

Sustainability in the urban context – the construction and operation of road and railway infrastructure

People as a whole are showing growing interest in environmental matters, one result of which is increasingly tough environmental legislation. This, in turn, has led the media to focus more on salient processes in the construction and operation of railways. Environmental impacts are now a much-debated issue especially as regards local public transport within built-up areas. For operators to be able to react to any queries received in this respect, they must have a full knowledge of the environmental relevance of the individual processes involved in servicing and maintenance. Applying the methodology of material-flow analysis helps them handle the many questions asked in this respect.

1 Sustainability and infrastructure

The basic job of a railway operating company is the transport of people and goods. In the urban context, however, this is limited to just people in the majority of cases.

As a general rule, the sums spent on rail-based transport in towns and cities (which are sometimes very substantial) provide support for activities by the local-transport operators that are considered desirable in macroeconomic terms in the sense of an optimally integrated transport service involving all carriers. The outcome of this is a genuine alternative to the use of private motorcars [1].

In many countries of the world, the railways do carry a very considerable

proportion of the total traffic load. In considering standard-gauge, long-distance railways, for example, systems of high-speed trains (such as the TGV or ICE) now carry the largest proportion of people travelling over the routes served by them. In those towns and cities that have extensive metro or light-rail systems, it would be virtually impossible to maintain mobility without them.

However, railway systems are not going to be able to operate smoothly unless there is a guarantee that they are going to be kept fully and properly maintained in their entirety.

Now, the maintenance management of urban rail-based transport systems demands a great deal of the responsible planners and engineers. Just two of the specific constraints they have to cope with are dense operations during up

to 20 hours a day and extremely limited space available for carrying out the necessary maintenance and repair jobs. In this respect, keeping an urban railway going bears very little comparison with a long-distance railway operation [2].

It is worth making the point that it is not always easy to draw demarcation lines in the larger built-up areas, since considerable parts of the track share land with other modes of transport. Many of the maintenance jobs needed on railway or trams lines occupying roads ought to be paid for at least in part by private motorized traffic. Examples of this are snow clearance (done in part by rail-based machines), gritting icy surfaces (which in some places is the duty of the owner or occupier of the land adjacent to the thoroughfare), renewal of the whole of the surface area used by all modes of transport on account of wear and tear



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caused by heavy goods vehicles, and so on.

Despite this complicated starting situation for urban rail-based transport networks, it is the duty of their operators not only to maintain the transport capacity of the railway or tramway network, but also to make sure that they do not forget environmental considerations. They must do all they can to minimize emissions and other impacts on the environment that might be caused by maintenance activities. Provided the companies concerned have a thorough knowledge of the environmentally relevant processes involved in their maintenance activities, they will be able to react quickly to any conflicts that may arise. The necessary discussion can then be a factual one amongst experts, rather than one carried out on the pages of the daily press, the effect of which is often to play yet more on people's fears. A prerequisite for a sober discussion away from the public gaze, however, is a fundamental analysis of the processes.

"No rules without measurements" – what sounds like a simple principle is, however, not easy to put into practice as regards railway engineering work. National railway networks often have their own R&D departments equipped with comprehensive measuring and analytical tools, with which they can establish the interrelationships between the individual processes. Local-transport operators often do not have any such resources at all. One exception to this is Vienna Public Transport (official name: "Wiener Linien"), which has commissioned numerous R&D projects in recent years, with a view to optimizing individual aspects (such as aligning routes, dimensioning the track substructure and coping with problems of noise) [3]. Some of these projects have led to quite remarkable successes, such as measures to prevent noise and vibrations. To date, however, there has been no strategic coordination of these measures.

Fundamentally, analyzing business processes is certainly far from a new approach for management. A detailed examination of the system does bring out a number of specific questions. It is, in particular, the heterogeneity and the interdisciplinary nature of the individual processes in a rail-transport organization that make it decidedly different from all other sectors. The aim of such surveys is always to arrive at having better means for steering those business processes that are relevant to success, and this generally goes hand-in-hand with a more effective deployment

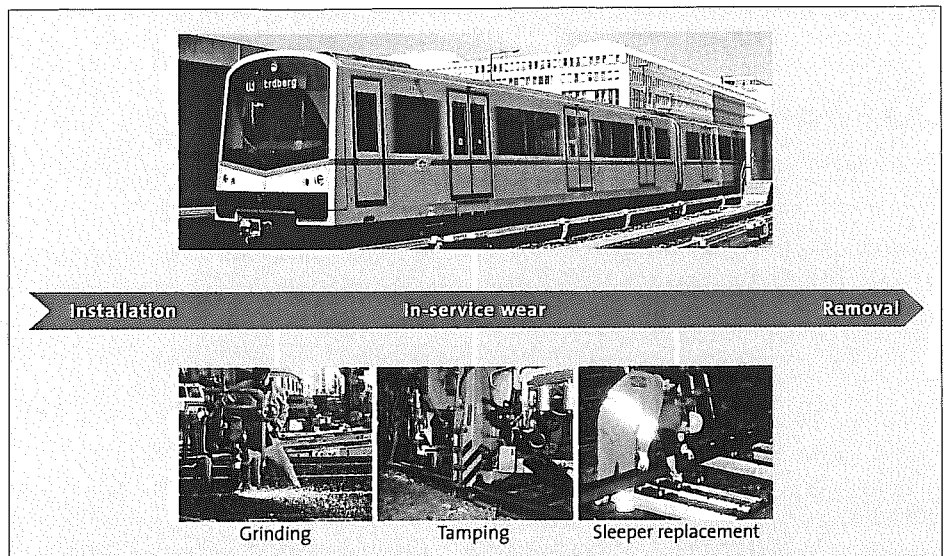


Fig. 1: Typical maintenance and repair jobs to be carried out by local public transport

of resources and more efficient working procedures.

2 The method of material-flow analysis

Material-flow analysis is a tool for describing and analyzing any systems, no matter how complicated they may be. It is used for identifying and quantifying all relevant material flows within a system that is precisely delimited in both time and space. It is a method based on the principle of balance, which means, in short: $\text{input} = \text{output} + \text{changes in stocks}$ [4, 5, 6, 7]. It can thus be used to calculate and/or check the flow of individual goods and materials within the system, following the law of the conservation of matter.

As far as the "railway company" viewed as a system is concerned, what has just been said is of importance both as regards the management of resources and environmental aspects. By using data already known for the purposes of construction of new infrastructure and its maintenance, as well as the procurement and operation of the whole fleet, it is possible to identify the systems goods' and materials' flows, to establish existing holding locations within the track and vehicle processes and, especially, to estimate their future development. This ensures that the most important decision inputs are available for judging future trends and for sustainable management of the infrastructure.

Another useful output from a mass balance is to pinpoint environmentally relevant flows (such as wear caused by brakes, wheels and rails or the use of

consumables). The mass differences between wearing parts as inserted and worn parts as removed at some later date must inevitably have been emitted into the environment. In combination with so-called transfer coefficients (i.e. the ratio between the output flows and the total process input), it is possible to detect the distribution of these emissions over the individual paths of entry into the environment.

The procedure for carrying out a material-flow analysis is not a linear one but more of an iterative one. How to apply it in the case of water is set out in detail in a document ("Regelblatt 514") published by the Austrian trade association of the water and waste-management industry (ÖWAV) [8]. It is further laid down with normative effect in an Austrian standard, ÖNORM S 2096, parts 1 and 2 [9, 10].

According to this standard [10], the system is defined through the creative drafting process, in which the structure of a system is determined for the specific questions (temporal and spatial limits, processes, goods, materials and their interrelationships).

The system definition is comprised of the following part-steps:

- ▷ *Establishing the system boundaries (spatial and temporal)*
The system's boundaries are drawn spatially and temporally as a function of the goals and jobs in hand.
- ▷ *Determination of the processes and goods*
A "process" describes the conversion (biological, chemical and/or physical), the transport or the storage of goods and materials.

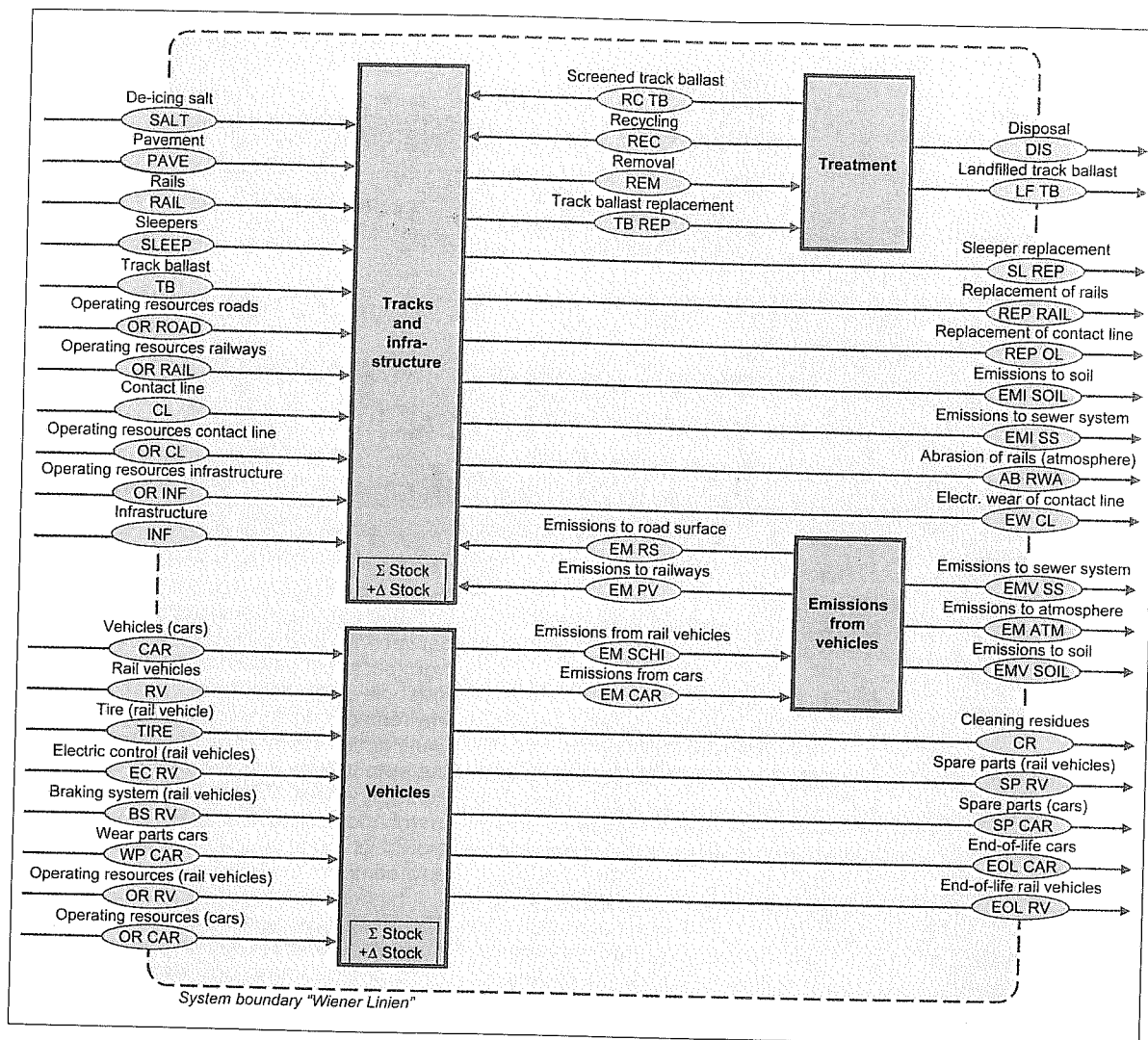


Fig. 2: Vienna Public Transport's material-flow-analysis system

▷ Selection of materials

The criteria for selecting materials are arrived at, on the one hand, as a function of contamination potential and, on the other hand, as a function of their economic relevance (resource potential) for the company.

▷ Determining the desired precision for the investigation.

The system definition is used to produce a surrogate image of reality. In this, real, complex factors with a large number of processes and interrelationships (flows of goods and materials) are mapped in such a way as to create a simple, uncluttered and manageable model. In the model, reality is reduced to its essential components. What has to be done is to identify which are the central flows and processes, so as to be in a position to solve the problem.

From an economic perspective too, an analysis of long-term behaviour and the resulting life-cycle costs are of central significance. If used correctly, such an analysis forms a systematic, corrected

view of accounting and controlling, which today is usually carried out with a SAP or similar system. In the system of double-entry accounting, items of plant and machinery and supplies are valued from the balance's short and medium-term economic views. These valuations are, however, subject to criteria which were originally established in legal frameworks that are no longer up-to-date. One example of this is the definition of "waste". Any change in the legal framework runs the risk of making inventory assets with book values close to zero into liabilities with massive consequential financial burdens on the operator. Two examples are railway sleepers impregnated in tar and loose chippings. The change in the practice applicable to disposing of left-over construction materials has led to similar consequences when a track substructure or superstructure is renewed.

If the accounting function, including the economic valuation of goods, now has the recording and valuation of materials and energy sources added to it, it is possible to create a powerful management

instrument. This is also the correct way of applying the principle from the cybernetic viewpoint too, since it informally closes the gap between two systems that used to be considered separately [11, 12].

In the course of the investigations, the decisive model scenarios are computed in detail at the scientific level, and these clearly highlight where the main potential resides for making improvements in the system. It is thus possible to provide the railway sector with an early initial feedback from the investigations, which also contains tangible measures for implementation.

Viewing the situation with the help of a material-flow analysis also supplies the necessary foundations for operational environmental management systems. International surveys have shown that the implementation of environmental management systems has made little progress with the railways or that the systems they are using still have plenty of scope for improvement as regards mapping their environmentally relevant processes.

3 Application to the "railway" viewed as a system

The spatial and organizational separation of railway operations and infrastructure makes it difficult to record the individual processes and flows in a railway systematically. In the case of a local passenger-transport operator, such as Vienna Public Transport, all the processes belong within a single company, but there are many different responsibilities there. This fact means that even establishing a shared pool of data constitutes a scientific challenge. In the case of national railway operations (such as Austrian Federal Railways, Deutsche Bahn and many others), the legislator – in this case, the European Union – has laid down that there must be compulsory separation of infrastructure and operations. The upshot of that provision is that all sorts of different companies now exist in all the countries of the European Union, some partly independent of one another and some, in part, mutually dependent and with differing degrees of authority to issue directives to others. It would require a truly massive logistic outlay to record everything

in a uniform manner at a European level, and such an undertaking might perhaps constitute a valid aim for a project to be coordinated in the context of the European Union.

For the purpose of analyzing the material flows, the first step involves dividing the railway system into its two subsystems (processes) of "vehicles" and "infrastructure", each of which can then be described in more detail.

▷ *The "vehicle" subsystem:*

The "vehicle" is further subdivided into rail-guided vehicles (trains and metros) and road vehicles (omnibuses), including any auxiliary vehicles needed for maintenance and repair purposes. The input goods captured for the process are vehicles (or their parts), wearing parts and consumables, whereas the output goods, in turn, include the vehicles again or worn parts, solid and liquid residues left after cleaning the fleet and emissions to the environment (in solid, liquid or gaseous form).

▷ *The "infrastructure" subsystem:*

The "infrastructure" subsystem records the running surfaces (rails and roads), overhead wires, electrical

installations and miscellaneous items of infrastructure (such as stations and tram and bus stops). In an analogous way to the "vehicle" subsystem, the input and output goods include the materials for constructing and maintaining the infrastructure network as well as the emissions due to consumption.

3.1 A practical example of material-flow analysis for the "infrastructure" subsystem: planning the grinding of rails

The precondition for being able to use material-flow analysis is the creation of an adequate pool of data. For this reason, Vienna Public Transport makes use of rail-guided recording cars for the Vignol profile of metro rails and the grooved profile of tram rails. In this way, wear data has been continuously recorded for the whole network and used for planning maintenance operations. This comprehensive planning has enabled the Viennese tram network to achieve a world first, with a track-recording vehicle for grooved rails now fully automated for the first time and doing its work on the basis of a referenced process. Figures 4 and 5 show examples of profiles recorded for Vignol and grooved rails.



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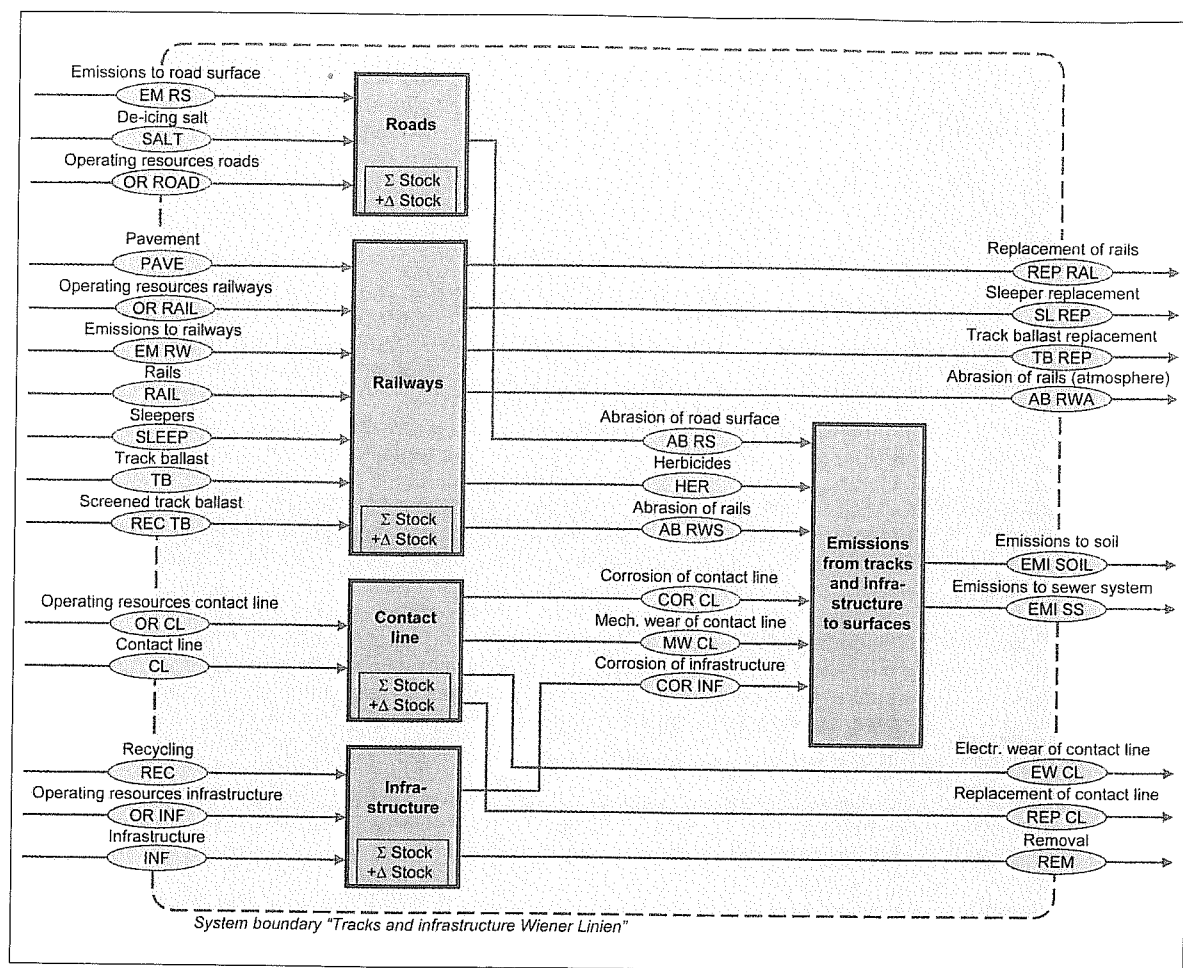


Fig. 3: Vienna Public Transport's material-flow-analysis system (infrastructure subsystem)

The measurements can be used to deduce both the current wear data and the material lost as a consequence of reprofiling the rail head. If the data is

analyzed for the whole length of a given line, it is possible to draw up a detailed material balance of the rails laid on individual lines with a locational accuracy

in the range of approximately 50–100 cm. These findings can then be used for the targeted planning and optimization of maintenance measures and stocks.

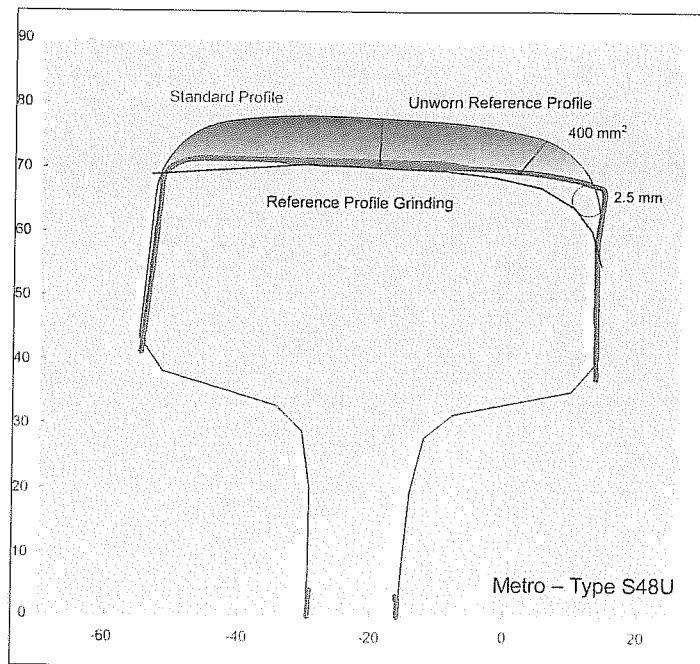


Fig. 4: Profile measurement with the actual, target and reference profiles superimposed for the S48U type of rails used for the Vienna metro (© typoPICHLER)

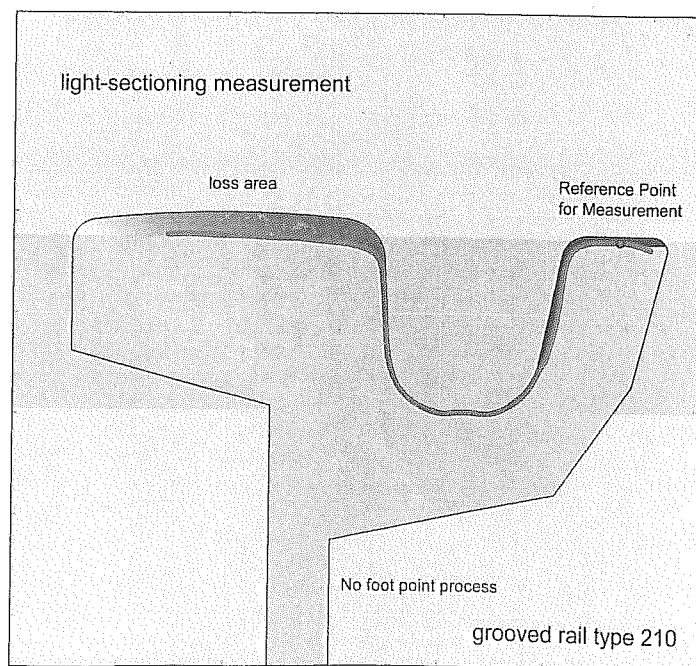


Fig. 5: Profile measurement of the type-210 grooved rails used for Vienna's tramways (© typoPICHLER)

4 Findings to benefit the infrastructure manager

The results obtained through a material-flow analysis make it possible to improve the economic management of the railway superstructure system as a whole:

- ▷ Firstly, environmentally relevant activities are identified and measures or, at the very least, approaches to achieving improvements by switching to other materials highlighted. Analyzing such a material change using the model developed even makes it possible to forecast environmental impacts before they actually occur.
- ▷ Secondly, resource management can be optimized, which then becomes the main focus of interest when expressed in hard-cash terms. Here, it is possible to show where there is potential for savings.

Maintaining the railway infrastructure as a “stock process” is a key business activity of any infrastructure manager. In the medium term, suboptimal management of the infrastructure leads to an appreciable deterioration in the quality of the railway operation. Maintaining this quality is, however, indispensable if the provision of transport services is to be dependable and achievable with reasonable ease.

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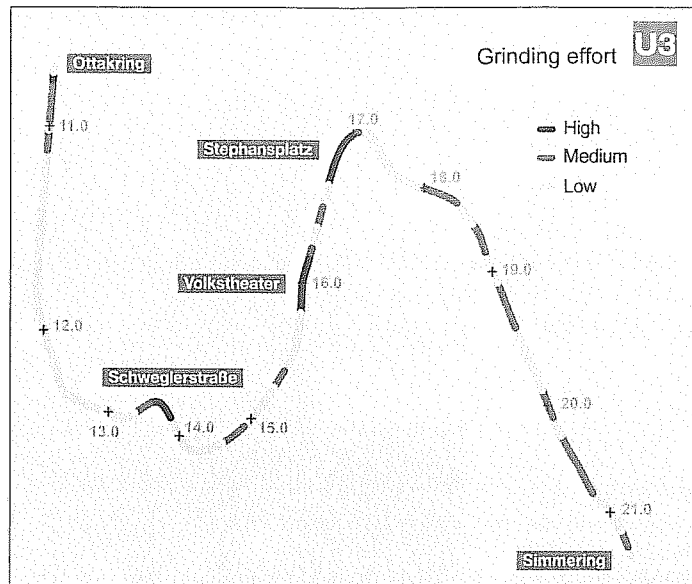



Fig. 6: The outlay that would be necessary for profiling the rails along Vienna's U3 metro line deduced from the material-flow data (© typOICHLER)

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