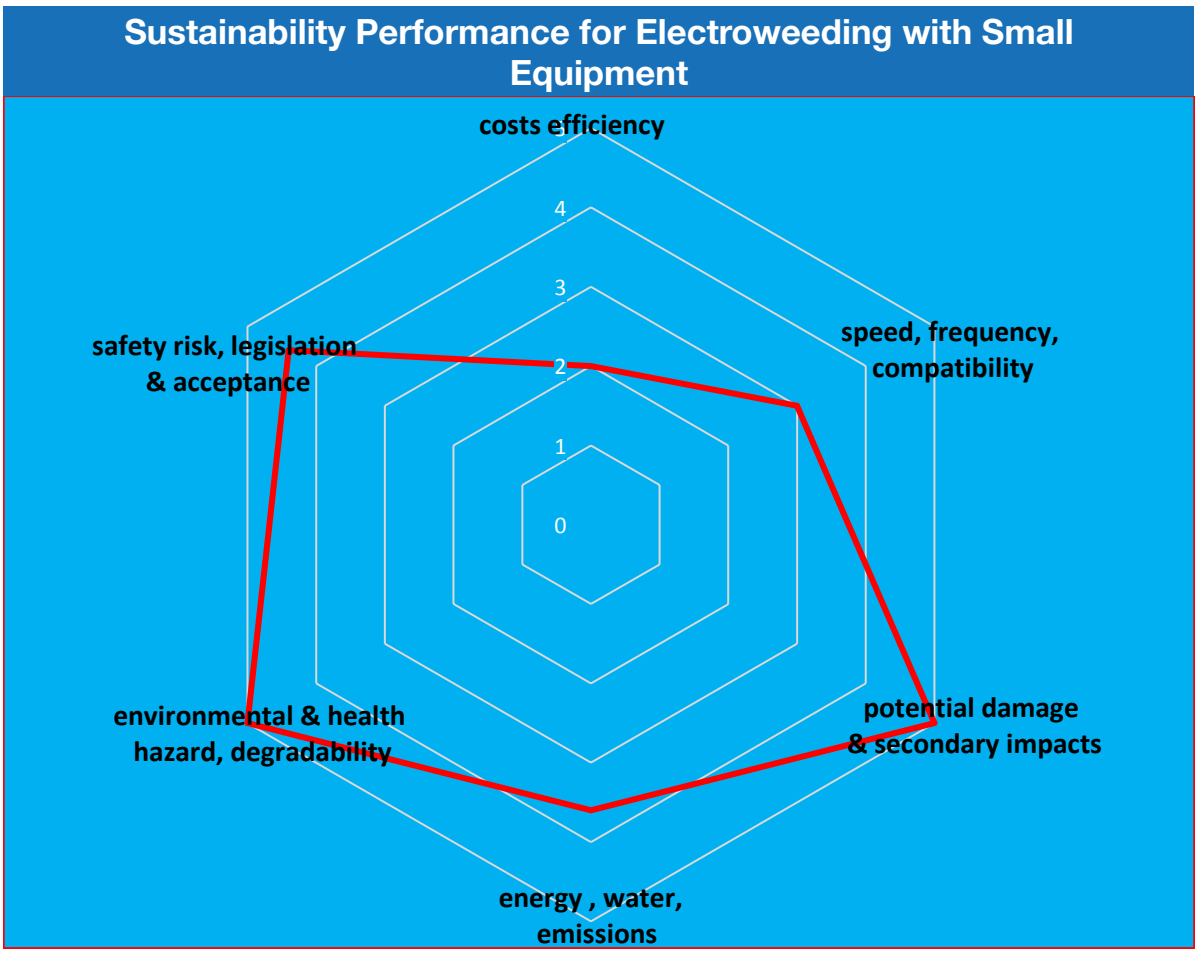


Figure 11: Sustainability Performance Profile for Electro-weeding.

The sustainability performance is similar to the one of the hot water method. It has a slightly lower operational performance I due to a lower process compatibility. Regarding the environmental performance, electro weeding is better due to significantly lower energy and no water consumption as well as lower potential damage to the track. Furthermore, preliminary tests did not show interference with electrical installations. The hot water and wet steam methods beside the electro-weeding are not yet available for railway tracks but are already commercially used with small equipment in other fields of application (urban areas, agriculture). Recent information and planned pilot projects suggest an interesting development potential for the future.

Summarizing the results discussed above it can be stated that all four assessed alternative methods for weed control have already an interesting combined economic and operational performance and seem to have a promising development potential for the future. All four methods – the three non-chemical ones (hot water, wet steam and electro-weeding) and the alternative chemical one (organic acids) do not face the same difficulties as methods based on conventional herbicides concerning acceptance as well as current legislation and regulation and should be therefore further tested, developed and professionalized. Although it should be noted that organic acids still have to go through the same lengthy process for registration and approval for the railway track area since they are classified as herbicides.

The main research & development focus should be on special adaptation to the railway track area, a high degree of automation and especially the improvement of cost performance and operational speed.

2. Summary of the Assessment Results

The combined economic and operational assessment has clearly shown:

- The technologies and methods based on the use of conventional herbicides – with the exception of weed-wiping – have currently the best performance
- Especially the spraying train with conventional herbicides and automatic plant detection constitutes the current state of the art in terms of operational and economic performance.

If taking into account the strong political pressure on Glyphosate as the most important active substance for all herbicide-based methods and the fact that the Glyphosate license has only be extended until the end of 2022, there is an urgent need to develop high performing alternative methods resp. active substances for vegetation control.

The assessment results for the whole range of alternative methods including alternative active substances show that currently every single one is not mature enough and has its limits. Furthermore, they are not performing well enough to replace the standard herbicide-based methods immediately. It could also be shown that there are 4 alternative methods of vegetation control with a promising potential for a good future operational and economic performance. Outside the railway sector, these alternatives can reach maturity already in a few years. But for large scale railway use, a strong effort for adaptation to railway needs and requirements is essential.

With strong effort, reaching maturity in only a few years and sufficient adaptation to railway needs and requirements. These four high potential alternative technologies resp. active substances are:

- Organic acids
- Hot water
- Wet steam
- Electro-weeding.

All four alternative methods resp. active substances for weed control have already an interesting combined economic and operational performance. Although actual operational costs for the alternative methods are by a factor of 3-5 higher than for the spraying train with herbicides and current operational speed is still significantly lower, they seem to have a promising development potential for the future. It should be pointed out again that the limited operational speed for treatments with organic acids is not a feature which is inherently connected with the usage of organic acids itself, but is due to the fact that with currently available substances the amount of acid plus water required per ha is too high for the application with high speed technologies such as spraying trains and road-rail vehicles. With intensified research into advanced application technologies for organic acids this problem should be solvable.

It has to be kept in mind that the sustainability performance for these methods is based on today's performance outside railways and therefore does not reflect the improvements to be expected with sufficient research & development and adaptation effort. Since the alternative technologies discussed here are currently only with small equipment and low degree of automation, the corresponding costs are still relatively high and operational speeds comparatively low. With increasing automation and use of special rolling stock both parameters could be improved considerably.

Very important for future vegetation control strategies and concepts is the fact that the three non-chemical alternative methods do not face the same difficulties as herbicide-based methods concerning legislation and regulation. The respective barriers for organic acids could be lower than those for conventional herbicides if pelargonic acids are listed as "low risk active substances" in the future – but this has still to be confirmed since there are currently no approval for railway track area for European railways and organic acids have to comply to the same regulation and approval process as conventional herbicides.

3. Recommendations

3.1. HERBICIDE-BASED METHODS OF VEGETATION CONTROL

The state-of-the-art analysis of vegetation control and management for the railway track area has clearly shown that the specific herbicide use varies significantly between different railway companies. The factor between the lowest and highest amounts of herbicides used per track km and year is about 5-6. Even taking into account important influencing factors such as the number of treatments per year, used herbicide products and concrete climate conditions this indicates further potentials for improvement. The following options for a further reduction of herbicide amounts should be considered in a short-term perspective:

- Companies currently not using automatic plant detection systems for their spraying trains should implement this-of-the-art technology.
- Best practice for spraying trains with conventional herbicides and plant detection is avoidance of double treatment by automatically closing the relevant nozzles as well as reduces spraying angles (e.g. for double track). These best practices should be followed.
- The implementation of plant species recognition and the automatic adaptation of mixture and dose of herbicides in accordance with the population of targeted plant clusters could be a future way for further reducing the amount of herbicides used as well as the combined use of substances or methods which are enhancing the penetration rate of the active substance.
- Since automatic plant detection is currently not used for the application of herbicides with road-rail vehicles and small equipment there should be a strong focus on the rapid implementation. Since the share of herbicides used with road-rail vehicles and small equipment is relatively high – in some companies it may reach 40-50% of the total herbicide use - this measure could significantly reduce the overall amount of herbicides for the track area.

3.2. ALTERNATIVE METHODS OF VEGETATION CONTROL

The multi-dimensional assessment of alternative technologies and methods for vegetation control and management of the railway track area has identified four promising alternative methods resp. active substances which have the potential to complement and further on to substitute the herbicide-based methods in the future:

- Hot water
- Wet steam
- Electro-weeding
- Organic acids.

Currently these four methods resp. active substances are mainly used with small equipment and at relatively low level of automation. This is reflected by the fact that their current economic and operational performance is lower than the traditional herbicide-based methods e. g. spraying train. Nevertheless, they have all a good potential for further improvement. The alternative methods are not yet fully matured and are currently mainly commercially used outside of the railways.

Taking these facts into account, railways should put a strong effort into further testing, developing, professionalizing and adapting these alternative technologies. The main research & development focus should be on

- special adaptation to the requirements of the railway track area,
- improvement of the operational speed and to a higher degree of automation,
- improvement of the effect time-span (reducing the multiple treatments respectively),
- improvement of cost performance.

In addition to these research & development efforts there is a need for acquiring validated data for the operational and economic performance of these technologies outside the railways and for the foreseeable improvement potentials. Since single railways are not able to cover all relevant alternative methods, larger projects addressing several alternative approaches should be jointly financed by several railways.

3.3. STRATEGY FOR AN INTEGRATED CONCEPT OF VEGETATION CONTROL FOR RAILWAYS

Based on current assessment data, a final decision for the best performing alternative technology or method cannot be taken. Looking at the assessment data and the development potential of all 4 alternative methods it is very likely that there will not be a single best performing method but that 3 or 4 methods will – after being mature and fully adapted to railway requirements - have the optimum performance for important railway purposes and applications. These methods will have to be combined in one way or another in order to reach the expected standard of track-quality.

This outlook and the fact that railways have a great variety of areas to manage – from track area to unsealed and sealed surfaces – indicate that an integrated approach is needed for the future were different technologies and methods are implemented and used for those purposes where they have the strongest performance. This includes the use of hybrid methods – i.e. the simultaneous application of two methods in one process (e.g. organic acids for ballast shoulder and pathways & electro-weeding for the ballast bed) as well as alternating between different methods over the years.

When implementing new regimes of vegetation control, railways should also focus on creating an integrated data base for vegetation control containing GIS based data about actual plant growth, vegetation types (annual, perennial, herbaceous, ligneous, invasive, non-invasive, harmless, problematic, etc.), detailed data about performed treatments etc. as well as advanced data analytics as a basis for reporting and strategic improvements. These extensive demands have to be implemented into already existing IT-Tools or should be taken into account when developing new tools and solutions. As mentioned before, the data should be used in GIS-systems since planning, execution of measures and documentation requirements and obligations are becoming more widespread and complex and cannot be adequately handled manually any more. As a next step, the relevant treatment data should be systematically linked to areas with specific protection requirements such as nature conservation and water protection areas.

Railways are actively developing strategies and measures to progress from herbicide (and mainly Glyphosate based) vegetation control to systems of integrated vegetation control based on a broad spectrum of methods. This is a difficult and lengthy transformation process with many challenges since the alternative methods

- require dedicated research and development effort since they are not yet matured technologically
- are not yet adapted to the special needs and requirements of the railway sector
- are not yet officially registered and approved for application in the railway sector
- are currently significantly more expensive than methods based on conventional herbicides

Taking also into account the fact that

- the timeline for developing and implementing alternative regimes for vegetation control is very tight since the license for Glyphosate has only been extended until the end of 2022 and a further extension is highly uncertain and even unlikely and
- that approval and official registration procedures of products and methods applied for the railway track area are lengthy and complicated,

railways need strong support from all relevant stakeholders in order to manage this challenging and highly complex transformation process. This extensive support should comprise the improvement of the respective legislation & regulation, the implementation of large scale development and adaptation projects for alternative methods of vegetation control as well as improved funding options for the transition period. It is also important to point out that rising costs for vegetation control add up to the current very unfavorable costing aspects of the railway-sector compared to other modes of transport (no true costs, no polluter pays principle) and therefore also hinder the highly needed modal shift to rail.

Even though the time frame for the transition is short and the transition itself is very ambitious, railways should start with small pilot projects for alternative methods of vegetation control and scale up as soon as alternative methods are further developed and professionalized, produce reliable results and show good overall performance. There are some companies on the market that treat weeds using alternative methods – but currently none that can take care of an entire railway network. Starting small allows contractors to develop the methods further and gives valuable experience to the railway companies. Thus, it helps the market for alternative weed control methods to develop.

3.4. ACTIVE KNOWLEDGE SHARING AND KNOWLEDGE TRANSFER

The further investigation, adaptation and development of the most promising alternative methods for vegetation control is a big effort for a single railway company. Strategically it makes much more sense to intensively cooperate in that field and share the work between the railway companies.

With this background in mind it is strongly recommended to

- Develop a common framework for an integrated future strategy of vegetation control for railways
- Set up a common database for alternative methods of vegetation control were railways share important insights and data for each promising method and application according to commonly accepted assessment criteria and standards
- Organize an active knowledge exchange between railway companies about ongoing and planned investigations, pilot projects and implementations in this field.

3.5. ASSESSMENT METHODOLOGY

The multi-dimensional assessment methodology and tool developed within the framework of the Herbie project has been successfully applied to a wide range of technologies and methods for vegetation control. The assessment results are robust and reproducible. Nevertheless, the multi-dimensional assessment tool can be further developed. This refers especially to the assessment parameters concerning the environmental hazard. Current values for these parameters are defined according to the harmonized Classification, Labeling and Packaging of substances and mixtures (CLP – EU regulation). Looking at CLP criteria and coverage, so far only two areas of environmental hazards are covered – hazards with respect to aquatic life and to the ozone layer. In a broader and more balanced approach other environmental hazards should be addressed as well. Parameters for environmental hazards could be taken out of standardized testing procedures of the registration process.

4. Appendix

4.1. APPENDIX PART A–CLASSIFICATION OF METHODS OF VEGETATION CONTROL ACCORDING TO THE UIC STUDY ON VEGETATION CONTROL (UIC 2003)

The following table was taken from UIC 2003 – UIC Study on Vegetation Control (UIC 2003 p. 44). It gives an overview over broad spectrum of methods for vegetation control in a condensed from.

Table 8: Currently known methods of vegetation control (these methods are either applied frequently by railways or tested in experiments) A more detailed overview of the various methods (M XX) can be found on page 64 forward, the methods are described in detail on page 120 forward.

Methods combating the cause Prevention of unwanted plants along the track								***Methods combating symptoms Elimination and suppression of unwanted plants***			
A) Constructional		**B) Biological**		**C) Mechanical**		**D) Chemical**		**E) Thermal/electrical**			
Lateral plant barriers/ Objects impeding plant incursion		M8	Greening	M13	Ballast cleaning	M18	Back-pack spraying	***Thermal***			
		M9	Selective embankment maintenance	M14	Ballast replacement	M19	Spraying train	M23	Burning		
				M15	Mechanical weeding	M20	Rail-road vehicle	M24	Infrared devices		
M1	Lateral plant barriers/ Objects impeding plant incursion in general	M10	Biological weed control	M16	Manual weeding	M21	Selective application by spraying train (e.g. weed eye)	M25	Hot steam		
				M17	Brushing			M26	Hot water		
		M11	Mowing					M27	Hot air		
M2	Thin vertical plant barriers	M12	Mulching			M22	Weed wiping	M28	Freezing		
		M33	Allelopathic plants					M34	Hot foam		
M3	Plant-inhibiting design of the transition area (Area C)							***Electrical***			
								M29	Direct contact with electrical fields		
M4	Porous concrete bars							M30	Microwaves		
M5	Amount and kind of ballast material							M31	Laser		
								M32	UV light		
Plant barriers beneath the track											
M6	Plant barriers beneath the track in general										
M7	Slab track										

A more detailed description of all methods covered in this overview can be found on pages 55 – 67, 69-73 and 123 - 186 of UIC 2003.

4.2. APPENDIX PART B – EXAMPLE CALCULATION FOR THE SCREENING SCORE

The following example calculation for method M18 – Conventional herbicides with backpack spraying - is shown here to illustrate the calculation procedure for the screening score.

M18: Conventional herbicides with backpack spraying as an example calculation:

Performance	Parameter	Weighting factor	Value	Points	Calculation	S-Score
Economic						
	cost efficiency	100%	same as spraying train	5	1,0*5	5,0
Operational						
	operational speed	40%	1-5 km/h	1	0,4*1	0,4
	frequency	40%	1 to 1,3x p.a.	4	0,4*4	1,6
	compatibility	20%	large adaptations needed	2	0,2*2	0,4
					Total S-Score	**7,4**

4.3. APPENDIX PART C - TECHNOLOGY FACT SHEETS

Overview over the technology fact sheets

Group A - Methods of Weed Control commercially used for the Track Area

	D) Chemical
Fact Sheet 1	Conv. Herbicides with Spraying train (plant detection)
Fact Sheet 2	Conv. Herbicides and Backpack spraying
Fact Sheet 3	Conv. Herbicides with Road-Rail vehicle
Fact Sheet 4	Conv. Herbicides and Weed wiping

Group B - Methods of Weed Control with Potential for the Track Area

	Chemical
Fact Sheet 5	Organic Acids and small equipment
	Thermal
Fact Sheet 6	Hot water and small equipment
Fact Sheet 7	Wet steaming (saturated steam and water) and small equipment
Fact Sheet 10	Infrared treatment
	Electrical & Radiation
Fact Sheet 8	Electroweeding and small equipment
	Mechanical
Fact Sheet 11	Weedbrushing
	Mechanical
Fact Sheet 12	Biological weed control

Group A – **Methods of weed control commercially used for the track area**

Fact Sheet 1: Spraying Train with Herbicides and Automatic Plant Detection

Fact Sheet	**Vegetation Control** Methods in operation for track area
Name of the method	**Application of conventional herbicides by Spraying train (incl. Automatic Plant Detection)**
 Source: ÖBB	
Description	Spraying equipment including tanks for water and for herbicides and mixing tanks as well as pumps and nozzles are mounted permanently onto special trains. An automatic plant detection system assures that herbicides are only used where needed. The volume of herbicides thus can be reduced by 50 %[1,2] compared to spraying equipment without plant detection systems. The plant detecting system uses infrared-sensors and video cameras. The weeds are detected from images using image processing and described by shape features.
General criteria	
Current status	Commercialization
Effect of method on plants	Solutions of water and herbicides are used to destroy vegetation. Effect depends on herbicide used (foil or root herbicide).
Experience of Railway companies	ÖBB, Infrabel, BaneNor, Trafikverket, DB, Network Rail[2]

Key benefits	This is the most effective method used for weed control along tracks. It is highly cost efficient and has a high operational speed. Thanks to the automatic plant detection system and to the automatic system to open the spray nozzles, a strong reduction of herbicide use/ sprayed areas and costs has been achieved. Segmentation of the area of application for targeted herbicide application (typically 8-9 segments).
Limitations	No use of herbicides in groundwater protection zones. Herbicide resistant problem plants exist and are a growing problem. The biggest limitation is the growing political and civil pressure against herbicide use leading to an increase of restricted and forbidden areas, increasing general restrictions – in the long term – the ban of herbicide use.
Potential improvements	Infrared detection and image recognition system, recognition of plants species. A plant classification based on the features will enable the optical sensors to detect different weed species or vegetation types (e.g. annual, perennial, herbaceous, ligneous, invasive, non-invasive, harmless, problematic, etc.) which can be mapped using GPS data to reveal the type and number of weeds per image.[4] It will enable to adapt different mixtures of herbicides or different dosages for different clusters of plants, further reducing the quantity of herbicides used. More precise GPS localization is needed in order to achieve this objective. Another recommendation for performance improvement is to integrate local knowledge into the process e.g. by taking a local infrastructure manager on board of the spraying train thus taking better care of sensitive places such as kindergardens, hospitals etc. but also protected species.
Cost efficiency	
Operating costs (total costs including treatment, traction, safety…)	Cost ranges: 100€ up to 500 €/track km [(2)] depending on the country and company
Operational Performance	
Operational speed (km/hour)	Typically 50 km/h[1](up to 60 km/h is possible without significant drift of herbicide solution)

Frequency of treatment (p.a.)	From once to twice a year[2] depending on the railway company and on national regulation. If application is twice per year there is typically a full spraying campaign in spring and a selective spraying campaign in autumn targeting only the hot spots (only 25% to 30% of the whole network)
Compatibility (processes, equipment)	Fully compatible with existing practices
Energy & Emission	
Energy consumption	Low energy consumption, mainly for traction of the spraying train + operation of pumps and other on-board equipment.
Resource consumption (water)	Low water consumption[5]- typically around 200 l / ha.
Emissions (air, water, soil, noise)	Moderate emissions: possible pollution of water and soil; use in groundwater protection zones is forbidden. Emissions of Diesel exhaust in case of Diesel traction.
Toxicity & Health Risks	
Toxicity for the environment	Toxic for the environment. Toxic effects depend on the herbicide used. Possible effect on water, soil, plants, animals and humans. The most commonly herbicides used are Glyphosate, Flazasulfuron and Diflufenican. Glyphosate: Aquatic Chronic 2 (Toxic to aquatic life with long lasting effects) according to CLP classification (Hazard Statement: H411), see Appendix B.
Health Risks	Moderate health risk. Possible negative impacts on human health. Glyphosate: Eye damage 1 (Causes serious eye damage) according to CLP classification (Hazard Statement: H318), only for direct contact with Glyphosate! see Appendix B.
Bio-Degradability	Moderately biodegradable / not readily biodegradable; Degradation in silt-clay soil: Glyphosate and its degradation product (AMPA) get metabolized down to 50% in 9 and 32 days, respectively. The higher the clay content the slower the degradation rate.[6] Average degradation times (down to 50%) are 30 days. See Appendix B.

Safety Risk & Potential damage	
Safety Risks (employees, costumer, 3rd parties)	Moderate safety risk. Operators have to be qualified, trained and informed about the risks related to chemical agents at work. Modern spraying trains have different safety features implemented in order to minimize safety risks. An on board supervisor is responsible for safety concerns and has to watch the track area at all times. The use has to be limited (Ref. art. 5, 7 and 8 Directive 2009/128/EC).
Risk of Damage to track parts	Small risk of damage
Risk of Damage to electrical equipment	Small risk of damage
Legislation & Regulation	
Current legislation & regulation	Moderate restrictions and barriers: • Directive 2009/128/EC • National legislation and regulation for herbicide use
Future legislation & regulation	High restrictions and barriers: Currently it is still possible for the railways to use glyphosate, but in some countries only with exemptions. It is not clear how long these exemptions will be valid. The license for Glyphosate has been renewed until 2022 but only after intense and very controversial discussions. Since many countries have voted against the extension of the Glyphosate license, strong restrictions on national level are to be expected for these countries.
Acceptance & Stakeholder Requirements	Already low acceptance for herbicide use and still declining. Frequent complaints; verdicts and pending lawsuits; requests for significant reduction of herbicide use or ban of herbicides use.

References/Publications

[1]Below M. Gächter F., Kuppelwieser H. (2003) UIC-Vegetation Control Project. Final Report (online: https://www.sparkrail.org/Lists/Records/DispForm.aspx?ID=15185

[2]Questionnairy-based data collected in 2017 by IZT on behalf of UIC

[3]Weis M., Gerhards R. (2009) Detection of weeds using image processing and clustering (online: http://www2.atb-potsdam.de/CIGR-ImageAnalysis/images/16_115_Weis_Poster%20_2_.pdf)

[4]Caine J. (2016) Managing weeds on railway lines. In: International Pest Control(online: http://international-pest-control.com/managing-weeds-railway-lines/)

[6]Simonsen L., Fomsgaard IS., Svensmark B., Spliid NH. (2008) Fate and Availability of Glyphosate and AMPA in Agricultural Soil. Journal of Environmental Science and Health - Part B Pesticides, Food Contaminants, and Agricultural Wastes 43 (5): 365–75 (online: http://www.tandfonline.com/doi/abs/10.1080/03601230802062000)

Additional comments

Due to national and international regulations further reductions of herbicides use are required because of the toxic effects of the active substances. The areas where the use of herbicides is restricted or forbidden are growing. Alternative methods are required.

Fact Sheet 2: Road-Rail Vehicle with Herbicides

Fact Sheet	**Vegetation Control** Methods in operation for track area
Name of the method	**Application of conventional herbicides by Road-Rail Vehicle**
 Source: http://www.weedfree.net/casestudies/case-studies-railway-weed-control/	
Description	Herbicides are sprayed onto the plants by using motor operated spraying devices mounted on a road-rail vehicle.[1]
General criteria	
Current status	Commercialization
Effect of method on plants	Solution of water and herbicides are used to destroy unwanted vegetation. Effect depends on herbicide used (foil or root herbicide).
Experience of Railway companies	UK (Network Rail), France (SNFC), Germany (DB), Hungary (GySEV), Indian Railways (JR), Australia (QR), Belgium (SNCB), Austria (ÖBB), Finland (FTA)
Key benefits	Safer, faster and more convenient than hand spraying methods. More flexible than spraying trains (e.g. in case of busy lines, since road-rail vehicles can be rapidly removed from the track if required).

Limitations	The main technical challenges, which are confronting sensor application in weed management are leaf coverage and growth status of the target plants.[1] No chemical use in groundwater protection zones. Herbicide resistant problem plants exist and are a growing problem. The biggest limitation is the growing political and civil pressure against herbicide use leading to an increase of restricted and forbidden areas, increasing general restrictions – in the long term – the ban of herbicide use.
Potential improvements	Automatic plants detection systems[2] coupled with the control of the nozzles can significantly reduce the quantity of herbicides used as has been already shown for spraying trains.
Cost efficiency	
Operating costs (total costs including treatment, traction, safety…)	Higher costs compared to spraying trains: up to 300 €/km and more[3], typically 2-3 times the costs of dedicated spraying trains.
Operational Performance	
Operational speed (km/hour)	Lower speed compared to spraying trains (max 40 km/h)[3], typically 20-40 km/h.
Frequency of treatment (p.a.)	From once to twice a year[5] depending on the railway company and on national regulation. If application is twice per year there is typically a full spraying campaign in spring and a selective spraying campaign in autumn targeting only the hot spots (only 25% to 30% of the whole network).
Compatibility (processes, equipment)	Compatible with existing practices. Degree of compatibility with existing processes is slightly lower than for spraying trains which are fully integrated into the time schedules.
Energy & Emission	
Energy consumption	Low energy consumption, mainly for traction of the road-rail vehicle + operation of pumps and other on-board equipment.
Resource consumption (water)	Low water consumption
Emissions (air, water, soil, noise)	Moderate emissions: possible pollution of water and soil; use in groundwater protection zones is forbidden Emissions of Diesel exhaust from traction engines.

Toxicity & Health Risks	
Toxicity for the environment	Toxic for the environment Toxic effects depend on the herbicide used. Possible effect on water, soil, plants, animals and humans. The most commonly herbicides used are Glyphosate, Flazasulfuron and Diflufenican. Glyphosate: Aquatic Chronic 2 (Toxic to aquatic life with long lasting effects) according to CLP classification (Hazard Statement: H411). See Appendix B.
Health Risks	Moderate health risk. Possible negative impacts on human health Glyphosate: Eye damage 1 (Causes serious eye damage) according to CLP classification (Hazard Statement: H318), only for direct contact with Glyphosate! See Appendix B.
Bio-Degradability	Moderately biodegradable / not readily biodegradable; Degradation in silt-clay soil: Glyphosate and its degradation product (AMPA) get metabolized down to 50% in 9 and 32 days, respectively. The higher the clay content the slower the degradation rate.[4] Average degradation times (down to 50%) are 30 days. See Appendix B.
Safety Risk & Potential damage	
Safety Risks (employees, costumer, 3rd parties)	Moderate safety risk. Operators have to be qualified, trained and informed about the risks related to chemical agents at work. Modern road-rail vehicles have different safety features implemented in order to minimize safety risks. The use has to be limited (Ref. art. 5, 7 and 8 Directive 2009/128/EC).
Risk of Damage to track parts	Small risk of damage
Risk of Damage to electrical equipment	Small risk of damage
Legislation & Regulation	
Current legislation & regulation	Moderate restrictions and barriers: • Directive 2009/128/EC • National legislation and regulation for herbicide use

Future legislation & regulation	High restrictions and barriers: Currently it is still possible for the railways to use Glyphosate, but in some countries only with exemptions. It is not clear how long these exemptions will be valid. The license for Glyphosate has been renewed until 2022 but only after intense and very controversial discussions. Since many countries have voted against the extension of the Glyphosate license, strong restrictions on national level are to be expected for these countries.
Acceptance & Stakeholder Requirements	Already low acceptance for herbicide use and still declining. Frequent complaints; verdicts and pending lawsuits; requests for significant reduction of herbicide use or ban of herbicides use.

References/Publications

[1]Shaner DL., Beckie HJ. (2014) The future for weed control and technology. Pest ManagSci 70:1329–1339 Crossref, PubMed

[2]Weis M., Gerhards R. (2009) Detection of weeds using image processing and clustering (online: http://www2.atb-potsdam.de/CIGR-ImageAnalysis/images/16_115_Weis_Poster%20_2_.pdf)

[3]Below M., Gächter F., Kuppelwieser H (2003) UIC-Vegetation Control Project. Final Report (online: https://www.sparkrail.org/Lists/Records/DispForm.aspx?ID=15185)

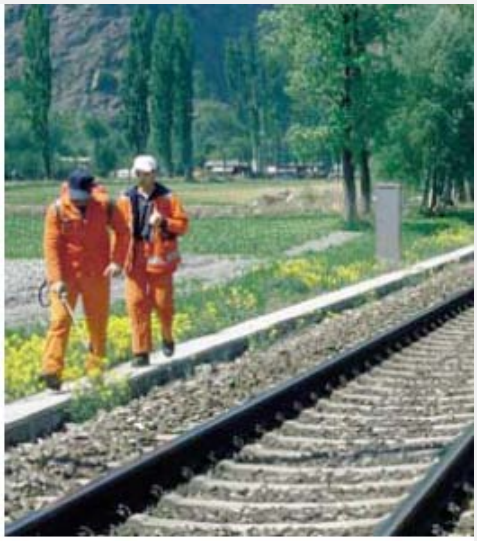
[4]Simonsen L., Fomsgaard IS., Svensmark B., Spliid NH. (2008) Fate and Availability of Glyphosate and AMPA in Agricultural Soil. Journal of Environmental Science and Health - Part B Pesticides, Food Contaminants, and Agricultural Wastes 43 (5): 365–75 (online: http://www.tandfonline.com/doi/abs/10.1080/03601230802062000)

[5]Questionnairy-based data collected in 2017 by IZT on behalf of UIC

Additional comments

Due to national and international regulations further reductions of herbicides use are required because of the toxic effects of the active substances. The areas where the use of herbicides is restricted or forbidden are growing. Alternative methods are required.

Fact Sheet 3: Backpack spraying of Herbicides

Fact Sheet	**Vegetation Control** Methods in operation for track area
Name of the method	**Application of conventional herbicides by Backpack spraying**
 Source: SBB (2001) Vegetation Control on Railway Tracks and Grounds	
Description	Herbicides are sprayed directly onto the plants by backpack sprayers
General criteria	
Current status	Commercialization
Effect of method on plants	Solution of water and herbicides are used to destroy unwanted vegetation. Effect depends on herbicide used (foil or root herbicide).
Experience of Railway companies	Yugoslavia (JZ), Belgium (SNCB), Germany (DB9, UK (RT), Lithuania (LG), Hungary (GySEV), Bulgaria (BDZ), Slovakia (ZSR), Australia (QR), Holland (RIB), Switzerland (SBB), Denmark (BS)
Key benefits	Only areas where plants are present are treated
Limitations	No chemical use in groundwater protection zones. Herbicides resistant problem plants.
Potential improvements	Spray tips and spray patterns should be checked and be replaced when found worn or damaged. Sprayer calibration should be also taken into account. Minimized stoppages and reduced filling times can improve the operational speed.[1]

Cost efficiency	
Operating costs (total costs including treatment, traction, safety…)	ca 855.00 €/ km[2,3] from 50.00 to over 1.000.00 €/km[4]
Operational Performance	
Operational speed (km/hour)	Low: up to 5 km/h[3] It also dependent on the plant cover present
Frequency of treatment (p.a.)	Once to twice a year[4]
Compatibility (processes, equipment)	Large adaptations needed
Energy & Emission	
Energy consumption	Not relevant
Resource consumption (water)	Law water consumption
Emissions (air, water, soil, noise)	Moderate emission: possible pollution of water and soil; use in groundwater protection zones is forbidden.
Toxicity & Health Risks	
Toxicity for the environment	Toxic for the environment Toxic effects depend on the herbicide used. Possible effect on water, soil, plants, animals and humans. The most commonly herbicides used are Glyphosate, Flazasulfuron and Diflufenican. Glyphosate: Aquatic Chronic 2 (Toxic to aquatic life with long lasting effects) according to CLP classification (Hazard Statement: H411). See Appendix B.
Health Risks	Moderate health risk. Possible negative impacts on human health. Glyphosate: Eye damage 1 (Causes serious eye damage) according to CLP classification (Hazard Statement: H318), only for direct contact with Glyphosate! See Appendix B.
Bio-Degradability	Moderately biodegradable / not readily biodegradable; Degradation in silt-clay soil: Glyphosate and its degradation product (AMPA) get metabolized down to 50% in, respectively, 9 and 32 days. The higher the clay content the slower the degradation rate.[5] See Appendix B.
Safety Risk & Potential damage	
Safety Risks (employees. costumer. 3rd parties)	Moderate safety risk. Operators have to be qualified, trained and informed about the risks related to chemical agents at work. The use has to be limited (Ref. art. 5, 7 and 8 Directive 2009/128/EC).

Risk of Damage to track parts	Small risk of damage
Risk of Damage to electrical equipment	Small risk of damage
Legislation & Regulation	
Current legislation & regulation	Moderate restrictions and barriers: • Directive 2009/128/EC • National legislation and regulation for herbicide use
Future legislation & regulation	High restrictions and barriers: Currently it is still possible for the railways to use Glyphosate, but in some countries only with exemptions. It is not clear how long these exemptions will be valid. The license for Glyphosate has been renewed until 2022 but only after intense and very controversial discussions. Since many countries have voted against the extension of the Glyphosate license, strong restrictions on national level are to be expected for these countries.
Acceptance & Stakeholder Requirements	Already low acceptance for herbicide use and still declining. Frequent complaints; verdicts and pending lawsuits; requests for significant reduction of herbicide use or ban of herbicides use.
References/Publications	
[1]Malik RK., Pundir, A., Dar SR., Singh SK., Gopal R., Shankar PR., Singh N., Jat ML. (2012). Sprayers and Spraying Techniques – A manual. CSISA. IRRI and CIMMYT. 20 pp. (online: https://agriknowledge.org/downloads/z316q1572) [2]BAV/SAEFL/SBB (2001) Vegetation control on railway tracks and grounds (online: https://www.bafu.admin.ch/dam/bafu/en/dokumente/chemikalien/uw-umwelt-wissen/vegetationskontrolleaufbahnanlagen.pdf.download.pdf/vegetation_controlonrailwaytracksandgrounds200133p.pdf) [3]Below M., Gächter F., Kuppelwieser H. (2003) UIC-Vegetation Control Project. Final Report (online: https://www.sparkrail.org/Lists/Records/DispForm.aspx?ID=15185) [4]Questionnairy-based data collected in 2017 by IZT on behalf of UIC [5]Simonsen L., Fomsgaard IS., Svensmark B., Spliid NH. (2008) Fate and Availability of Glyphosate and AMPA in Agricultural Soil. Journal of Environmental Science and Health - Part B Pesticides, Food Contaminants, and Agricultural Wastes 43 (5): 365–75 (online: http://www.tandfonline.com/doi/abs/10.1080/03601230802062000)	
Additional comments	
Due to national and international regulations further reductions of herbicides use are required because of the toxic effects of the active substances. The areas where the use of herbicides is restricted or forbidden are growing. Alternative methods are required.	

Fact Sheet 4: Weed Wiping with Herbicides

Fact Sheet	**Vegetation Control** Methods in operation for track area
Name of the method	**Application of conventional herbicides by Weed Wiping**
 Source: https://www.quadbikeswales.co.uk/oblitorator-1800-weed-wiper-system-with-a-55l-quad-sprayer.html	
Description	Direct contact between the plants and strips of cloth (ex. carpet roller) saturated with the herbicide. There are various factors that influence the performance of the method, such as the type of wiping material and the application's speed.[1]
General criteria	
Current status	Commercialization. Wiper applicators with properly adjusted herbicide concentration rates and wiper pad wetness have better potential for controlling weeds. Electronic control systems (sensors) to regulate herbicide flow in response to changes in weed density can be used.[1]
Effect of method on plants	Solution of water and herbicides are used to destroy vegetation. Glyphosate was found to have a much higher wicking rate compared to other herbicides.[1]
Experience of Railway companies	Sweden (BV), Australia (QR), Germany (DB) Used for maintenance only (with road-rail vehicles or small equipment)

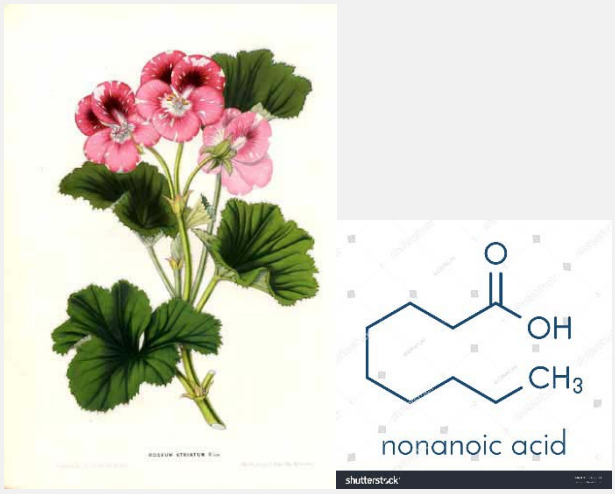
Key benefits	Suitable for weeds of one meter or more of heights (tall weeds).[2]
Limitations	No chemical use in groundwater protection zones. Herbicides resistant problem plants.
Potential improvements	A shift from passive to pressurized systems and electronic moisture sensors can improve its performance.[1]
Cost efficiency	
Operating costs (total costs including treatment, traction, safety…)	0.2 €/m^{2}[(3)]
Operational Performance	
Operational speed (km/hour)	Low: max 10 km/h[(3)]
Frequency of treatment (p.a.)	Depending on herbicide used (half a year up to 2 years).[3]
Compatibility (processes, equipment)	Moderate adaptations are needed
Energy & Emission	
Energy consumption	No data available
Resource consumption (water)	Low water consumption
Emissions (air, water, soil, noise)	Moderate emission: possible pollution of water and soil; use in groundwater protection zones is forbidden.
Toxicity & Health Risks	
Toxicity for the environment	Toxic for the environment Toxic effects depend on the herbicide used. Possible effect on water, soil, plants, animals and humans. Glyphosate: Aquatic Chronic 2 (Toxic to aquatic life with long lasting effects) according to CLP classification (Hazard Statement: H411). See Appendix B.
Health Risks	Moderate health risk. Possible effects on human health. Glyphosate: Eye damage 1 (Causes serious eye damage) according to CLP classification (Hazard Statement: H318), only for direct contact with Glyphosate! See Appendix B.
Bio-Degradability	Degradation in silt-clay soil: Glyphosate and its degradation product (AMPA) get metabolized down to 50% in, respectively, 9 and 32 days. The higher the clay content the slower the degradation rate.[4] See Appendix B.

Safety Risk & Potential damage	
Safety Risks (employees, costumer, 3rd parties)	Moderate safety risk. Operators have to be qualified, trained and informed about the risks related to chemical agents at work. The use has to be limited (Ref. art. 5, 7 and 8 Directive 2009/128/EC).
Risk of Damage to track parts	Small risk of damage
Risk of Damage to electrical equipment	Small risk of damage
Legislation & Regulation	
Current legislation & regulation	Moderate restrictions and barriers: • Directive 2009/128/EC • National legislation and regulation for herbicide use
Future legislation & regulation	High restrictions and barriers: Currently it is still possible for the railways to use Glyphosate, but in some countries only with exemptions. It is not clear how long these exemptions will be valid. The license for Glyphosate has been renewed until 2022 but only after intense and very controversial discussions. Since many countries have voted against the extension of the Glyphosate license, strong restrictions on national level are to be expected for these countries.
Acceptance & Stakeholder Requirements	Already low acceptance for herbicide use and still declining. Frequent complaints; verdicts and pending lawsuits; requests for significant reduction of herbicide use or ban of herbicides use.
References/Publications	
[1]Moyo C. (2008) *Improving the Efficiency of Herbicide Application to Pasture Weeds by Weed-Wiping and Spot-Spraying.* (Doctoral Thesis at Massey University, Palmerston North, New Zealand) (online: https://muir.massey.ac.nz/bitstream/handle/10179/779/2whole.pdf) [2]English Nature 2003 in association with FACT (2003) The Herbicide Handbook: Guidance on the use of herbicides on nature conservation sites (online: https://www.whatdotheyknow.com/request/124080/response/303958/attach/2/herb1%204%201.pdf) [3]Below M., Gächter F., Kuppelwieser H. (2003) UIC-Vegetation Control Project. Final Report (online: https://www.sparkrail.org/Lists/Records/DispForm.aspx?ID=15185) [4]Simonsen L., Fomsgaard IS., Svensmark B., Spliid NH. (2008) Fate and Availability of Glyphosate and AMPA in Agricultural Soil. Journal of Environmental Science and Health - Part B Pesticides, Food Contaminants, and Agricultural Wastes 43 (5): 365–75 (online: http://www.tandfonline.com/doi/abs/10.1080/03601230802062000)	
Additional comments	
Due to national and international regulations further reductions of herbicides use are required because of the toxic effects of the active substances. The areas where the use of herbicides is restricted or forbidden are growing. Alternative methods are required	

Group B – **Methods of weed control with potential for the track area**

Note: This part of the appendix covers methods which have development potential with regards to future application for the railway track area. This comprises the 4 methods with high development potential and already interesting performance identified by the multi-dimensional assessment – spraying of organic acids, hot water treatment, wet steam treatment and electro-weeding which are currently used outside the railway sector and with small (motorized) equipment. It also includes 4 other methods with moderate development potential and overall performance (hot foam treatment, infrared treatment, weed brushing and biological weed control) which can be still interesting for special applications in parts of the track area if the better performing alternatives are either not suitable, not available or even forbidden.

Fact Sheet 5: Spraying of Organic/PelargonicAcid

Fact Sheet	**Vegetation Control** Technologies from other areas with transfer potential
Name of the method	**Spraying of Organic/Pelargonic Acid with small motorized equipment**
 Source: http://www.meemelink.com/prints_pages/13089.Pelargonium.htm https://www.shutterstock.com/image-vector/nonanoic-acid-pelargonic-molecule-ammonium-salt-724670200	
Description	Pelargonic acid is a fatty acid, which is present in many plants. For the first time it was detected in the leaves of *Pelargonium roseum*. A spray application of a salt of the fatty acid has a nonselective impact on young plants.[1]
General criteria	
Current status (research, development and testing, demonstration or commercialization)	Commercialization in other fields of application, e.g. roadside application, urban areas; Developing and testing for railway applications.

Effect of method on plants	Damage of the foliage of vegetation
Experience of Railway companies	France (SNFC), Finland (FTA), Austria (ÖBB)
Key benefits	Organic acids / Pelargonic acid can be used in areas near residential zones, bodies of water, wetlands, or other areas where use of conventional herbicides is not welcome or prohibited.[1] They can also be used against problem plants. Organic acids are quick-acting, often within hours.
Limitations	High costs: currently a high amount of acid is needed per ha and multiple applications are needed per year (at least three times) Compared to the use of conventional herbicides the operational speed is also lower due to the current limitation to low speed applications technologies such as small equipment and backpack spraying. Risk of damage to track parts/electrical components (e.g. corrosion) has to be investigated. Nauseous odor can be a problem when using pelargonic acid in railway stations and close to settlements. The stench is persistent and can be smelled even three days after application.
Potential improvements	Automated spraying equipment designed for spraying trains or other special vehicles, precision application technology and weed detection technology would reduce the cost and improve operational speed. If the amount per ha would go down to 20l existing spraying trains could be used for the application of organic acids.
Cost efficiency	
Operating costs (total costs including treatment, traction, safety…)	21,33cts €/m^{2}[(2)] 216£ /application[(3)] In both cases its performance is about three times lower than with classical herbicides
Operational Performance	
Operational speed (km/hour)	Currently about 10 km/h (for application with small equipment).
Frequency of treatment (p.a.)	At least 3treatments for adequate suppression of vegetation growth.[1]
Compatibility (processes, equipment)	Full compatible with existing practices

Energy & Emission	
Energy consumption	Low energy consumption, mainly for traction of the spraying train / vehicle + operation of pumps and other equipment.
Resource consumption (water)	About 3.000 l/ha (compared to about 200 l/ha for conventional herbicides).[3]
Emissions (air, water, soil, noise)	Moderate emissions
Toxicity & Health Risks4	
Toxicity for the environment	Harmful Pelargonic Acid: Aquatic Chronic 3 (Harmful to aquatic life with long lasting effects) according to CLP classification (Hazard Statement: H412). See Appendix B.
Health Risks	Moderate health risk: skin and eye irritant Skin irritation 2 (Causes skin irritation) according to CLP classification (Hazard Statement: H315), only for direct contact with Pelargonic Acid! See Appendix B. Eye irritation 1 (Causes serious eye irritation) according to CLP classification (Hazard Statement: H319), only for direct contact with Pelargonic Acid! See Appendix B.
Bio-Degradability	Highly biodegradable /Readily bio-degradable: according to OECD criteria. Pelargonic acid does not hydrolyze in water, but will volatilize from water over time (if microbial degradation or adsorption to sediments does not occur) – see Appendix B.
Safety Risk & Potential damage	
Safety Risks (employees, costumer, 3rd parties)	Moderate safety risk. Operators have to be qualified, trained and informed about the risks related to chemical agents at work. The use has to be limited (Ref. art. 5, 7 and 8 Directive 2009/128/EC).
Risk of Damage to track parts	Moderate risk of damage (to be assessed)
Risk of Damage to electrical equipment	Moderate risk of damage (to be assessed)
Legislation & Regulation	
Current legislation & regulation	Small legislative restrictions (pelargonic acid is allowed to be sprayed on hard surfaces even if there is a risk of run-off).[5]
Future legislation & regulation	No restrictions & barriers
Acceptance & Stakeholder Requirements	Strong acceptance, some requirements

References/Publications
[1]Barker A. V., Prostak R. G. (2008) Herbicide Alternatives Research. Transportation Center
[2]ChemAdvocacy (2017) Analyse des impacts économiques et socio-économiques d'une interdiction du glyphosate
[3]Bristol City Council (2017) Weeds, treatment of unwanted vegetation; Trial and comparison for glyphosate free weed treatment in Bristol parks and highway surfaces
[4]Marin Municipal Water District Vegetation Management Plan. Draft. (2010)Herbicide Risk Assessment (Chapter 7-Pelargonic acid). online: https://www.marinwater.org/DocumentCenter/View/252
[5]Kristoffersen P., Rask A.M., Grundy A.C., Franzen I., Kempenaar C., Raisio J., Schroeder H., Spijker J., Verschwele A. &Zarina I. (2008) A review of pesticide policies and regulations for urban amenity areas in seven European countries. Weed Research 48. 201–214
Additional comments

Fact Sheet 6: Hot Water Treatment

Fact Sheet	**Vegetation Control** Technologies from other areas with transfer potential
Name of the method	**Hot Water Treatment**
 Source: http://heatweed.com/xl/	
Description	Hot water weed control machines use hot water to destroy weeds by delivering an efficient low pressure treatment at 98°C.[1]
General criteria	
Current status (research, development and testing, demonstration or commercialization)	Commercialization in other fields of application, e.g. communal and urban environment. Developing and testing for railway applications.
Effect of method on plants	Hot water treatment kills plants above ground. Heatweed Technologies claims that using hot water of 98 °C with a specific application technology yields a systemic effect with impacts on the root system of the plants. This claim has still to be confirmed – especially for the type of plants typically growing in the track area.[2]
Experience of Railway companies	New Zealand, Germany (DB), Sweden (Trafikverket), Switzerland (SBB), Austria (ÖBB)
Key benefits	This method overcomes some of the disadvantages of herbicides, such as spray drift and soil/groundwater pollution. It is non-toxic. It also avoids the physical effort required for manual weed removal.[3]

Limitations	The operational speed and range of hot water systems are currently restricted.[3] Heat distribution can be rather uneven, decreasing the overall efficiency. Energy and water consumption aretoo high and species dependent. Leaching effects should be investigated.
Potential improvements	An automated machine designed for spraying train or other specialized vehicles, precision application technology and more precise weed detection sensors, would reduce the cost, speed up the treatment and reduce the water consumption.
Cost efficiency	
Operating costs (total costs including treatment, traction, safety…)	Cost range p.a.*: from 0.15 to 0.80 €/m$^{2(1)}$ *about 3-5 treatment p.a.
Operational Performance	
Operational speed (km/hour)	Treatment speed: from 3 to 5 km/h$^{(2)}$ Operating speed: from 0.5 to 5 km/h$^{(2)}$
Frequency of treatment (p.a.)	Between 3-5 $^{(1)}$ and 6 $^{(2)}$ treatments per year.
Compatibility (processes, equipment)	Slight adaptations needed
Energy & Emission	
Energy consumption	About 5000 MJ/ha (about twice energy compared with flame/IR weeding. Twenty times more energy input than chemical or mechanical method).[4] The energy required is usually regulated by the driving speed. If the driving speed to achieve sufficient thermal weed control and reduce weed regrowth is low, the treatment time and costs are high.[5] The most effective and eco-efficient combination of treatment frequency and energy dose is species dependent.[6]
Resource consumption (water)	More than 600 liters per hour.[7] Use of water is also depending on the height of plants.
Emissions (air, water, soil, noise)	Few emissions exhaust gases (diesel).
Toxicity & Health Risks	
Toxicity for the environment	Hot water treatment: being non-toxic, personal protective clothing or certification is not required for applicators.[3]
Health risks	Moderate health risks: Operators should be trained in the use of the methods and equipment and the associated health and safety implications.

Bio-Degradability	Fully degradable
Safety Risk & Potential damage	
Safety Risks (employees, costumer, 3rd parties)	Small safety risks: however, operators should be trained in the use of the methods and equipment and the associated health and safety implications (burn injury).
Risk of Damage to track parts	moderate risk of damage (to be assessed)
Risk of Damage to electrical equipment	moderate risk of damage (to be assessed)
Legislation & Regulation	
Current legislation & regulation	No restrictions and barriers
Future legislation & regulation	No restrictions and barriers
Acceptance & Stakeholder Requirements	Strong acceptance, some requirements
References/Publications	
[1]Cardley-Wave Machine Systems (http://www.cardley-group.com/how-it-works) [2]HEATWEED SENSOR 400/34 (online: http://heatweed.com/sensor/) [3]Method for weed control with hot foam (online: https://www.google.com/patents/EP1450603B1?cl=en) [4]Ascard J. et al (2007) Thermal Weed Control. In: Non Chemical Weed Management. CAB International. pp 155-175 (online:https://books.google.de/books?hl=it&lr=&id=6ZFdboWaA7UC&oi=fnd&pg=PA155&dq=Ascard+J+et+al++(2007)+Thermal+Weed+Control&ots=YxK4PVuaFr&sig=bGCaMfu2d3aXcORvAlkX5Fr5LE#v=onepage&q=Ascard%20J%20et%20al%20%20(2007)%20Thermal%20Weed%20Control&f=false) [5]Rask AM., Kristoffersen P. (2007) A review of non-chemical weed control on hard surfaces. Weed Research 47. 370–380 [6]De Cauwer B., De Keyser A., Biesemans N., Claerhout S., Reheul D. (2017) Impact of wetting agents, time of day and periodic energy dosing strategy on the efficacy of hot water for weed control. Joint workshop of the EWRS Working Group Physical and Cultural Weed Control & Crop-Weed Interactions Nyon (Switzerland) [7]Banks J., Sandral G. (2007) Report on weed control using hot water / steam and herbicides in the city of Joondalup	
Additional comments	
Promising method for the future. Spraying train technology is not yet available for this method but can be adapted, use of automatic plant detection in combination with hot water is also feasible. High automation potential.	

Fact Sheet 7: Wet Steam Treatment

Fact Sheet	**Vegetation Control** Technologies from other areas with transfer potential
Name of the method	**Wet Steam Treatment**
 Source: http://www.weedtechnics.com/steam-weeding-machines/	
Description	Saturated steam is created by increasing the boiling point of heated water under pressure to approximately115 – 120° C. Depressurizing in close proximity to vegetation delivers a mixture of saturated steam and hot water at 100° C to the weeds.[1]
General criteria	
Current status	Commercialization in other fields of application, e.g. communal/urban environment, development and testing for railway applications.
Effect of method on plants	Due to pressurization of the water it does not boil. As it depressurizes it explodes into saturated steam, causing thermal shock: It removes the waxy cuticle coating on plant leaves and stems, breaking down the cellular structure and causing rapid death. One treatment can kill many annuals and some young perennials.[2] Since roots are often able to survive protected in the ground, the concrete impact on the plants typically growing in the track area has to be further investigated.

Experience of Railway companies	Germany (DB), Sweden (BV), Yugoslavia (JZ), Switzerland (SBB), Denmark (BS), Czech Republic (CP), France (SNCF) (testing), Austria (ÖBB)
Key benefits	Wet steam overcomes some of the fire risk of open flame. It also can be used in groundwater protection zones.
Limitations	The volume of wet steam produced to provide commercial applicability to larger areas and lengths of track is too low at the moment.[1] Due to high water consumption frequent refills of the tanks are needed. Another problem is the poor ground penetration of steam leading to higher frequencies of treatment. The hot water content of the wet steam should be high enough for acceptable ground penetration and to avoid rapid cooling. Possible leaching effects should be investigated.
Potential improvements	An automated equipment designed for spraying trains or other specialized vehicles would reduce the cost and increase the operational speed considerably. The integration of an automatic plant detection system could further decrease cost as well as water and energy consumption. Measures should be taken to avoid rapid cooling (e.g. the integration of heat shields etc.).
Cost efficiency	
Operating costs (total costs including treatment, traction, safety…)	From 900.00 to 2000.00 €/ track km[(3)] 0.48 €/m [(2),(4)] from 50 to 200 € per km of pathway (approx. 0.5m wide) for manual operation.[6]
Operational Performance	
Operational speed (km/hour)	Currently around 1-2 km/h for manual operation; (ca 1 km/h [(3)]), around 5 km/h for use of small equipment/light vehicles. Operating speed depends on plant cover and weather conditions. Slower speed in wet conditions is recommended.[3]
Frequency of treatment (p.a.)	Between 2-5 treatments p.a. (3-4 treatments p.a.[3], 2 treatments p.a.[4], 3-5 treatments p.a.).[6]
Compatibility (processes, equipment)	Slight adaptations are needed
Energy & Emission	
Energy consumption	High energy consumption (from 700 to 5000 l Diesel per ha for current soil steaming in agriculture).[5]

Resource consumption (water)	Water consumption of approx. 250 – 350 l per hour for manual treatment.[6]
Emissions (air, water, soil, noise)	Few emissions (mainly Diesel exhaust emissions for traction if mounted on vehicles)
Toxicity & Health Risks	
Toxicity for the environment	Non toxic
Health Risks	Moderate health risks: Operators should be trained in the use of the methods and equipment and the associated health and safety implications.
Bio-Degradability	Fully degradable
Safety Risk & Potential damage	
Safety Risks (employees, costumer 3rd parties)	Small safety risks: Operators should be trained in the use of the methods and equipment and the associated health and safety implications.
Risk of Damage to track parts	moderate risk of damage (wooden sleepers impact to be assessed).
Risk of Damage to electrical equipment	moderate risk of damage (to be assessed)
Legislation & Regulation	
Current legislation & regulation	No restrictions and barriers
Future legislation & regulation	No restrictions and barriers
Acceptance & Stakeholder Requirements	Full acceptance, no requirements
References/Publications	

[0]Rask AM., Kristoffersen P. (2007). A review of non-chemical weed control on hard surfaces. Weed Research 47. 370–380

[1]Winer J. (2014) Holistic weed control practice for urban storm water catchments. Global trends, methods, limitations and cost benefits (online: http://www.weedtechnics.com/wp-content/uploads/2014/11/Winer-J-Holistic-weed-control-The-Weeds-Network.pdf)

[2]Byron Shire Chemical Free Landcare . Heat Treatments. Saturated Steam Weeding (online accessed: http://byronshirechemicalfreelandcare.org/techniques-2/general-weed-management/)

[3]Below M., Gächter F., Kuppelwieser H. (2003) UIC-Vegetation Control Project. Final Report (online: https://www.sparkrail.org/Lists/Records/DispForm.aspx?ID=15185)

[4]ChemAdvocacy (2017) Analyse des impacts économiques et socio-économiques d'une interdiction du glyphosate

[5]Ascard J et al (2007) Thermal Weed Control. In: Non Chemical Weed Management. CAB International. pp 155-175 (online: https://books.google.de/books?hl=it&lr=&id=6ZFdboWaA7UC&oi=fnd&pg=PA155&dq=Ascard+J+et+al++(2007)+Thermal+Weed+Control&ots=YxK4PVuaFr&sig=-bGCaMfu2d3aXcORvAlkX5Fr5LE#v=onepage&q=Ascard%20J%20et%20al%20%20(2007)%20Thermal%20Weed%20Control&f=false)

[6]Banks J., Sandral G. (2007) Report on weed control using hot water / steam and herbicides in the city of Joondalup

Additional comments
Promising method for the future, but high energy consumption. High automation potential, combination with automatic plant detection technology is feasible.

Fact Sheet 8: Electroweeding

Fact Sheet	**Vegetation Control** Technologies from other areas with transfer potential
Name of the method	**Electroweeding**
 Source: Zasso Group	
Description	The electric applicators touch the plants, pass a low current at high-voltage through them (5.000–15.000 V) and destroy their water supply systems right down into the ground.[1]
General criteria	
Current status (research, development and testing, demonstration or commercialization)	Commercialization in other fields of application, e.g. in organic agriculture. Developing and testing for railways in progress.
Effect of method on plants	Plants dry off and die, this takes between a few minutes to several days (depending on the weather conditions). Depending on the type and height of plants, there can be some regrowth requiring a second (and in rare cases a third) annual treatment.
Experience of Railway companies	Switzerland (SBB) (testing), Germany (DB)
Key benefits	Non toxic for the environment, no restrictions. Immediate impact. No development of genetic resistance.
Limitations	High costs (low operational speed and high energy consumption). Interaction with signaling and railway safety systems needs to be investigated. Risk of burning/fire. Even though test regarding the impact on soil biology have not identified negative impacts, further extensive testing is recommended in this field.

Potential improvements	Automatic plant detection system and improvement of operational speed to reduce energy consumption and costs. Higher degree of automation possible. Could also be used against problem plants.[1]
Cost efficiency	
Operating costs (total costs including treatment, traction, safety…)	No reliable costs available at the moment. Just one cost reference: ca. £28/ha (around 32 €) pure operating costs per single treatment[2], costs for machinery not included.
Operational Performance	
Operational speed (km/hour)	Between 5 km/h and 10 km/h (7.2 km/h (ca 2 m/sec).[3]
Frequency of treatment (p.a.)	1tomax 3 typically 1-2 treatments p.a. (tests are currently being conducted).
Compatibility (processes, equipment)	Moderate adaptations needed
Energy & Emission	
Energy consumption	Most recent figures: 3-4 l of Diesel per ha without traction.[4] In the range of 5 to 15 Liter diesel/ha for traction and a first approximation of 300 Joule per 15 cm of plant.[5] Between 418 and 16500 MJ/ha for weed density between 5 and 200 weeds/m$^{2(6)}$ In agriculture applications. Energy consumption is highly dependent on weed density. Energy consumption is estimated to be between 2x – 5x the energy for chemical weed control, even at low weed densities.[7] Tests are currently being conducted.
Resource consumption (water)	No water consumption
Emissions (air, water, soil, noise)	Moderate emissions, from Diesel exhaust.
Toxicity & Health Risks	
Toxicity for the environment	Non toxic
Health Risks	Moderate health risks: Operators should be trained in the use of the methods and equipment and the associated health and safety implications.
Bio-Degradability	No waiting time - no soil or plant residues

Safety Risk & Potential damage	
Safety Risks (employees, costumer, 3rd parties)	• Small risk of dispersion of electric power in soil: electric fields are highly focused under applicators and since plants resistance is lowest, electric flow is almost exclusively through plants. Further testing and validation should be undertaken in this respect. • No risk of soil heating due to high frequencies
Risk of Damage to track parts	small risk of damage, small risk of fire
Risk of Damage to electrical equipment	Small to moderate risk of damage (to be assessed).
Legislation & Regulation	
Current legislation & regulation	No restrictions and barriers
Future legislation & regulation	No restrictions and barriers
Acceptance & Stakeholder Requirements	High acceptance, some requirements concerning safety issues.
References/Publications	
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Additional comments	
Very Interesting and promising alternative method for future weed control with high development potential, high automation potential, combination with automatic plant detection is feasible.	

Fact Sheet 9: Hot Foam Treatment

Fact Sheet	**Vegetation Control** Technologies from other areas with transfer potential
Name of the method	**Hot Foam Treatment**
 Source: https://weedingtech.com/WeedingtechFactsheet.pdf	
Description	Heat is applied to the weeds in the form hot foam. The foam is created with an injector using hot water, pressurized air and an added detergent substance.[1]
General criteria	
Current status (research, development and testing, demonstration or commercialization)	Developing and testing/ Commercialization in other fields of application (ex. urban environment).
Effect of method on plants	This thermal treatment heats up the vegetative parts of the plant rapidly and mainly destroys the surface parts of the weed.[2] Since the roots mostly survive this procedure, repeated treatments are necessary for sufficient weed control.
Experience of Railway companies	New Zealand, Germany (DB), Sweden (Trafikverket), Austria (ÖBB)
Key benefits	Heated foam has been demonstrated to expose plant tissue to heat for a longer period increasing efficacy when compared to hot water.[5] This method also overcomes some of the disadvantages of herbicides, such as spray drift and soil/groundwater pollution. It also avoids the physical effort required for manual weed removal.[6]

Limitations	Slow operational speed, high water consumption. Heat distribution can be rather random, decreasing the overall efficiency.
Potential improvements	An automated machine designed for larger scale (e.g. for spraying trains) applications could reduce the cost and speed up the treatment. The water use has also to be reduced.
Cost efficiency	
Operating costs/per treatment	From 1.2 to 1.9 €/track meter=1200-1900 €/ track km).[4] Another study estimated the specific costs of hot foam treatment to be about six times higher than the treatment with classical herbicides.[8]
Operational Performance	
Operational speed (km/hour)	100 track meters/h[4]
Frequency of treatment (p.a.)	3-4/2-3 applications a year[3,4] 7-8 applications a year[5, 6]
Compatibility (processes, equipment)	Moderate adaptations are needed
Energy & Emission	
Energy consumption	Specific energy consumption for hot foam treatment seems to be lower than for most hot water systems[7], but reliable data and extensive comparative studies regarding the energy consumption are still lacking. It should also be mentioned that the lower energy consumption per treatment for hot foam can still lead to a higher specific energy consumption p.a. because of a required higher frequency of treatment.
Resource consumption (water)	The water use for the hot foam method was estimated to be between 15.000 -17.000 l/ ha for weed treatment in Bristol parks and highway surfaces (compared with 200 l/ ha for herbicides and 3000 l/ha pelargonic acid).[8]
Emissions (air, water, soil, noise)	Possible risk of pollution, exhaust gases (Diesel).
Toxicity & Health Risks	
Toxicity for the environment	The impacts on the environment of the detergents used to make the foam are being tested by some companies.[9]
Health Risks	It is currently being tested

Bio-Degradability	It depends on the detergents used; the most of them are biodegradable.
Safety Risks & Potential damage	
Safety Risks (employees, costumer, 3rd parties)	Small safety risks: however, operators should be trained in the use of the methods and equipment and the associated health and safety implications (burn injury).
Risk of Damage to track parts	moderate risk of damage
Risk of Damage to electrical equipment	moderate risk of damage
Legislation & Regulation	
Current legislation & regulation	No restrictions and barriers
Upcoming legislation & regulation	No restrictions and barriers
Acceptance & Stakeholder Requirements	Medium acceptance
References/Publications	

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[2]EMS (2015) Weeds; Best Practice Guidance Notes for Integrated and Non-chemical Amenity Hard Surface Weed Control (online: http://www.emr.ac.uk/wp-content/uploads/2015/03/BPWeeds2015web1.pdf)

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[7]Method for weed control with hot foamhttps://www.google.com/patents/EP1450603B1?cl=en

[8]Bristol City Council (2017) Weeds, treatment of unwanted vegetation; Trial and comparison for glyphosate free weed treatment in Bristol parks and highway surfaces

[9]Foamstream Weed Control (onlinehttps://www.weedingtech.com/faq/)

Additional comments
Interesting method for the future, but high number of applications needed, since the root system is not affected.

Fact Sheet 10: Infrared Treatment

Fact Sheet	**Vegetation Control** Technologies from other areas with transfer potential
Name of the method	**Infrared treatment**
 Source: FTA,US Department of Administration[7]	
Description	Infrared radiation (IR), produced by heating ceramic or metal surfaces, is used to induce thermal injury to weed tissues. IR radiators operate at red brightness temperatures of about 900°C.[1]
General criteria	
Current status (research, development and testing, demonstration or commercialization)	Developing and testing/ Commercialization in other fields of application (ex. urban environment).
Effect of method on plants	High temperature destroys plants. The performance of IR may differ between species. It depends on weed species, plant size and the propane consumption per unit working width.[2] Root survival leads to regrowth requiring repeated annual treatments.
Experience of Railway companies	Germany (DB), Switzerland (SBB)
Key benefits	Usable in areas where chemical vegetation control is prohibited (groundwater, protection zones, ...)
Limitations	Only effective on the visible part of the plant. No long-lasting effects. Risk of burning/fire. Treatment frequency and efficacy is species dependent.

Potential improvements	Improvement of operational speed to reduce costs is required. Reduction of fire hazards.
Cost efficiency	
Operating costs (total costs including treatment, traction, safety…)	7.200.00 €/km(3)
Operational Performance	
Operational speed (km/hour)	About 2 km/h (3)
Frequency of treatment (p.a.)	About 5 treatments p.a.[3]
Compatibility (processes, equipment)	Moderated adaptation needed
Energy & Emission	
Energy consumption	About 2700 MJ/ha (ten times more energy input than chemical or mechanical methods)[4] IR at driving speeds of 1.5 and 2.5 km/h was the most effective of three compared thermal methods (hot water, open flame and IR),but it used almost four times more energy input.[5]
Resource consumption (water)	No water consumption
Emissions (air, water, soil, noise)	Air emission (liquefied petroleum gas, such as propane, are used)
Toxicity & Health Risks	
Toxicity for the environment	Non toxic
Health Risks	Moderate health risk (lung disease because of propane and thermal injury, high noise level). Operators should be trained in the use of the methods and equipment and the associated health and safety implications.
Bio-Degradability	Fully degradable
Safety Risk & Potential damage	
Safety Risks (employees, costumer, 3rd parties)	Moderate safety risk if conducted properly: injury risk, risk of radiation. Operators should be trained in the use of the methods and equipment and the associated health and safety implications.
Risk of Damage to track parts	Moderate risk of damage. Risk of fire
Risk of Damage to electrical equipment	Moderate risk of damage. Risk of fire
Legislation & Regulation	
Current legislation & regulation	Small legislative restrictions.[6]
Future legislation & regulation	Small legislative restrictions
Acceptance & Stakeholder Requirements	Strong acceptance, some requirements

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[3]Below M., Gächter F., Kuppelwieser H. (2003) UIC-Vegetation Control Project. Final Report (online: https://www.sparkrail.org/Lists/Records/DispForm.aspx?ID=15185

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Additional comments

Fact Sheet 11: Weed Brushing

Fact Sheet	**Vegetation Control** Technologies from other areas with transfer potential
Name of the method	**Weed Brushing**
  Source: https://www.boels.nl/en/rental/gardening-landscaping/weed-control/weed-brush-230v http://publikationer.slu.se/Filer/Rjrapportslutversionskrivskyddad.pdf	
Description	Plants are mechanically brushed away. The equipment can be tractor mounted or hand-pushed.[1]
General criteria	
Current status (research. development and testing. demonstration or commercialization)	Developing and testing/ Commercialization in other fields of application (ex. urban environment).
Effect of method on plants	Plants are removed, but depending on the plant species roots can persist and lead to regrowth.
Experience of Railway companies	Sweden (BV), Switzerland (SBB), France (SNCF)
Key benefits	Usable in areas where chemical vegetation control is prohibited (groundwater, protection zones, ...)
Limitations	High costs. Low operating speed. Safety risks. Dust production. Risk of damage.
Potential improvements	Increasing the operational speed could reduce costs and energy inputs. Vibration, noise levels and dust should be reduced.

Cost efficiency	
Operating costs (total costs including treatment. traction. safety…)	Costs: • 1- 4 €/m²[2] Equipment/Machine costs plus adaptation for railways (a machine can be used for 10 to 15 years)[2] • 0.28 €/ m²[3] per treatment
Operational Performance	
Operational speed (km/hour)	Low operating speed (between 1 and 5 km/h)[2]
Frequency of treatment (p.a.)	Up to 4 treatments p.a.[2]
Compatibility (processes, equipment)	Large adaptations needed
Energy & Emission	
Energy consumption	Low energy consumption
Resource consumption (water)	Not applicable
Emissions (air, water, soil, noise)	High vibration and noise levels can occur, especially for hand-pushed machines[1]; Possible risk of pollution, exhaust gases (Diesel).
Toxicity & Health Risks	
Toxicity for the environment	Emissions from the use of fuel to power the equipment.[3]
Health Risks	Moderate health risks: Operators should be trained in the use of the methods and equipment and the associated health and safety implications.[4]
Bio-Degradability	Not applicable
Safety Risk & Potential damage	
Safety Risks (employees, costumer, 3rd parties)	Moderate safety risk if conducted properly (injury, dust).[4]
Risk of Damage to track parts	Moderate risk: Steel bristles can damage joints or other parts of the tracks.
Risk of Damage to electrical equipment	Moderate risk: Steel bristles can damage or interfere with the electrical equipment.
Legislation & Regulation	
Current legislation & regulation	No restrictions & barriers
Future legislation & regulation	No restrictions & barriers
Acceptance & Stakeholder Requirements	Full acceptance, no requirements

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Additional comments

Fact Sheet 12: – Biological Weed Control

Fact Sheet	**Vegetation Control** Technologies from other areas with transfer potential
Name of the method	**Biological Weed Control**
 Source: https://www.slideshare.net/rajeshdebnath545/biological-control-of-weeds	
Description	Any organism that can cause damage to a plant that is unwanted by humans, thus restricting its development, is a potential biocontrol agent[1]: insects, fungi or nematodes are being tested for the selective eradication of some unwanted plant species.
General criteria	
Current status (research, development and testing, demonstration or commercialization)	Only few organic acids (in the sense that these substances occur in nature) have been commercialized.[2]
Effect of method on plants	Biological vegetation control methods are only effective against specific plant species while other plants survive. Therefore it seems unlikely to archive full weed control for the track area, but the application under specific circumstances (regarding certain problem plants and targeted areas) seems to have some potential.
Experience of Railway companies	Austria (ÖBB) concerning tree of heaven and grazing.
Key benefits	Reduction of the herbicides' use

Limitations	Biological agents can easily spill over onto adjacent areas and damage plants, including such as may be considered desirable there. Before the official release of a biocontrol agent, extensive studies have to be carried out to ensure that the agent will not damage other non-target plants. Limitation of the market size. Although biological control does not require large capital investments, first results may not be obtained for long periods (even 10–15 years). Grazing is only possible in limited areas on the embankment or can be used to avoid overgrowth of abandoned tracks (France).[9]
Potential improvements	Molecular biology and genetic engineering offer opportunities to improve the performance of biological weed control methods furthermore, equipment already available for chemical weed management (optical sensors together with automated spraying system) can be adapted to the needs of living organisms.[1]
Cost efficiency	
Operating costs (total costs including treatment, traction, safety…)	Lack of information about economic benefit/ cost analysis: continued, regular, long term monitoring is necessary. Also initial costs to research, purchase and import the biocontrol agents.
Operational Performance	
Operational speed (km/hour)	Not applicable
Frequency of treatment (p.a.)	Species and agent specific. Ideally one release, followed by monitoring. A supplementary release can occur
Compatibility (processes, equipment)	Large adaptations are needed
Energy & Emission	
Energy consumption	No data available
Resource consumption (water)	No data available
Emissions (air, water, soil, noise)	No emissions
Toxicity & Health Risks	
Toxicity for the environment	It is currently being tested. See OECD Guidance to the environmental safety evaluation of microbial biocontrol agents.[3]
Health Risks	Small health risk: there have been some rare cases of adverse effects on human health in allergic reactions to some organisms.
Bio-Degradability	Fully degradable

Safety Risk & Potential damage	
Safety Risks (employees, costumer, 3rd parties)	Small risk of damage. Impact on human health are minor, since the agents used don't affect humans
Risk of Damage to track parts	small risk of damage
Risk of Damage to electrical equipment	small risk of damage
Legislation & Regulation	
Current legislation & regulation	High restrictions & barriers: EC (2014) Regulation (EU) No 1143/2014[4] EC (2013) Regulation (EU) No 284/2013[5] EC (2000) Council Directive 2000/29/EC[6]
Future legislation & regulation	Moderate restrictions and barriers: Currently there is a wide range of different regulations to releases of biological control agents at global. European and national levels.7 More harmonization is required.[8]
Acceptance & Stakeholder Requirements	Moderate acceptance & requirements: The acceptance can probably only be high if the users perceive the biological product as less hazardous than chemical methods to people and environment.[2]

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Additional comments

4.4. APPENDIX PART D – HAZARD PROFILES AND TOXICITY OF PELARGONIC ACID AND GLYPHOSATE ACCORDING TO CLP CLASSIFICATION & BIO-DEGRADABILITY

Hazard Profile & Toxicity of Pelargonic Acid

according to GHS/CLP Classification

CLP Regulation - Harmonised classification - Annex VI of Regulation (EC) No 1272/2008

Nonanoic Acid	**(Pelargonic Acid)**
Physical hazards	none
Health hazards	
Hazard category	Skin irritation 2
Hazard Statement	**H315**
	causes skin irritation
Hazard category	Eye irritation 1
Hazard Statement	**H319**
	causes serious eye irritation
Environmental Hazards	
Hazard category	Aquatic Chronic 3
Hazard Statement	**H412**
	Harmful to aquatic life with long lasting effects
Major accident hazard	no
substance (Seveso)	
Labelling	Warning
Hazard pictogram	GHS07: exclamation mark
Hazard pictogram	Lower systemic health hazard

Hazard Profile and Toxicity of Glyphosate

according to GHS/CLP Classification

CLP Regulation - Harmonised classification - Annex VI of Regulation (EC) No 1272/2008

Glyphosate	
Physical hazards	none
Health hazards	
Hazard category	Eye damage 1
Hazard Statement	**H318**
	causes serious eye damage
Environmental Hazards	
Hazard category	Aquatic Chronic 2
Hazard Statement	**H411**
	Toxic to aquatic life with long lasting effects
Major accident hazard	yes, category E2
substance (Seveso)	
Bio-degradibility	not readily biodegradable according to OECD criteria
	moderately biodegradable
Labelling	Danger
Hazard pictogram	GHS05: Corrosive; GHS09: Environmental Hazard

Bio-degradability	
Glyphosate	not readily biodegradable according to OECD criteria
	moderately biodegradable
	less than 72% in 29 days
	soil half life average 44-66 days, range 3 - 130 days
Pelargonic Acid	readily biodegradable according to OECD criteria
	highly biodegradable
	> 72% in 29 days (OECD 301B)

4.5. APPENDIX PART E - BIBLIOGRAPHY / REFERENCES

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