IMPROVERAIL

IMPROVE d tools for ***RAIL*** way capacity and access management

Deliverable 10

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COMPETITIVE AND SUSTAINABLE GROWTH

(GROWTH) PROGRAMME

TABLE OF CONTENTS

INDEX OF FIGURES

INDEX OF TABLES

0 REPORT SUMMARY FICHE

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1 EXECUTIVE SUMMARY

1.1 The Railway Context

Throughout history, the rail industry has been one of the most heavily regulated sectors of the economy. The following elements have led to government controls on entry, exit, prices, technology, operating practices, inter-company relationships and ownership:

- **Cost characteristics of the industry**, with up to 80 per cent of infrastructure costs being fixed in the short run;
- Presence of **indivisibilities and economies of scale** in the longer run;
- Potential for **exploitation of existing monopoly**.

These elements were based on the assumption that a fully competitive organisation, such as railways, was both undesirable and unfeasible. As a result of these considerations, the railway industry has historically been thought as a natural monopoly requiring unitary ownership of both infrastructure and operations. And this has been the way in which the industry has evolved in most countries around the world.

However, there has been an increasing discontent with the traditional public utility regulation of railway, mainly due to its declining market share and the worsening financial performance, which has resulted in the increasing interest in privatisation and deregulation as potential solutions to such problems. These have since been regarded as means to promote efficiency and innovation, by freeing railways from government control, further helping removing subsidies. At the same time, governments have been keen on reducing public expenditure and seemed willing to transfer new rail investments to the private sector.

Such reasoning has therefore triggered a process of dramatic changes. Starting in the early 90s, the business has suffered an important structural reform with the separation of roles and organisations within the railway system. Although a few situations seem to prove that some decisions taken to this respect should deserve serious thought, such as the privatisation process implemented in the UK, it is undeniable that keeping the status-quo is not one of the choices for railway. Therefore, continued efforts have been applied by the European commission towards the implementation of Railway reforms in Europe, which helped paving the way for drastic changes in the manner railways are managed

The ultimate aim of these changes is the overall modernisation of the railway business in order to render this industry less dependent on subsidies for its financing, along with improved flexibility and capacity to face complex environments, helping its integration in to the global transport system.

A new vision for railway underlies this reform, which appears as a result of the continuous declining performance on a transport sector traditionally steered by public service concerns, loosing ground for other more flexible transport concepts such road base ones. A whole new approach is now understood to be necessary for the self sustainability of the railway sector, pursuing its growth potential and exploring its strengths while acknowledging and sorting out or at least minimizing, the inherent weaknesses.

One of the major strengths of railway is related to the increased environmental concern associated with road transport, that railways are eager to take advantage of. This is seen as the *leitmotiv* for improving railway sector's performance, rated very positively with respect to environmental and sustainability concerns. The current moment provides therefore a chance for the successful renovation of railway, should it be able to cope with key market requirements. Not only in the traditional passengers segment but also, and in particular, in the freight traffic and in the High Speed passenger services, the latter in direct competition with Air transport.

However, these promising segments call the attention to, perhaps, the major weakness of railway that, unlike road and air passenger transport and road haulage, is rather inflexible in accompanying transport trends. This means that to ensure that the outcome of the huge investments required to cope with the new set of challenges are worthing, will depend on a strong ability to anticipate future market behaviour, based on a long term strategic planning.

With regard to freight traffic, one of the top barriers is the difficulty in providing convenient and "value worthing" door-to-door transport services as road haulage does. However, such acknowledgment should only help to place correctly railway in the whole transport system, driving the right decisions regarding strategic investments and alliances with other modes e.g. promoting intermodal transport in cooperation with road and maritime modes.

1.2 The Challenges for Railway and Next Steps

By proposing the split of the Operation of trains from the Network Possession and Management, the EU has paved the way to a deep structural change aiming to enable better economical usage of the railway assets, further creating the conditions for competitiveness in railway transports; to a large extent due to the fact that the concept of a Public Railway (for long, kept away from private sector logic), has progressively proven wrong, at the cost of growing operation deficits, which are today urgent to keep under tight control. In that sense, splitting operation from network was, naturally, a milestone.

However the consequences of such can be far more important than one may expect, as it has also shaken historical relationships and ways of approaching and performing a whole business, as it has created a cleft between old partners, namely operation and network related management areas.

Undoubfully railway lagged behind in a growing transport sector and such less than optimal behaviour can be partially explained by the inherent public sector rationale, which was hard to change. However, it is undeniable that whatever the rationale adopted, the inertial effect associated to a sector of activity heavily dependent on capital, with difficulty in adapting quickly to the pace of structural changes occurred in a fast growing transport market, did not help promoting railway to the top of the market choices.

Along with this, business processes that appear today as crucial ones such as *accounting* became increasingly complex, as intrinsic costs of the activity seen as a whole needed now to be split. This is necessarily a crucial challenge for railway, as the infrastructure manager need now to balance the "income from infrastructure charges", based on effective (but complex) cost analysis. This is however simply absent most of the times, as it depends on information that cannot be easily and readily obtained. This aspect in particular may be even corroborated from our privileged contacts with several IM's along the development of IMPROVERAIL, as, apart from a few exceptions and initiatives being carried out by some of them, knowledge about effective cost drivers related to the provision of service are generally poor.

An additional challenge is to balance revenues from charging core activities with "State funding", a ever more scarce resource. Also necessary will be to manage "infrastructure expenditures" while reducing the costs of provision of infrastructure and the level of access charges "with due regard to safety and to maintaining and improving the quality of the infrastructure service". In practice railways need to improve their service levels to those available in other transport modes. And as the transport industry becomes more international and deregulated, rail transport in Europe should be able to take actions looking at the EU dimension rather the individual Member States.

Moreover, IMs should develop specific measures based on a strategic definition of long term goals, accounting for the thorough understanding of the new requirements of railway undertakers and stakeholders in general. In particular it should pay close attention to the challenges posed by the implementation of optimised logistic flows led by freight integrators, requiring improved flexibility in adapting to new situations, assuming its natural role of conveying freight traffic across Europe under specific and suitable circumstances.

All together, it requires from Railway a strong commitment towards change.

Based upon the research areas developed in IMPROVERAIL it has been seen that the main challenges related to the future of Railway Infrastructure management contributing to the overall success of the railway sector remain associated to the following topics:

- ✔ Competitiveness Concerns and Commitment Towards Intermodality
- ✔ Optimization of Railway Capacity based on Maintenance and Renewal Planning Tools
- ✔ Promote Smooth Infrastructure Provision Across E.U Member States
- ✔ Reaching Higher efficiency in Network Provision and Capacity Allocation
- ✔ Specification of Data Requirements for the Development of Information Systems
- ✔ Foster Financial Sustainability of Railway Infrastructure Management
- ✔ Promote Continuous Improvement and Implement Best Practices

Therefore, and besides the specific research addressed in IMPROVERAIL itself, future initiatives envisaging to promote Railway Transport in Europe, such EC Research Programs and EU Policy making, should focus on these topics, reflecting some of the most important barriers to the successful development of the Railway Sector.

1.3 Implementation of BPR in Railway

Recent regulatory changes and the creation of a new relationship provider-client with Railway Undertakers (R.U) came to stimulate the implementation of Business Process Reengineering. Indeed, being its own performance now subject to external evaluation and having lost its traditional role in specifying the service to the final client, means that Railway Infrastructure Managers need to undertake a serious review of both internal and external business related processes.

Approaching business processes at the light of Business Process Reengineering, reflects this approach, by exploring the rail business and the regulatory environment and assessing its current positioning. To this end, it is of utmost importance for the IM to first gain awareness of the competitive environment, the railways dynamics, the challenge and opportunities and the impacts of the new regulations in the railway industry. As a result the IM will be in a position to influence the positioning of the railway company, understanding the major trends shaping the future of railway.

Besides, approaching BPR implies realising that different organisational and sectoral structures exist. Hopefully, this will help the IM's in reaching the most effective, efficient, and feasible structure for the railway company, looking at each country's unique legal, economic, political, and social environment.

But BPR requires from Railway a strong commitment towards change. However, as railway industry is often heavily politicised, it is sometimes difficult to sustain management commitment and leadership. Indeed a strong and intelligent senior management may enable to drive through policies and step by step plans for a change in the short/medium term. With senior management usually a political appointment, both management board composition and policy followed may change as often as governments themselves.

<u>It is thus difficult to sustain commitment in a particular direction.</u>

On the other hand, it is important for the IM to focus on the processes that are critical for a successful re-engineering process. A solid understanding of the processes and their relationship to re-engineering is a basic requirement. In order to implement BPR, IMs should also be strategically prepared for the considered adoption of a particular institutional model and service that best-matches the specific IM's competitive environment and growth prospects. Because a wide range of re-engineering models exists, a BPR methodology such as the one propose in IMPROVERAIL, should be able to define and cover the most important options of the identified BPR spectrum. Most importantly, it is not only how the railway industry is structured or organised, but rather to achieve a clear understanding of the processes involved.

Although Business Process Reengineering is not the solution to all the problems and challenges of the railway industry, it does provide a fresh way of analysing and looking at an "old industry" that has been thought about in the same way for quite a long time.

BPR provides therefore an opportunity to streamline the key business processes, whatever the organisational structure is. It is, however, impossible to reengineer the processes of the infrastructure manager in isolation from the rest of the industry. It is essential to identify and understand the interfaces where processes pass between different organisations, with regard to e.g. freight slot allocation and relationships between freight operators and the infrastructure manager.

BPR could be used to help achieve some high level objectives but will not set or solve those objectives or policies on its own. It should therefore be understood as a tool, whereas if the objectives set are not correct, the application of BPR might end up potentially risky. Should this aspect be taken in to account, BPR could indeed play a significant role in improving the efficiency of the European railway industry. All in all this implies that major railway stakeholders are clear and agreed on what they are trying to achieve.

It has been seen that the vast majority of BPR projects have been carried out in the private sector, with only a handful in public organisations. Even in private companies with strong market orientation and profit motive as well as clearly defined customers, between half and three quarters of all BPR exercises fail. Those public sector projects that have been attempted have met with very limited success.

A review of the BPR that has been carried out in the European railway industry revealed that very little has taken place. Whilst there has been extensive restructuring, mainly as a result of the EC Directives 91/440 and 95/19, this has been almost exclusively organisational, with little or no focus on processes.

Thus any attempts in BPR should be treated with caution and will always represent a challenge, regardless the number of successful case studies. It should be noted that the decision to re-engineering should be taken with reference to the IM structure and considering the actual national policy environments and stakeholder interests.

Finally, there is no single formula for IM re-engineering but rather several ones. The selection of the best formula is a responsibility of the IM stakeholders. The work carried out in **IMPROVERAIL** did not aim at suggesting ways to produce a perfect IM; it rather gives the basics for apprehension as well as a general way of thinking on how a BPR process should be implemented.

1.4 Market Oriented Infrastructure Management

Due both to political trends and to a general growth of the transport market, the traffic on main European railways corridors seem bound to increase. As a consequence, many rail infrastructure owners will face, in time, capacity bottlenecks on their network. But there is always a trade-off between meeting the demands of the market (passengers, shippers, forwarders) and the needs to expand and maintain the infrastructure in a reliable and safe condition.

Hence, saturated railways sections raise two contradictory issues: the maintainability and the availability of the infrastructure. Several railways companies put a very high importance on the availability of their network and tend to reduce traffic interruptions for infrastructure maintenance activities, inducing either lacks of maintenance or a drift of maintenance costs. Others put the focus on the maintainability of their infrastructure and allow extended traffic interruptions, neglecting the quality of the service provided to operators and end-customers.

Both views are either a consequence accrued from evaluation methods or else are inherited from past practices. This calls the attention to the fact that to carry out a lean railway business will always require adopting careful long term planning of both network capacity investments and infrastructure maintenance, as railways investments often suffer a time gap between planning activities and actual deployment of the infrastructure itself.

At this stage, it should be stressed that the capacity assessment of a railway network is indeed a core task of the infrastructure manager, unable to be outsourced, as track works are. The more saturated a network is, the more important and also more difficult this task becomes.

As long as the railway was an integrated railway company, the capacity assessment was an internal process, mainly based on experience. Little, if any, importance was given to the cost efficiency of the capacity assessment. The main concern was to get own trains running with the desired quality. The reforms in the European railways with the introduction of competition and the split of operations from infrastructure management introduced new elements to the process of capacity assessment:

Today, in a competitive environment and with limited public funding, the capacity management task of the IM has significantly changed towards market orientation. The goal is to sell as many slots as possible in order to maximise the IM's revenues. The capacity manager is now faced with different competing operators, focused on efficiency and trying to meet the market demands and opportunities. Therefore the IM became bound by contracts that generally include penalties for late or missed provision of services (slots).

Moreover tracks occupied by M&R possessions mean a reduction in revenues, either when planned slots have to be suppressed or when they are re-routed over the network of a competing IM (e.g. in transalpine traffic).. An anticipated planning of the infrastructure possessions is therefore a crucial element in the negotiations with the operators.

This new, commercial-based reality for the infrastructure managers calls for new and innovative methods and tools to support the capacity manager in his decisions in the M&R possession planning. The traditional methods mainly based on year-long experience of the slot managers and maintenance planners, may supposedly not lead to the optimum in terms of global costs.

Here is where models developed in IMPROVERAIL enter. They have neither the objective to replace the experience of the capacity manager nor will they provide automatically the best solution, but they will help and support the IM in solving the contrast between meeting the demands of the operators and maintaining the infrastructure in a reliable and safe condition.

With proposed tools, the capacity manager gets an added value for his task of capacity assessment. Where he until now had to rely mainly on empirical knowledge and was able to assess just the timetable for one worksite at a time, the proposed tool enables him to assess worksite combinations, thus giving him the possibility to analyse alternatives and find the best solution. The most relevant benefit of tools is perhaps their capability to address the network effect. This functionality significantly contributes to an improved use of infrastructure capacity and represents an added-value compared to the current linear approach of M&R possession planning.

Long-term related decisions that must be made by infrastructure managers should be aimed at the satisfaction of the train-path demand at any time, in quantity and quality, with a minimal overall cost in the long term. The IM's challenge to fulfil this objective is therefore twofold:

- The capacity management aims at optimising network capacity in terms of future train-path demand. By anticipating future train-path demand based on traffic forecasts, the IM has to identify and plan the necessary capacity extensions in order to meet the future demand. The optimisation task is complicated by the fact that capacity evolution occurs in leaps with typically a long time lag between identification and realisation, whereas the demand evolution is a rather continuous process. An optimum is reached if the available capacity follows the demand development as close as possible.
- The maintenance and renewal management defines and plans all the activities in order to maintain the infrastructure at a desired quality level with minimum total cost in the long-term view. The long-term M&R policy has to follow the strategic objectives of the IM and the technological evolution as well as to determine the impact of M&R on the network capacity evolution.

At the medium/short term level (tactical) infrastructure managers also face challenges. Here the concern is the optimisation of the use of resources, keeping up with the objectives set for infrastructure maintenance and renewal, while securing the network availability contracted with operators without incurring in situations of contractual compensations at the cost of both financial and image loss.

1.5 Planning Infrastructure Investments Supported By Lifecycle Costing Decision Tools

To the extent that Railway is characterised by the need for large initial investments and large annual budgets for maintenance/renewal activity, a very long life cycle and significant correlation between quality of investments and need for maintenance, Life Cycle Cost assessment (LCC) becomes today a crucial issue for the economic sustainability of the railway business. The increasingly competitive business environment, declining resources and an ever-increasing need to obtain value for money will inevitably lead to the wide adoption of LCC in railway, contributing to ensure that available resources are rationally used.

From the LCC combination of the investment and the maintenance/renewal a number of potential areas for cost-reduction could be identified. To such extent it was seen from previous research that a lean and appropriately specified infrastructure, may offer a two digit reduction potential for investment and maintenance/renewal.

From previous studies it was also seen that Life-Cycle related choices, like timing of renewal, quality and maintainability of assets have an important effect on cost-competitiveness. Circumstances of construction as well as maintenance and renewal (traffic interruptions, local accessibility and track access time) are of vital importance for LCC considerations.

It was further revealed that technical and operational knowledge which was traditionally in the hands of practitioners tends to get lost. Therefore LCC analysis should see whether possible raising costs of subcontracting dependence may have an impact on long term cost estimations.

Moreover, the commercial assessment of technical and operational issues is often neglected, sometimes constituting even a “blind spot”. Few practical decisions are really taken on well-informed commercial grounds. The lack of knowledge at the technical-economic interface is widespread and sometimes astonishing. Relevant areas for knowledge acquisition and decision-support should be, among others:

- the effect of standards and quality-levels on cost
- planning and optimisation of asset-replacement strategies, extensions of useful life for “cyclic components” like rail, etc.
- asset condition monitoring and prediction for tailor-made maintenance processes
- technical solution and innovations, driven by clear-cut commercial objectives
- the understanding of mechanisms and quality-aspects of various maintenance processes and inspection tools and
- the commercial assessment of the impact of rolling-stock quality on infrastructure LCC

It was seen that several LCC calculation models exist for the assessment of railways rolling stock costs, while almost every Railway Operator has its own model. However, this does not stand for the infrastructure side of the railway industry.

Although during the he past 20 years, most European Infrastructure Managers made efforts to develop and implement tools that are required for professional life cycle design and maintenance management, these tools are still in an early phase of development and examples of successful implementation in the decision-making processes are almost absent.

The initial uses identified some problems that relate largely to the RAMS terminology and the financial analysis of the results. The deficiencies in the terminology definitions is being addressed through the development of CEN standards though care must be taken to ensure that there is consistency between the various groups working on the standards.

In an effort to summarise all the progress done in Life Cycle Costing in Railways Infrastructure Management, a review of European Railways Procedures took place. Out of all, only RIB showed significant attempts to introduce and eventually establish LCC techniques in the infrastructure management.

In any case, decisions at RIB (recently renamed and integrated as PRORAIL) are usually taken based on case-to-case judgements of maintenance managers and are financed through separate budgets. The reduction of government funds makes it necessary to reduce the total costs and to increase the accountability of costs. Hence, strategies have to be analysed comprehensively on their maintenance and availability effects. In the cases performed until now, each LCC decision support system (DSS) is fitted to its specific context. Indeed, although a decision might concern the same asset, the conditions for infrastructure management vary a lot (e.g. type of traffic, allocation of risks, and payment regime).

The application of a DSS to the design of new high-speed line shows that many factors influence the actual costs and performance. Uncertainties related to, for instance, the train operations and innovative technologies complicate the analysis. These uncertainties are worsened due to the poor availability of historic maintenance data.

A univocal expectation of infrastructure costs and performance is therefore missing for inclusion on LCC models

The possibilities for planning infrastructure costs and performance are therefore somehow limited, especially in the design phase, due to the above-mentioned reasons. This is one of the acknowledged reasons why Railway companies do recognise that the introduction of LCC is a long-term process that is costly and requires changes within company structures and also cultures to become effective,

Overall, we have seen that the development of a harmonized methodology for assessing rail infrastructure Life Cycle Costs (LCC) related to investment (infrastructure related), maintenance and renewal costs, vehicle-infrastructure interaction, delay and scarcity costs and accident/environmental costs, requires that reliable data is available and that common criteria is adopted.

Furthermore, LCC techniques applied to railway should not only include time dimension and costs attributable to the project analyzed, but also account for cost variation patterns. Also the possible changes in cost structures due to the implementation of the EU Directives should be considered. In fact the implementation of the EU Directives had the consequence of driving changes in railway cost structures, primarily due to the separation of roles between operation and maintenance.

However, this does not mean a straightforward and simple split, since much of this process has implied a refinement of the quality of the data along with cost allocation criteria. In fact this separation has brought along also charging issues for access to the infrastructure by the operators and therefore well identified "IM related" cost arguments are required for the IM to support billing schemes that are fair and reflect signals of the real cost of the provision of railway infrastructure.

Nevertheless, such change is not yet fully put to place, as the implementation process mentioned is in most cases still underway or least still in its maturity phase. Therefore it is expectable that the fine tuning required in railways regarding cost accounting structures in result of the new regulatory environment may also foster LCC implementation, since analytical accounting and cost knowledge concerns are broadly shared by both LCC requirements and charging schemes' requirements.[1]

However, the quality of the data on which designs and judgments have to be based on is often a critical issue. Free exchange of data between competing companies is mostly seen as being commercially sensible and therefore it is difficult to obtain elements of data with the required detailing for LCC.

In any case, new projects undertaken in railway nowadays should at least be framed by life long cost concerns, which although possibly based only on raw data and statistical studies will nevertheless represent second best approaches to LCC that are worthing to be explored.

[1] See Workpackage 7 - Deliverable 9 , dedicated to Data Harmonization for Charging

1.6 Setting Up Efficient Infrastructure Charging Systems

The separation between provision of train services and the infrastructure management has provided the basics for a new railway business concept, calling for a new approach regarding the relationship between network managers and new coming competing operators. Such cleft raises the need for feedback relations among railway stakeholders, fostering the rational production of the railway transport service. This means that it becomes necessary to implement a market structure based on financial flows, promoting the system's optimisation. Such structure should account for:

- **Welfare of end-users**. The provision of railway services should meet the end-users demands.
- **Cost structures**. Both internal and external costs should be reflected in the market. Cost efficient production should be a concern across the "production line".
- **Differences in companies' cost structures**. Relative differences in productivity among competing firms should lead to a situation where the most competitive firm wins contracts and is given opportunities to expand and evolve its production.
- **Intermodal competition**. The railway market should face the same external conditions as competing modes of transport
- **Flexibility** needed for adapting new traffic into the railway framework
- **Non-discrimination of operators**, freight -companies and passengers
- **Need for clear information flows** between operators and infrastructure managers to secure that decisions taken are rational and that the whole railway system is taken into account

Hence, infrastructure charging emerges as a crucial "part of the picture" required to fulfil the expectations that remain in railway transport with.

The directive 2001/14/EEC defends that the infrastructure charging schemes have to encourage the infrastructure manager to minimise disruption and improve the performance of the railway network. While respecting the management independence, the specific charging rules are established by the state member or the infrastructure manager. As already considered in the previous directive 91/440/EEC, the infrastructure manager determines and collects the charge for the use of infrastructure except if the infrastructure manager is not independent in its legal form, organization and decision-making from any railway undertaking.

In general, the charging systems analysed in IMPROVERAIL allow clarifying the role of charging in promoting access to services facilities and supply of services, including the different capacity allocation strategies combined with the levying of the charges. A discussion on the adherence of Marginal Cost pricing principles to the recent EC Directives on this subject is also included, along with the importance of the charging systems in the relationships with the Railway Undertakers and in the promotion of cross border railway traffic.

In direct relation to the charging issue comes the fair allocation of capacity, adopting the concept of ***train paths*** related to capacity allocation. Indeed, this became a crucial issue in the context of the provision of track access service. This is actually a scarce commodity in most corridors across Europe, regarding departure times, arrival times and transit times. Existing timetables favour the established rail operators with multiple train paths at times that suit their business and with preferential transits that minimise the number of crossing delays. New operators are left with train paths that do not meet commercial or operational needs, but still costing the same, sometimes even more than those of the major operators.

This places new entrants in disadvantageous positions in relation to existing rail operators, in particular if we think about one of the most promising market segments for rail represented by freight. Hence there is a clear and real need to rationalise train paths allocation along with suitable charging mechanisms, in order to provide a level playing field between the railway undertakers while promoting the railway as a true alternative to road concerning freight.

The ***quality of the infrastructure*** is also critical in valuation of the service being provided. The track condition is a key factor, as there are large sections of track that cannot accept the top speed of high-speed trains. These substandard track sections reduce the ability of the traffic planner to maximize the efficiency of train paths. This causes sub optimal transits and increases the operational costs of the railway undertaker.

Also the ***information systems*** *must* be developed coherently on a cross-border perspective, in order to provide real time information concerning trains running and must be accessible to the rail operators. Currently, a number of different systems are used in different states. There would be benefits from deciding on a single system and ensuring that the system provides the operational and commercial requirements for both the track authority/company and operators.

Charges should be set for each corridor to encourage fair **competition with road and aviation**. Rates should be published and held for a minimum 12-month period. The current practice in some states, of negotiating with individual operators on the annual fee and/ or the usage fee, provides an area of uncertainty for rail operators regarding the equity of the result. Large annual fees on some track sections create **barriers to entry** for new operators. **The rates and fees must be uniform, transparent and reflect the quality of train path provided.**

The network authority/ company IM should be required to provide a range of services at a level consistent with rates, transit times and quality of ride competitive with road. Documentation of agreements should be standardised to incorporate uniform elements for all rail operators.

The **agreements** will need to address the levels of performance of both parties. The issues of termination, insurance and cost retrieval need to be reviewed and brought up to commercial grounds. Requests for train paths and negotiations for agreements should be given time frames and standard procedures and documentation introduced to facilitate this process.

All in all, charging procedures should give the right incentives for total railway production, competition between operators and between railway transport and road and aviation transport. The following chapter shows how this can be achieved.

Finally, **International traffic** which is heavily dependent on national charging schemes, priority rules and bureaucracy should be supported by common principles and clear charging systems ensuring transparency, predictability and non-discrimination. Financial **mark-ups** to cover parts of investment costs to the infrastructure charges, despite extolled in the recent EC Directive 2001/14, may create a sub-optimal situation at a national level. In international traffic, the disadvantages of such systems are even more visible, as each national IM will have few incentives and will often miss the ability to see the impact of reducing international operators' surplus. It is therefore recommended to analyse carefully the definition of a cross border charging system

1.7 Implementing Best Practices – Benchmarking

The aim of the Benchmarking part of IMPROVERAIL has been the development of methodologies for comparative analysis within railway infrastructure firms. The approach adopted covered from definitions and harmonization of concepts for benchmarking methodologies to final assessment of the operational, commercial and managerial performance of the railway infrastructure managers, using a integrated approach. This process has included the definition of proper and specific indicators for the industry.

The final goals of this benchmarking exercise have been to stimulate the exchange of information between stakeholders, promote standardization processes in the industry and contribute to better management of information within the industry. As such, IMPROVERAIL Benchmarking has dedicated to the development of benchmarking methodologies, frameworks and indicators for future benchmarking, and its aim was not to undertake a definitive comparison of performance between IMs.

The key characteristics of the benchmarking methodology developed and proposed by IMPROVERAIL in support of the adoption of best practices in business, are as follows:

- ✔ Covering up all dimensions of the IM – i.e. not just cost, or reliability
- ✔ Committed to continuous improvement and search for best practices
- ✔ Recommend IMs adopt both performance and process benchmarking
- ✔ Be practical: A system to achieve transferable and implementable results – benefits without achieving 100% comparability
- ✔ Set up Key Performance Indicator (KPI) system for IMs to apply in the future (top-down hierarchy)
- ✔ Recommend achieving harmonisation and comparability
- ✔ Recommend that for unit cost / efficiency benchmarking, the INFRACOST benchmarking model (UIC) is maintained
- ✔ Recommend that benchmarking process must be led by the stakeholders (the IMs)

It has been shown that railway infrastructure companies are large, complex, and their scopes of operation differ between European countries. This adds an additional level of complexity to the application benchmarking to this industry. Moreover, between European railways, the existing mechanisms for the measurement performance (such as the measurement and definition of train delay) vary considerably. Even when performance measures are comparable, the influence of geography and local economics can hide differences in performance which are truly due to those superior practices. A successful benchmarking study should be committed to the search for and emulation these superior practices.

Comparability of performance measures between European IMs is therefore a major barrier to benchmarking. The present report therefore aims to provide a holistic methodological framework for future benchmarking between Infrastructure Managers in support of the required implementation of change in this business and its continuous improvement.

Vertical separation has also meant that benchmarking of national railways in the traditional manner has to be adapted to reflect the new IM's specific priorities. The IM has to consider performance in the context of what is within its managerial control. Therefore, how success is measured and the focus of priorities for improvement will be different to those of the integrated railway.

Railways and metros have achieved some substantial results from benchmarking over the past few years. However, It is the adoption of best practice which generates the clearest immediate benefits. More or less all of an IM's functional areas can benefit from benchmarking to improve performance. Some examples are provided of ways in which integrated railways or IMs that have already benefited from benchmarking projects in the past.

2 CURRENT AND FUTURE CHALLENGES FOR RAILWAY TRANSPORT IN EUROPE

2.1 Introduction

Besides high speed (TGV) and suburban passenger services, the **intermodal freight market** appears therefore today as one of the main segments, where a new emerging railway market seems to be able to succeed, should European railway stakeholders be able to join efforts to tackle the current barriers, namely those related to interoperability and legal frameworks.

The step envisaging the separation between provision of train services and the infrastructure management has put forward the basics for a new business concept among operators and for new strategic decisions to be made regarding the provision of railway infrastructure.

This approach is supported by the Common Transport Policy and several other initiatives indicating the way forward with this respect, such as the guidelines for the 6th Framework Program, envisaging the Implementation of change in European Railway Area by setting up a new concept for the role of railway in rendering logistic operations across Europe more sustainable by suggesting a set of feasible railway corridors, including those currently considered as “Accession Countries”.

This new railway reality should have an impact on passengers, shippers, and train operators as well as the infrastructure managers. The infrastructure managers in Europe face therefore a whole new set of challenges and opportunities, but also face serious risks and obstacles.

Along with those, a strong belief that railway may have a prominent role in the pan European context is also crucial to drive initiatives deemed necessary for the success of railway, such as those related to the required enlargement of railway capacity via improved management and slot allocation procedures, both aspects addressed hereby, supported by suitable reengineering of production processes.

2.2 Competitiveness Concerns and Commitment Towards Intermodality

Railway market share has been declining during the last 30 years from nearly 20% in 1970 to around 8% in the late nineties. This decline has been often related to several factors such as the lack of interoperability among national railway systems, poor end-user perceived quality standards, and strict regulation of the sector. However, and as stressed in the EC Railway packages, despite restructuring of the historic railway undertakings in several European Union Countries, the market share of railway seem to be bound to further decline. Not surprisingly, the quality of service offered by rail appears in this context far from satisfactory, being questionable whether this is a mere result of exogenous variables driving the unsuccess of railway or else if this is indeed part of the causes for its decline.

A good example is the difficulty of railways in presenting reliable alternatives to road haulage in a pan European intermodal context. In fact, this is one of the most discussed topics of railway performance nowadays, clearly limiting its role in the whole transport system. However there should be nothing inevitable about the decline in rail’s share of the freight market, which is indeed expected to provide a significant contribution to render transport operations more sustainable, while penalisations to less sustainable modes are slowly starting to be implemented via the internalisation of the external costs, in particular regarding road transport.

Transport demand has revealed signs of continuous growth and further increases are expected in the next 10 to 20 years, if the world economic development is sustained. On the other hand, the rail sector encounters competitive pressures from other modes, for both, passenger and freight traffic for short, medium and long distances. In particular, for freight traffic rail is threatened by intensive road, water (inland and maritime) and pipeline competition. As a result, rail industry has lost market share although there are increases in traffic volumes, because service reliability and product deficiencies have become more pronounced compared to the other modes.

Moreover, the unequal conditions of competition amongst modes are obstacles for the railways to remain competitive, especially in the freight sector. As long as the conditions of competition amongst modes are not harmonised, air and road transport will continue to develop their markets causing negative effects to the railways. The unequal conditions, which penalise the railways, are: the non-observance of social legislation by the road mode (especially regarding the drivers working hours), the lack of allocation of external costs (environment and public health, including the cost of accidents) and the inequality of tax systems (VAT, duty-free sales and excise duties on fossil fuel).[2]

A well functioning single market with freedom of movement for both freight and passengers will not be possible if bottlenecks affect traffic movements. Such bottlenecks are to be found in local and regional levels in almost every European urban area. Therefore, relieving congestion by providing fast and efficient rail transport in urban areas is not a local or regional issue, but also of utmost importance for the overall vitality of the European single market. To this respect, it has been identified barriers to the success of railway in a fierce competing environment such as:

- ✓ Lack of common standards
- ✓ Lack of harmonised regulation (e.g. safety)
- ✓ Network saturation at nodes
- ✓ Noise and vibration
- ✓ Pressures on first cost of equipment and over-capacity in manufacturing
- ✓ High fixed costs of operation
- ✓ High cost of infrastructure investment and maintenance
- ✓ Defined relationships between public authorities and railway undertakings

Hence, congestion problems are increasing and there is no alternative, even by other modes, for the satisfaction of demand by the existing capacity and methods. This is also due to the changing demand pattern for transported goods (from bulky to lighter commodities).

To satisfy demand, companies are increasingly dependent on user-oriented, time-reliable intermodal transport networks. It is argued that only a liberalized and interoperable rail system, open to competition, can reach its full potential as an indispensable link in the intermodal transport chain and as an individual mode. In that way it might satisfy a greater portion of the demand than currently does. By introducing competition, a more efficient rail sector could emerge, since the operators will implement the necessary rationalization measures and receive the benefits of a market-based approach.

Customer and operator satisfaction is an ultimate goal, aiming at the introduction of advanced service technologies: remote diagnostics based on knowledge; and preventive maintenance based on existing conditions; fleet management with "on demand services"; interactive passenger information and entertainment from ground based server stations.

In this sense, there is a need to improve information on the availability/capability of services, and to provide technology that will make seamless transfers between modes. The added value in terms of timesaving and movement patterns that satisfies users' needs and not the supply side provision, suggests that some significant benefits could accrue in this area.

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[2] http://europa.eu.int/comm/employment_social/soc-dial/social/euro_agr/data/en/960208b.htm

This constitutes the orientation towards commercialisation. A factor measuring such orientation is the growing attention to customer satisfaction based on two main requirements: the quality of the service *per se* and the quality of the products needed to provide the service (e.g. efficient infrastructure, safe command and control systems, safe, new and comfortable rolling stock, efficient and intelligent freight trains). In order for the system to be successful, customers need to travel on time, in comfort and safety.

However, railway activities have traditionally been conceived and operated with a national perspective by domestic companies. They have been enjoying exclusive rights or dominant market power in their respective national territory for a large proportion of their businesses.

Given the railways' special characteristics, Governments have been hesitant towards liberalizing the sector. Furthermore, they have not allowed sufficient managerial independence and have imposed certain service obligations upon railway companies without compensating fully for the costs involved. On the other hand, unlike other transport modes, railways have been confronted with the full costs of their activities. The absence of intra-modal competition has prevented railway activities from benefiting from the positive effects that free market and competition conditions produce. These are cost reduction, improvement of services and development of new products and markets.

Overview of Railway competitive environment

Experiences from competitive or semi-competitive public transport markets suggest that some level of market power is normally necessary to run a profitable business. This indicates that some sort of oligopoly may be "natural" in railway markets.

Generally, three forces interact to shape the environment, within which the railway infrastructure managers have to operate:

A - Rivalry among existing modal competitors

Rail vs. Road: Both in absolute terms and relative to the other transport modes, road transport has shown a large increase in traffic volumes for decades. On the other hand, rail, including both passenger and freight traffic, has been deteriorating compared to road traffic. However, evidence suggests that on the longer distances, rail freight traffic is most likely to be competitive with freight carried by road.

Rail vs. Aviation: Aviation has increased its market share rapidly since the period of Post World War II. In the present millennium this rapid growth has deteriorated, although it has not been asserted whether this deterioration is temporary or stable. The railways have been relative successful in the long-distance market (up to 500kms), where high-speed trains represent a large share of the passenger traffic between many main European cities.

Rail vs. Maritime: Since international maritime traffic uses few large ports (mainly hubs for transhipment), the conditions for efficient railway handling of goods on the land leg appear good. Unfortunately, a rather large number of railways are not able to provide this type of service, since they cannot offer trains and personnel on short notice or according to the schedules of the deep sea carriers.

B - Bargaining power of railways

Fixed vs. variable prices in the railway companies: The railway industry has been often criticised for having an extremely rigid pricing and production system. This is probably due to two main reasons: Firstly, limited competition, strong unions and old-fashioned sales departments are obstacles, since they cannot adjust to different demands in the market. Secondly, the infrastructure is limited and in addition it has to be used by different types of trains running in tight schedules; therefore it is difficult to add another train path in the system in a short period of time.

C - Bargaining power of train operators and other service providers

The economic theory suggests that a monopolistic position in a certain market can be very profitable to the producer of the service/ product. However, with market competitors' entering continuously, this monopolistic market power is reduced. On the other hand, through the appearance of operators or through some business conditions the relative power of the operators can be different.

2.3 Optimization of Railway Capacity based on Maintenance and Renewal Planning Tools

A declining rail mode market share, as described before, has been often accompanied by railway management decisions bringing infrastructure to a minimum required extension, whereas less used branches were discontinued. This allowed focusing the attention on main routes, both in terms of maintenance and renewal, given increasing budget difficulties.

The underlying decreasing importance of railway in the transports panorama which have driven such decisions have, however, implied that a response from Railway to a possible change to this situation would necessarily require either better capacity management capabilities, investment in more infrastructure or a mix of both.

Such investments should be able to foster additional capacity of the network, through not only the optimisation of the resources currently available but also the possible renewal of existing but less used sections, by means of investment in maintenance and renewal. Those sections should present considerable potential for decreasing the overall stress on the main corridors, furthering the performance of freight traffic as one of the most promising market segments for railway, balancing the network as a whole.

In turn these investments take time to translate in to effective deployment of hardware and therefore a time gap between the decision taking and the deployment will occur. This means that to increase railway capacity to cope with expected additional demand calls for strategic approaches in the medium and the long term, further accounting for cost-effectiveness concerns based on realistic growth scenarios.

This is where models such as the one discussed in IMPROVERAIL enters, helping to adjust infrastructure to match the expected capacity needs (new lines, extensions, upgrade, …), being this a process which may take years or even decades. The infrastructure manager, up to a certain extent, wants to accommodate future demand for capacity as well as possible.

Because of the long development time the infrastructure manager needs a long-term forecast on how much capacity is needed on his network. The required network capacity is dependent on two main factors: the demand for transport and how this demand is translated into capacity usage.

There are several models for estimating future demand for transport. Usually such models also incorporate some evaluation of alternatives (scenarios). In IMPROVERAIL the translation of transport demand to capacity demand were analysed in a model considering how operators will deal in the future with this demand for transport. Apart from the uncertainty involved with long term estimates on size of the demand, there is also some uncertainty on the way rail operators will behave.

Moreover capacity of rail infrastructure is extremely dependent on how it is used, i.e. how trains of different characteristics are mixed. There are also different routes to transport certain demand, the choice of routing actually influencing the demand for capacity.

What this means is that capacity will not only depend on infrastructure itself but also on crucial decisions taken at the strategic management level with regard to the actual use of the infrastructure. Capacity management is therefore a key topic for the future of railway, promoting the best use of the infrastructure supported by optimisation concerns.

2.4 Promote Smooth Infrastructure Provision Across E.U Member States

Given railway specific ability to convey people at high speed in direct competition with air transport on one hand and the natural logistic vocation on the other, the latter in direct competition with road haulage and short sea shipping, one should expect from railway suitable levels of integration and compatibility.

However, while a large share of TVG track sections are built new on a strong cooperative basis (with demands possible to extrapolate directly from statistics on air transport), the freight traffic, relying on traditional networks, suffer from heavy historical compatibility hindrances, which can make border crossing a rather complex issue. From technical obstacles, such as different gauges, to incompatible infrastructure management decisions regarding allocation of capacity, a myriad of obstacles can be listed, that prevent the lean continuity of freight services. This happens at the cost of a negative image that railways pass to the logistic stakeholders, who often complain that railway does not provide reliable alternatives to road haulage and therefore choose to depend on railway only when good practice in specific trans-European railway corridors are assured or else when they are strictly obliged to do so for e.g. safety or environmental reasons. As mentioned before, both fast passenger services (TGV) and railway freight services at EU Level appear clearly as the top segments in which railway should be able to play a key role.

Therefore, and besides the technical issues involved in border crossings, it is also important to devise a comprehensive strategy addressing the particularities and complexities of non-technical aspects involved in the process of engaging railway stakeholders (demand and supply side) in the investments deemed necessary for the development of smooth cross border linkages, at the light of the European Transport Policy. Current prospects for an enlarged E.U. calls for improved performance of railway in particular regarding freight. But several obstacles exist to this objective, which are not only technical but also political and financial. While the alignment of both EU policy and technical issues seem to envisage development of cross border interoperability, the individual political willingness of Member States and of Infrastructure Managers and the financial obstacles about how costs should be shared, are often major hindrances to the effective implementation of the necessary investments, which in turn will depend on a suitable charging policy being applied.

2.5 Reaching higher efficiency in Network Provision and Capacity Allocation

In contrast to road infrastructure, the physical inflexibility of railway vehicles makes it impossible to deal with track capacity shortages by way of queues dissolved in real time. Conversely, decisions about how to run trains are taken well before a service departs, and these timetabling decisions are typically valid for a considerable period of time, in Europe normally from one semester to one year. One task of the IM is therefore to decide which operators that have the right to run services over its infrastructure and on which departure times [Nilsson, 2000]. In return for the right to run services, each operator pays fees according to a pre-specified charging structure. European Commission (1998) provides a plan for how the Commission envisages the future of this system. The concentration of EU's policy is indeed on the open access; the purpose being to open up for the benefits of competition also within this traditionally closed market. Obviously, there is a need of establishing practicable ways to charge for scarce capacity and to allocate this capacity among the different users.

The principle of track access charging is easy to understand. For railways, the infrastructure is limited in each section to serve one or a few vehicles at the same time. The access to a sequence of sections of the infrastructure at a specific sequence of points in time is called a slot or a path. These two terms are used as synonyms in this deliverable. The operators have a different willingness to pay for different slots, varying with the underlying demand function of the passengers and the characteristics of the operators.

For traffic running according to a timetable, real time pricing is impossible. The slot pricing must be done in advance during the setting of the timetable and must be based on demand-supply relationship. Supply is closely related to how the infrastructure is divided in blocks. Making the blocks shorter, possibly by improved control and signalling installations, which may reduce the distance between consecutive trains, can increase supply. Demand is derived from the underlying demand for passenger and freight transport. Generally, demand is varying strongly over the day, and this will make the value of different slots very different.

Given all these constraints, the challenge imposed is on how the Infrastructure Managers should deal effectively with this kind of problems, targeting economical optimisation based on an in-depth knowledge of cost elements related to infrastructure provision?

About a decade ago, the implementation of the rail infrastructure-charging concept in Europe was limited to Sweden. European Railways were typically state-owned vertically integrated companies. The question of infrastructure charging was thus irrelevant for most European countries.

Since then, the continued declining of Railway in favour of other modes, have brought this subject to light in view of the necessary improvement in its efficiency, seen today as a basic requirement for the sustainability of railway. Based upon economic theory, several documents related to this subject have been emphasising that introducing innovative pricing instruments may be the right approach.

Notably among these is the Green Paper of the European Commission, published in 1995', entitled "Toward Fair and Efficient Pricing" clearly stating that accidents, congestion, environmental cost and infrastructure maintenance costs weren't correctly reflected in the prices underlying the use of transports in general. The Commission has since published its proposals for a common transport infrastructure charging, as this topic is seen as an important way of improving the efficiency and marketing of rail transport and, hence, of increasing the role of railways in Europe.

Overall, the socio-economic success of a given approach on charging will always be challenged by efficiency of the regulation and by the degree of competition between Railway Undertakers (RU). To this respect, regulation should be able, not only to ensure the discrimination-free access to path capacity at earlier stages of implementation, but also to ensure the right incentives to the IM in order to promote efficiency.

2.6 Specification of Data Requirements and Development of Information Systems

Before the separation of train and track, the national railways were able to carry out an integrated analysis of costs and revenues (subsidies) with little concerns on a deep understanding of the cost relationships, which have thus remained within the academic field.

Upon the full implementation of the EU-Directive 91/440, the understanding of actual costs incurred becomes crucial. In order to apply charging methodologies based on the effective knowledge of the costs associated to Infrastructure Management, it is necessary to have information systems available.

To dive into deeper and more detailed analysis will require comprehensive cost accounting systems enabling powerful "drilldowns" into the databases in order to get useful correlation analysis, further providing additional features such as those related to the calculation of Key Performance Indicators supporting the application of best practices.

Today, some systems are standard accounting systems, some are simulation systems and some are based on more or less regular studies carried out by accountants and consultants. But as the railway market becomes more disaggregated and complex, the demand for reliable and more complex information increases. Regulatory organs, control organs and researchers need to have available detailed information.

Under this pressure and due to Directive 2001/14, IMs should consider developing and adopting a more disaggregated cost analysis. This is an important step for the management of the interactions with R.U, allowing relating actual costs with the provision of services.

Indeed, contractual relationships established by IM's with the Railway Undertakers oblige to build up financial compensation schemes, to apply whenever delays in operation occur due to the IM with a loss to the Operator. Such costs must be considered together with Investment, Maintenance and Renewal, since the risk of delays underlies all these three types of activity. Therefore, penalties and delays may be seen as relevant in this scope.

Such information systems should therefore allow keeping track on costs and the identification of relevant categories, including its allocation to activity levels to develop historic information in support of, e.g. maintenance and renewal decisions. Also the allocation of overhead costs that currently follows different principles, which is an obstacle for the true assignment of costs. To this respect, it is necessary to reduce these costs to the minimum aggregation level in order to keep tight control over the costs which are driven by level of activity in order to fairly reflect those variations in the pricing principle applied, in particular regarding SRMC

In addition, IMs are obliged to publish the key data based on their infrastructure management systems. Currently, most IMs are either using or in the process of implementing integrated information systems. Notably among these, it is SAP R/3 (and follow-ups) for internal data management, which could enable to build a common platform for effective data exchanges. However, one further challenge comes from the very different definitions of cost categories used in practise make it uneasy to get a harmonised input into cost data sources.

Asset management system (AMS) combined with a Geographical Information System (GIS) should not be overlooked when it comes to railway information systems.

Such types of database are very useful as they contain dynamic maps of the infrastructure and at the same time provide accurate information about the exact geographical location of the infrastructure object. The challenge of linking this information to other databases, would translate into a very useful management and decision support system for an IM. It is however essential that all information on network condition, individual assets and their relationships is updated and available at all times.

With regard to international traffic, centralized Information systems must be developed coherently, in order to provide real time information concerning trains running to be accessible to the rail operators and stakeholders in general. Currently, a number of different systems are used in different states and pioneering websites aiming at such objectives are already implemented. However, there would be benefits from deciding on a single system ensuring that it can provides the operational and commercial requirements for both the track authority/company and operators

The emergence of such integrated and complex systems will however depend on a strong commitment form the IMs which can only be made viable if they are developed at a large scale. Based upon initiatives already underway to this respect, we do expect a significant grow in the deployment of comprehensive and integrated railway information systems within the next five years

2.7 Foster Financial Sustainability of Railway Infrastructure Management

Besides raising revenues from charging, it should be kept in mind that non-traditional revenue, earmarked for railway development, may become a crucial issue for IMs in order to support the required investments for a new dynamic in this sector.

In this context, fostering railway financial sustainability might be a crucial step towards decreasing the dependence from public budget, bringing private rationale to the railway business adopting e.g. Value Capture approaches to the use of those assets, somehow related to railway business, but which do not correspond to the very provision of transports but rather to commercially orientated businesses orbiting around the railway core business.

Indeed, and while Railway infrastructure in European countries has been funded and financed through public capital ever since the creation of state railways, examples of different contexts show that it is possible to rethink funding of railway, should the right steps are undertaken and suitable frameworks are put to place.

A good example of this situation, explored in IMPROVERAIL, comes from Japan, where urban rail investment has tended to be the domain of the private sector, even after the war in the case of the private railways. Funding for railway investment is to a large degree obtained through commercial loans. There is however limited levels of government support available under strict terms:

As such, the Development bank of Japan has offered low interest loans from 1959 onwards to assist private companies with, for example, grade separation work at railway crossings, line extensions, and platform extension.In 1972 the government instituted a program to support the construction of urban private railways, whereby rail lines could be financed by a state-owned entity, called the “Railway Construction Public Corporation”. After completion, the rail lines are turned over to the private operator, with the construction cost to be repaid over a period of 25 years (World Bank, 2000), thus this does not represent a grant (investment subsidy), but only a financing arrangement. Furthermore, only 8% of new lines constructed use this Corporation as most companies choose to finance the construction of new lines by using their own resources (Van de Velde et al., 1993).

Another program is the ‘Subway Construction Scheme’ established in 1978, which provides subsidies for the construction of urban underground railway systems mainly by public corporations and municipal governments. A subsidy corresponding to 70% of eligible construction expenses is provided, which corresponds to roughly half the total construction cost.

Over the years subsidy levels rose sharply due to the increasing complexity (and costs) of new construction under high density areas. Three mechanisms for railway value capture may be considered, as follows:

Laws and regulations (particularly in the form of taxes). This mechanism involves government agencies collecting taxes from land developers, residents and businesses that either directly or indirectly has benefited from an urban rail project. These funds can then be used to provide low-interest loans in an effort to reduce some of the financial barriers to railway investment.

The Osaka municipal government for instance, raised funding for the development of the city’s own urban rail network (subway) by earmarking the incremental revenue from increases in existing local taxes. The contributions were determined by a formula which accounted for land area, distance to the nearest station and a multiplier dependant on proximity to the city centre.

Agreements between land developers and railway companies: either voluntary or through ‘administered guidance’. This type of transfer involves a scheme of administrative guidance that was developed by the Japanese Ministries of Finance, Transport and Construction during the early 1970s. The scheme attempts to focus new land developments in a manner that is congruent with the existing or planned railway network in order to avoid inefficiencies with haphazard development.

The scheme only applies to so-called “new town” railways that are constructed by the 3rd sector (joint ventures of municipal government and private railway operators and companies). The key features of the scheme, which is thus not available for private operators, are as follows:

- The real estate developer bears half the construction costs for at-grade rail infrastructure.

- The real estate developer transfers the rail right-of–way at its original prices to the railway operator, if the land is located within the new town area.. If the land is located outside the new town area, acquisition of the rail right-of-way becomes the responsibility of the railway operator (however, the real estate developer pays the difference between the original price of the property and its actual purchase price).

The central government and local governments will, respectively, subsidise up to 18% of the rail construction costs. These subsidies are to be paid in annual instalments over six years after construction has begun.

Voluntary costs sharing arrangements are also often used in the development of rail station precincts in Japan. Municipal governments, housing authorities, transport operators and private developers often form 'land readjustment co-operatives'; schemes designed to optimise development opportunities through the reallocation of parcels, and hence maximise potential profits in these areas.

Internalisation of the gain from land development by the rail operator: This third mechanism of value capture involves cross-subsidisation between governmental departments. A portion of rise in land prices due to construction of infrastructure and a portion of profits generated from land development and other associated businesses are transferred to the transport agency of the municipality (municipal subway operator). In Kobe for example, the municipal government undertook integrated rail and new town development by following the experience of private railway companies. In addition to developing residential areas, the municipal government initiated various kinds of development projects along the rail corridor in cooperation with private partners. The Development Bureau of the municipal government acted as a land developer, and the Transport Bureau constructed the rail system using various funding instruments (World Bank, 2000). Besides relying on subsidies and developers' contributions, the profits earned by the Development Bureau were put into the city's general account, helping the city to service debt on the rail investment and cover operating losses. In Kobe too, the municipality initiated the construction of an underground system to connect four private railways with the city centre. A rail infrastructure company owned by the municipality (40%), the four railways (40%) and other parties (20%) was created for this purpose to facilitate the financing of the construction of the facility (World Bank, 2000).

2.8 Promote Continuous Improvement and Implement Best Practices

It is well know that benchmarking facilitates and accelerates knowledge development across an industry. For the new environment created with the separation of IMs from train operators prescribed by EU directive, it will became crucial to establish performance indicators measuring the most relevant topics for the success of the Infrastructure Manager and railway as a whole.

Therefore, a benchmarking framework as envisaged hereby, should help the IM thinking about the success of organisation. As the IM's direct client is often the train operating company or the government, rather than the passenger who is an indirect client, measures of performance must reflect this. Several examples emphasize the need for the IM to think about the context of the contribution of the infrastructure to the end customer and stakeholders, not to forget about end customers and concentrate exclusively on the TOCs. This has indeed been one of the contributory factors for the UK Government putting Railtrack into liquidation.

A common set of key performance indicators (KPI) and process indicators (PI) applicable to all IM's need to be developed and implemented, but leaving room to accommodate different subsets of indicators for each IM, reflecting specificities such as their market orientation. The challenge is therefore also conceptual, implying an agreement on the set of KPI's and their definitions, the development of consistent measurement methods.

The adoption of Benchmarking represents also an important supporting element for future of the contractual relationships with R.U., with the correct measurement of KPI's. This aspect is also important with regard to the establishment of PSO agreements with the Government.

Currently each different railway measures different things in different ways, and even when they measure similar things, they use different definitions and categories. This is a key challenge to IM's when addressing benchmarking and implementation of best practices.

Regarding the transferability of best practices the challenge is to use as KPIs those measures that have already proven to be valuable to benchmarking participants. Furthermore, comparing definitions and performance measures assessing best practices within the railways and adapt to the best of them is necessary. As it may take many years to achieve a fully satisfactory level of comparability in the way in which participants measure agreed KPIs, these must be developed with full involvement and buy-in from IMs.

This was beyond the scope of IMPROVERAIL, so the set of KPIs presented in this benchmarking framework report are currently at a second level of iteration.

The **challenge that IMPROVERAIL raises** is that definitions and the set of KPIs must be finalised by the stakeholders themselves, namely the Infrastructure Managers, or else there is a serious risk that they will not adopt them for practical measurements.

This can only be achieved if each participating IM compares the KPIs suggested with the definitions that they already use, refining the measures of success from the IM's point of view.

3 BUSINESS PROCESSES IN INFRASTRUCTURE RAILWAY MANAGEMENT

3.1 Introduction

The necessary tools for modelling the customer chain, business processes and market orientation of railway infrastructure managers have been the subject of analysis in this part of IMPROVERAIL. These tools come in support of the assessment of infrastructure managers' performance in different dimensions with the ultimate aim of improving the organisation's productivity.

The fact that the Infrastructure Management has been consistently separated from operation creates a ground for innovative approaches towards the improved performance of the infrastructure management activity, possibly where the need for such approach turns out to be more sensible.

Indeed, a number of infrastructure managerial decisions and processes can be source of inefficiencies and/or failure to meet objectives, which result to the ineffectiveness of actions or decisions taken by other key players such as railway undertakers. A methodological framework along with a self-assessment management tool was developed here, according to the generally accepted principles of Business Process Reengineering (BPR), here in attention to the specificities of BPR in Railway Infrastructure Management. This generic but innovative BPR methodology is supported by inputs accrued from the cross sectional work carried out in IMPROVERAIL. The main concern driving its development has been the easiness in use and applicability in most IM structures. The mentioned toolbox was shaped as a software tool integrating practical guidance for helping the infrastructure managers to evaluate performances and structuring BPR initiatives. Its frame of reference is the full range of IM structures.

The objective of BPR methodologies, when applied to companies that have been traditionally dominated by the public sector (as is the case of railways), is to provide a road map rather than specific solutions for business process re-engineering.

BPR provides therefore a unique opportunity to streamline the key business processes, being however inseparable from the rest of the industry. Therefore, it is essential to identify and understand the interfaces where processes pass between different organisations (e.g. freight slot allocation, between freight operators and the infrastructure manager). There are a large number of processes and they were selected using a series of selection criteria. The IMPROVERAIL project concentrated on the management processes of the infrastructure manager and therefore in the context of BPR it looks at those processes that remain within the infrastructure manager scope of action.

Representative processes were chosen in each of the three identified areas of the organisation: operational, commercial and managerial. The selection of these processes shows how processes could be identified and examples of the possible analyses.

3.2 The BPR Methodological Approach

The methodological framework consists of five phases that are interrelated and they are somewhat the required logical steps that follow the pattern:

Understand the environment → Set the Objectives → Use tools to accomplish them → Produce outputs → Recommend activities / implementation

At the first phase of the methodology the roles and functions of IMs are set out and the forces shaping railway dynamics in today's competitive world are identified. This is done in view to the forthcoming changes in regulatory frameworks (transport deregulation, privatisation, specific EU Directives for railways, etc.), which are expected to redefine the attitudes of the IMs. It includes two steps: the reconnaissance and the assessment of IM position within the railway industry.

The second phase describes the objectives that re-engineering is designed to achieve. It also defines the IM's strategies for the future, enhancing the sources of its competitive advantage and redirecting its competencies. It consists of three steps: an environmental scan, a benchmarking process and a guideline to set the Objectives and Strategies.

The third phase provides a description of different structures and organizational models (possible in the identified regulatory frameworks). It also suggests different change paths to shift from one structure to the other and highlights their strengths and weaknesses. It includes the sectoral and the organisational steps.

The fourth phase provides a description and classification of some key processes that can be re-engineered. These include: Procurement, Track possession management and Slot allocation. This phase also describes specific mechanisms and options from two case studies, involving a core and a non-core activity. It includes three steps; the core processes, re-engineering options and the BPR assessment.

The fifth phase describes how to get from concept to effective implementation. It also provides a methodology to assess the performance of the IM after re-engineering. It is structured in two steps: the strategic and the transaction preparation.

This methodological framework is provided in IMPROVERAIL also as a software Toolbox, featuring an interactive electronic book, complemented by a user's manual. This will facilitate the understanding and simulation of steps to develop specific re-engineering measures based on the IM's goals and the needs of train operators and other recipients of IM provided services. It also provides an insight of the interplay between competition and regulation and understand how the risks and rewards vary from one re-engineering option to another.

3.3 Implementation of BPR in Railway Industry under a Changing Regulatory Framework

Since early 90s, the railway business has suffered important structural reforms, starting from the separation of roles within the railway system. The core aim of these changes has been the overall modernisation of the railway business in order to render the industry less dependent on subsidies, along with improved flexibility and capacity to face complex environments. Hopefully, this would help its better integration in to the overall transport system. In this context, BPR represents a useful streamlining tool, in view of the innovative way of doing things..

Consequently, IM should be able to take appropriate steps to develop specific measures based on a strategic definition of long term goals, accounting for the thorough understanding of the new requirements of railway undertakers and railway stakeholders in general. In special looking at the challenges posed by the implementation of optimised logistic concepts led by freight integrators, requiring from railway improved flexibility in adapting to new situations, conveying freight traffic across Europe.

The vast majority of BPR projects have been carried out in the private sector, with only a few situations in public organisations such as Railway. But even in private companies with strong market orientation and profit motive as well as clearly defined customers, between half and three quarters of all BPR exercises fail. Those public sector projects that have been attempted have met with very limited success. Thus any attempts in BPR should be treated with caution. A review of the BPR that has been carried out in the European railway industry revealed that very little has taken place. Whilst there has been extensive restructuring, mainly as a result of the EC Directives 91/440 and 95/19, this has been almost exclusively organisational, with little or no focus on processes.

In this context, it is proposed a methodological framework accompanied by a software toolbox allowing Infrastructure Managers to simulate and plan BPR strategies, supported by a wealth of supporting information and guidance methodologies, accounting for the specificities of the railway business:

3.4 Identifying Key Areas for Railway Reengineering

There are a large number of processes and they were selected using a series of selection criteria. The IMPROVERAIL project concentrated on the management processes of the infrastructure manager and therefore it looks at those processes that remain within the infrastructure manager scope.

Representative processes were chosen in each of the three identified areas of the organisation: **operational, commercial and managerial**. The selection of these processes shows how processes could be identified and examples of the possible analyses.

It became that certain issues need to be addressed if reengineering is to be implemented successfully. IMPROVERAIL did not try to make the case for BPR, which is only one of a number of management techniques that could be applied to an organisation. As the adequacy of BPR as a tool will depend to a large extent on the nature of the organisation in which it is applied, the IMPROVERAIL has attempted to segment railway companies as production, commercial and market oriented organisations, which is required in order to compare the appropriateness of the technique in different circumstances. Railways with different degrees of market orientation make them more or less open to the opportunities presented by BPR.

It should be noted that the decision to re-engineer is made with reference to the IM structure and considering the actual national policy environments and stakeholder interests. There is no single formula for IM re-engineering but rather a number of these. The selection of the best formula is a responsibility of the IM stakeholders.

Process improvement initiative is to be measured against its stated aims and achievements through an analysis of performance improvement in re-engineered processes. Those new processes that achieve the goals of the IM should be kept, and made part of the organisation's culture and working practices. Because a wide range of reengineering models exists, the methodology does not elaborate on all models available to infrastructure managers. Instead, it defines and covers the most important options of the identified spectrum. Importantly, it also provides tools for assessing hybrid options and for understanding their merits and risks.

3.5 Interactions Among Railways Stakeholders

In order, to understand the internal environment of railways, it is necessary to identify the relevant actors involved and the core-interactions among them. In specific it is important to identify the interactions between the rail infrastructure managers and decision-making actors and customers, since they have the strongest impact on the organisational structure of the rail infrastructure manager and the institutional relationships. Hereafter, is presented an overview of identified relationships, between the above mentioned actors, as well as an examination of other (possible) external actors interfering with the rail infrastructure managers, like contractors and engineering consultancy firms. Based on research carried out, it has been seen that there are countries with a similar set of external actors interfering with the rail infrastructure manager and countries with different actors, each with a specific objective. The ‘standard’ set of external actors that are found involved in the majority of the railways, are:

- Rail infrastructure manager
- State Government
- Direct Customer (s)

- Contractors
- Engineering consultancy firms

A similar set of actors is found in organizations, other than those who had active participation in IMPROVERAIL. “Specific cases” exist, denoting additional or only minor differences as to the actors involved. The following actors have been identified in this respect:

- Rail Regulator
- Local Governments
- Specific owner of the track
- Special authorities

Government at national level: Because of the traditional public characteristics of the railway sector, all rail infrastructure managers interact to some extent with their national government. In most cases this interaction is quite substantial and important. The national governments in Europe are the main actors concerning agreements with the rail infrastructure manager on authorisations, tasks and responsibilities. Furthermore, the national government is often the player who provides the licenses to the train operating companies and permits the use of certain rolling stock. A performance contract is usually linked to these licenses. All states, except United Kingdom, provide long - term infrastructure planning/ frameworks, which have to be respected by the rail infrastructure managers and train operating companies regarding new infrastructure projects. Within this planning/framework, rail infrastructure managers, or in some countries train-operating companies, can produce proposals/ plans, which in turn have to be approved by the national government.

The state is, in most cases, the owner of the infrastructure (the network). For this reason the train operating companies have to pay for concessions (the rights to run operations on a part of the network) directly to the State, instead to the rail infrastructure manager. The national government is using (part of) this income to provide funds to the rail infrastructure manager.

At the light of the new EU directives, this process will probably change in most countries. In the Netherlands, for example, all related actors are searching for possibilities to allow the rail infrastructure manager to be a self-financing organisation. This implicates no state subsidies and the introduction of new charging methods, solely between the rail infrastructure manager and the train operating companies.

In all cases, the Ministry of Transport is the national government’ department responsible for the railway sector. In some cases the national government delegates some of its tasks to a special authority or regulator or local administration.

Direct Customers: Most rail infrastructure managers have more than one direct customer, i.e. train operators. The country with the most train operating companies is the United Kingdom. This can be understood from the fact that the United Kingdom has stressed a far more market-orientated view in respect to the railway sector compared to other EU member-states.

Contractors: All partners involved in the IMPROVERAIL consortium indicated that their national rail infrastructure manager outsources a portion of the maintenance and renewal activities to contractors. Other firms through public tenders undertake only large works on renewal and periodic preventive maintenance.

Engineering Consultancy Firms: As in the case of contractors, all rail infrastructure managers make, to some extent, use of external engineering consultancy firms in order to get advice on new projects and activities. Thus, these companies can play an important role in bringing together the ideas and wishes from rail infrastructure managers on one hand and ideas and wishes of the direct customers on the other. Thus, it is to be expected that the consultancy firms gather much valuable information. Hence, when the rail sector moves slowly from operational and commercially orientated to more market orientated, the influence of the engineering consultancy firms can become quite important.

Local States: Concerning rail, some countries provide special authorities to local states (regions). In Switzerland and Germany, the local states (Landen, cantons) are responsible for the Performance Contract with the regional passenger operators. The relation between the rail infrastructure managers and the local states is usually not as important as the relation with respect to the train operating companies. In Germany the influence of the local state authorities is quite strong. They authorise the same activities and have decision-making processes as the national government, with an exception to the process of providing permits for the use of certain rolling stock, which is the exclusive right of the national government.

Rail Regulators: Some countries have set up a separate Rail Regulator. Examples among the partner countries can be found in Bulgaria (Railway administration), Portugal (INTF) and the United Kingdom (Office of the Rail Regulator). The example of the ORR in the UK can be used to clarify the tasks of a rail regulator. The United Kingdom has a focus on market orientation in contrast with more commercial oriented countries, where the tasks and authorities of the rail regulator are less than those of the UK.

The UK Rail Regulator's principal function is to regulate Railtrack's (now Network Rail) management and maintenance of the national rail network. He provides the economic regulation of the infrastructure monopoly and dominant elements of the rail industry and is independent from the State. Railtrack is the monopoly owner and operator of the rail infrastructure and operates under a network licence issued by the State but enforced by the Regulator.

The UK Regulator has a range of statutory powers. Through these powers, he sets the contractual and financial framework within which Railtrack functions, in order to maintain, renew and expand the network. Regulator’s job is to ensure that Railtrack's income, a combination of private finance and public subsidy set by the Regulator, is spent on the appropriate actions at the right time.

3.6 Current and future responsibilities of IM upon the introduction of the EU Raiwlay Packages

As of March 2003, responsibilities of the IM are based on Directives 91/440, 95/18 and 95/19. The directive 91/440/EEC defines the *infrastructure manager* as “any public body or undertaking responsible in particular for establishing and maintaining railway infrastructure, as well as for operating the control and safety systems”. The directive 95/19/EEC adopts the same definition for the infrastructure manager.

The directive 95/18/EEC defines the *licensing authority* as “the body charged by a Member State with the issue of licences”. *Nevertheless, the hereby directive does not specify whether the licensing authority is the infrastructure manager.*

Moreover, the directive 95/19/EEC considers the existence of an *allocation body* defined as “the authority *and/or* infrastructure manager designated by the Member States for the allocation of infrastructure capacity”. In other words, the infrastructure manager is not inevitably the allocation body of the railway infrastructure capacity. These responsibilities have changed and the new ones adopted, shown below in the section dedicated to “The future responsibilities of IM”

Organization and accounts

The infrastructure manager can be either a distinct division within the sole national railway company or a separate entity from the operating railways companies. In any case, the accounts for the management of railway operation and infrastructure, as well as for the provision of railway transport services are kept separate. No transfer of aid between the two areas of activity is possible. If the infrastructure manager is the allocation body, a fair and non-discriminatory allocation of the railway infrastructure capacity must be ensured as well as an optimum effective use of the infrastructure. In case of infrastructure capacity allocation in the interests of public service, if decided by the State, the infrastructure manager may have compensation by the State for any financial losses.

Charging

A fee for the use of the railway infrastructure is charged, payable by railway undertakings and international groupings using that infrastructure. The rules for determining this fee are defined by Member States after consulting the Infrastructure Manager. Directive 95/19/EEC adds that these rules may authorize a marketing of the available infrastructure capacity "*efficiently".* According to the directive 91/440/EEC, the user fee, which shall be calculated in such a way as to avoid any discrimination between railway undertakings, may in particular take into account the mileage, the composition of the train and any specific requirements in terms of such factors as speed, axle load and the degree or period of utilization of the infrastructure. The directive 95/19/EEC went more general and considers that the fees shall be fixed according to "the nature of the service, the time of the service, the market situation and the type and degree of wear and tear of the infrastructure". The infrastructure manager shall provide information on the determination of the fees and on modification of the infrastructure quality and capacity to the State and to the railway undertaking.

Access to the infrastructure

The directive 95/18/EEC considers the allocation of licence for railway undertaking defined as "authorisation issued by a Member State to an undertaking, by which its capacity as a railway undertaking is recognised". The licence is necessary for the provision of rail transport services. However, "such a licence shall not itself entitle the holder to access to the railway infrastructure". These licences are issued by a licensing authority body, charged by a Member State, although, the directive does not specify whether the licensing authority is necessarily the same as the infrastructure manager.

The licensing authorities of the Member State before granting the licence to a specific railway undertaking, they check whether the railway undertaking meets the requirements relating to good repute, financial fitness, professional competence and cover for its civil liability. These requirements are defined for both the state and the licensing authority. If a railway undertaking can no longer meet the requirements of the Directive, the licensing authority shall suspend or revoke the licence.

The infrastructure manager concludes the necessary administrative, technical and financial agreements with railway undertakings engaged in international combined transport of goods and international groupings. The EC Directive 95/19/EEC gives more details on the allocation procedure, compared to the EC Directive 91/440. The railway undertaking submits an application for infrastructure capacity to the infrastructure manager, if the latter is the allocation body. A decision is taken on the application as soon as possible, but no later than two months after all relevant information has been submitted. The railways undertaking has to obtain a safety certificate relating to the technical and operational requirements specific to rail services and the safety requirements applying to staff, rolling stock and the undertaking's internal organization. The traffic rules are those "applied" by the infrastructure manager. The EC Directive 95/19 indicates that the safety certificate is issued "by the authority designated for the purpose by the Member State". *But the infrastructure manager is not inevitably this authority.*

In case of a problem on the allocation of infrastructure capacity or the charging of fees, the State had to implement an independent body, where railway undertakings could appeal.

The future responsibilities of IM[3]

The future responsibilities of the IM are based on Directives 2001/12/EEC, 2001/13/EEC and 2001/14/EEC (as adopted by the European Parliament and the Council), which amend respectively the Council Directives 91/440/EEC, 95/18/EEC and 95/19/EEC.

These directives introduce new arrangements and provisions regarding the previous directives and provide further information on the rules and actors. In particular, the directives consider the case where the functions of the infrastructure manager on a network or part of a network may be allocated to different bodies or undertakings. Moreover, their goal is to increase the open access and organise competition in the European railways system. As it was the case with the previous directives, the analysis is focused on the infrastructure manager.

In Directive 2001/12/EEC, the *infrastructure manager* is defined more precisely, compared to the definition of Directive 91/440/EEC. The *infrastructure manager* is "any body or undertaking responsible in particular for establishing and maintaining railway infrastructure". However, the responsibility of the management of infrastructure control and safety systems by the infrastructure manager is an eventuality and not an obligation. In other words, the directive considers that a different body to the infrastructure manager may undertake these activities. *Moreover the infrastructure manager functions may be allocated to different bodies or undertakings*. This possibility of decomposition for the infrastructure manager is not mentioned in the previous directives but the latter distinguishes the responsibilities for infrastructure provision to three different bodies: infrastructure manager, allocation body and licensing authority.

Directive 2001/14/EEC introduced a new notion: "applicant". Applicant is defined as "a licensed railway undertaking and/or an international grouping of railway undertakings, and, in Member States which provide for such a possibility, other persons and/or legal entities with public service or commercial interest in procuring infrastructure capacity, such as public authorities under Regulation (EEC) No.1191/69(12), shippers, freight forwarders and combined transport operators, for the operation of railway service on their respective territories". In other words, applicants are numerous actors and not only railways undertakings.

Organisation and accounts

An effort has to be made to ensure that separate profit, loss accounts and balance sheets *are kept and published*, for the provision of transport services by railway undertakings as well as for the costs of managing the railway infrastructure. Moreover, *accounting has become more complex*. The infrastructure manager has to balance on one hand "income from infrastructure charges, surpluses from other commercial activities and State funding" and on the other hand "infrastructure expenditures" and at the same time to reduce the costs of provision of infrastructure and the level of access charges "with due regard to safety and to maintaining and improving the quality of the infrastructure service". The infrastructure manager has to draw up a *"business plan including investment and financial programs"* within the framework of general policy set by the State. The plan shall be designed to ensure optimal and efficient use and development of the infrastructure while ensuring financial balance and providing means to achieve these objectives.

[3] The references of the different directives on the Community railways are:

1. Directive 2001/12/EEC of the European Parliament and of the Council of 26 February 2001 amending Council Directive 91/440/EEC on the development of the Community's railways (*Official Journal L 075 , 15/03/2001 P. 0001 – 0025*)
2. Directive 2001/13/EEC of the European Parliament and of the Council of 26 February 2001 amending Council Directive 95/18/EEC on the licensing of railway undertakings (*Official Journal L 075 , 15/03/2001 P. 0026 – 0028*)
3. Directive 2001/14/EEC of the European Parliament and of the Council of 26 February 2001 on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification (*Official Journal L 075 , 15/03/2001 P. 0029 – 0046*)

As previously, the infrastructure manager may benefit from significant financing from Member states. However, to ensure the financial viability over the years, the resources of infrastructure manager, granted by the Member States, are implemented through *a contractual agreement* covering a period of not less than three years. This agreement provides State funding and establishes appropriate regulatory measures with adequate powers granted to the IM.

Charging

Regarding charging, Directive 2001/14/EEC adopted similar principles of charging to those previously defined. The infrastructure charging schemes have to encourage in particular the infrastructure manager, to minimise disruption and improve the performance of the railway network.While respecting the management independence, the specific charging rules are established by the state member or the infrastructure manager. As it has been considered in Directive 91/440/EEC, the infrastructure manager determines and collects the charge for the use of infrastructure. However, for the collection of the charge it is not relevant whether the Infrastructure Manager is dependent or not from a railway undertaking.

The charging is related to four packages of services described precisely in Directive 2001/14/EEC: the minimum access package, track access to services facilities and supply of services, additional services, and ancillary services.

- For the minimum access package and for the track access to services facilities and supply of services, the principle of charging seems to be the marginal cost. Indeed, the charge is set at "the cost that is directly incurred as a result of operating the train service".

- For the additional services and the ancillary services the principle of charging seems to be the full cost. In effect, if one supplier provides these two types of services, the charge, imposed for such a service, is related to the cost of its provision, calculated on the basis of the actual use.

Nevertheless, the infrastructure manager may introduce additional charges and exceptions and discounts in the infrastructure charge. Two types of additional charges may be included:

- Charge of scarcity for "the identifiable segment of the infrastructure during periods of congestion".

- Charge for the cost of the environmental effects caused by the operation of the train.

These additional charges are conditioned by the implementation of such charging and are applied under the condition that they do not renter the total charge greater than that of competing transport modes.

Further detailing can be found in the section of this report dedicated to charging methodologies (WP7)

Allocation and access to the infrastructure

For the allocation of capacity in the form of a train path, the directive adopts the following rules:

- The infrastructure manager or the allocation body – if the infrastructure manager is not independent in its legal form, organization or decision-making functions of any railway undertaking - have to be equitable and non discriminatory for the allocation capacity with all applicants.

- The allocation capacity proceedings have to be transparent. All the necessary information required to use access rights are to be published.

- The commercial confidentiality of information, provided to the infrastructure managers and the allocation bodies has to be evaluated.

The implementation of these principles will lead to the definition of obligation for the infrastructure manager. In particular, the infrastructure manager or the allocation body have to produce a "*network statement*" for the applicants. It provides details on general rules, deadlines, procedures and criteria concerning the charging and capacity allocation schemes. It shall also contain the required information so as to enable the application for infrastructure capacity.

For the accepted applicant, the infrastructure manager or the allocation body defines with the specific applicant a "*framework agreement*" as a legally binding general agreement on the basis of public or private law. It sets out the rights and obligations of each partner in relation to the infrastructure capacity to be allocated and the charges to be levied over a period longer than one working timetable period.

The infrastructure manager should meet, as far as possible, all requests for infrastructure capacity including requests for train paths crossing more than one network, and should take into account all constraints on applicants, including the economic effect on their business. The infrastructure manager should consult interested parties about the draft-working timetable and allow them at least one month to present their views. In this case, the infrastructure manager makes an effort to co-ordinate all requests.

In spite of this co-ordination, if a dispute relating to the allocation of infrastructure capacity occurs, a dispute resolution system shall be made available in order to resolve it.

In case of congestion in a section of the infrastructure, caused by the fact that demand for infrastructure capacity cannot be fully satisfied during certain periods even after coordination of the different requests for capacity, the infrastructure manager develops a "*capacity enhancement plan*". It is defined as a measure or series of measures with a time plan for their implementation, which is proposed to alleviate the capacity constraints.

For a congested infrastructure section, some priority criteria to allocate infrastructure capacity are defined. These criteria relate the importance of a service to society (public-service rail freight) and to any other service. The State member grants the infrastructure manager compensation corresponding to loss induced by these services.

For the open access to the network, the Directive considers that all the railway undertakings shall be granted the access to the Trans-European Rail Freight Network (defined in Article 10a and in Annex I) and, after the 15 March 2008, to the entire rail network, for the purpose of operating international freight services. It means that the open access is not restricted to some type of railways undertakings. Only the international freight businesses are affected and not the passenger traffic and the cabotage. Only the tracks of the TERFN are opened to competition.

To control the open access, Directive 2001/14/EEC implements a "*regulatory body*", which can be represented by the Ministry responsible for transport matters or any other body. This regulatory body shall be independent regarding funding decisions, legal structure and decision-making from any infrastructure manager, charging body, allocation body or applicant.

Proceedings are developed with this "regulatory body". Any applicant can place a complaint with this body if he feels that he has been treated unjustly or has been the subject of discrimination or has been suffered any damages. This regulatory body shall decide at the earliest opportunity on appropriate measures to correct undesirable developments in these markets.

Directives 2001/12/EEC and 2001/14/EEC mention a number of exceptions in the implementation of this independent body to ensure equitable and non-discriminatory access to infrastructure. Specific countries such as Ireland, United Kingdom in respect to the Northern Ireland (both located on an island, with a rail link to only one other Member State) and Greece (that does not have any direct link to any other Member State) can postpone this implementation for a period of five years from the implementation date of 15 March 2003.

The Directives 91/440/EEC, 95/18/EEC and 95/19/EEC are not sufficiently accurate. In many cases, in their application on a national level, there is confusion in the meanings amongst the railway actors and more specifically regarding the functions of the infrastructure manager. In fact, it is clear whether the infrastructure manager is an independent body from its organisation, how funding decisions are taken, what is the legal structure and decision by the railway undertakings. Moreover, the infrastructure managers with the support of the railway undertaking, can limit sharply the open access and competition.

In order to stimulate the European railways system, Directives 2001/12/EEC, 2001/13/EEC and 2001/14/EEC clarify the principles and rules for each actor and in particular for the infrastructure manager, for which they define a number of responsibilities. They also consider a *situation with not a monolithic infrastructure manager but with different bodies* for the allocation of railway capacity, the allocation of licences, the control of the safety, and the control of the implementation of the equitable and non-discriminatory charging and allocation principles.

3.7 Conclusions and Recommendations

A BPR methodological framework adapted to the Railway Infrastructure Management has been developed in this part of IMPROVERAIL, providing detailed guidance for those business process re-engineering of IMs' processes and structure. The generic, but innovative, BPR methodology is supported by inputs and general descriptions accrued from the whole project, its main concern being the easiness of use and applicability in most IM structures.

The methodology is provided in a theoretical and conceptual form. The frame of reference is the full range of IM structures. It shares the most common characteristics of BPR methods, and its objective, when applied to companies that have been traditionally dominated by the public sector (as is the case of railways), is to provide a road map rather than specific solutions for business process re-engineering.

In such context, below are presented some key conclusions as well as recommendations supporting BPR initiatives in Railway Infrastructure Managers

As a complement to the output of this workpackage, a toolbox was developed shaped as a software application, integrating practical guidance for helping the infrastructure managers to evaluate performances and structuring BPR initiatives. Therefore, we would recommend the reader to install and explore the Toolbox Software, which is an important result from this part of the project.

3.7.1 Specification of IM's Objectives and Performance Assessment

Process improvement in Railway should be measured against its stated aims and achievements. This can be done with an analysis of performance improvement in re-engineered processes, upon the development of an evaluation framework to assess the performance of a railway infrastructure manager, as well as the impacts on the IM performance from the chosen BPR strategy resulting from the implementation of the EU Directives.

The evaluation methodology should consider the following steps:

1. Develop business vision and process objectives
2. Understand existing situation
3. Identify strategy for redesign
4. Identify change levers

5. Evaluate new strategy and obtain feedback (based on predicted results)
6. Implement new strategy
7. Make new strategy operational

It should further include four criteria for performance assessment:

a) business performance improvement,
b) organisational effectiveness,
c) user acceptability, for several items
d) conformity with EU and country regulation

The four criteria indicators are introduced for the measurement (quantitative or qualitative). This phase of evaluation is a safeguard against using time and resources ineffectively and inefficiently, or performing an evaluation of poor quality and limited usefulness. The main procedures in this step are:

1 - To derive a list of impacts to observe and monitor with the necessary associated indicators;

In any evaluation method, impacts and their relevant indicators are directly connected with the respective criteria of the evaluation method. An extensive list of impacts and indicators is presented next

Table 1 - Criteria-Impacts-Indicators

Criteria / Impacts	***Indicators***
$\mathbf{C_a}$: Business Performance Improvement	$\mathbf{C_{a1}}$: Raise in Revenues $\mathbf{C_{a2}}$: Costs Reduction
$\mathbf{C_b}$: Organisational Effectiveness	$\mathbf{C_b}$: Market Responsiveness
$\mathbf{C_c}$: User Acceptability	$\mathbf{C_c}$: Growth in Market Share
$\mathbf{C_d}$: Conformity with EU and Country Regulation	$\mathbf{C_{d1}}$: Conformity with Regulations $\mathbf{C_{d2}}$: Strategy's Implementation Cost

2 - To forecast impacts on the basis of the strategy's functional specification and user expectations;

To retain the compatibility between the evaluation method and the BPR Toolbox, as designed for the IMPROVERAIL project, the "forecasting" adopted is based on "user inputs". In other words, the user, being in this case the IM, will use expert knowledge and give values to the indicators in order to mobilise the forecasting, always according to the chosen path for change.

3 - To choose an appropriate evaluation method;

The existence of more than one criterion makes the Multicriteria Appraisal (MCA) the most appropriate evaluation method for use. The main stages of an MCA are five:

i. Identification of options for assessment
ii. Identification of objectives and criteria that reflect the value associated with the consequences of each option
iii. Description or expected performance of each option against the criteria
iv. Weighting of the criteria
v. Combination of weights and scores to derive an overall value for criteria performance in each option

Options for Assessment

The IM will choose the strategy for change; therefore the chosen BPR strategy will be the option under evaluation. The strategy's choice will be done after the development of business vision and process objectives, which comes after the understanding of the existing situation. Based on the findings of IMPROVERAIL, the existing organisational models, the possible aims and strategies as well as the potential outcomes are presented next.

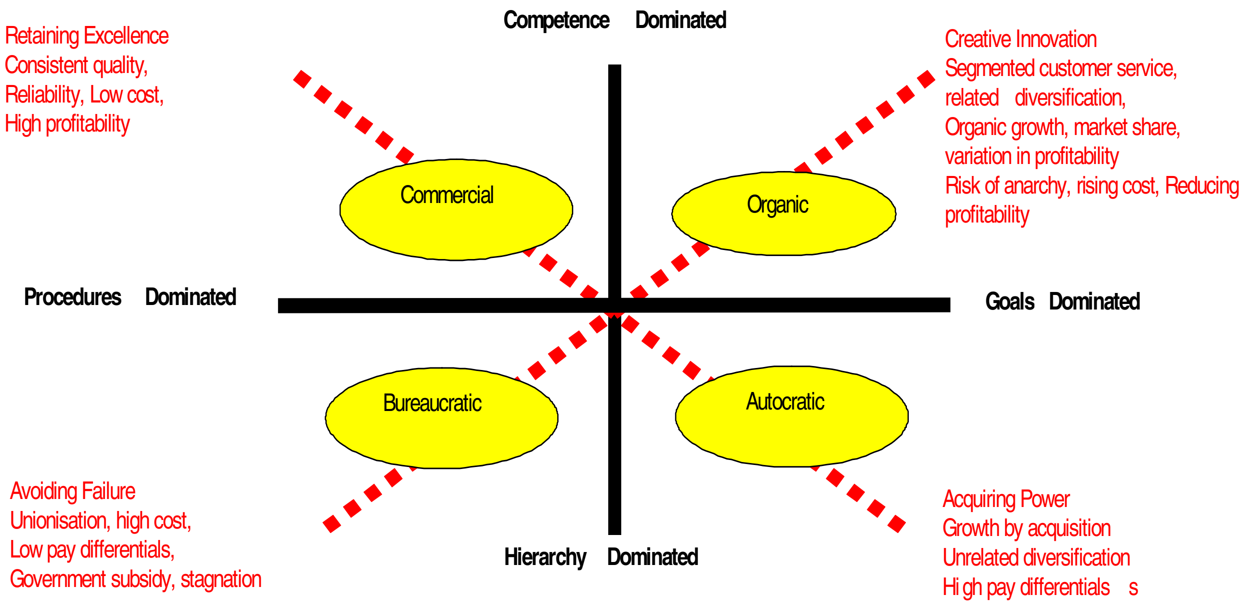


Figure 1 - Organisational models, aims and strategies and the potential outcomes

Objectives and Criteria

The objectives of the IM as well as the possible strategies under evaluation are shown in the next Table. These are formulated according to the targeted status the IM desires to reach.

Table 2 - Objectives of the IM for each Option

Desired Profile	*Objectives*
Bureaucratic	**Avoiding Failure** Avoid risk, Retain status quo, Neutralise internal competition
Autocratic	**Acquiring Power** Growth by acquisition, Reduction of regulation, Incentives for top management
Commercial	**Retaining Excellence** Predictability, Quality, Consistency
Organic	**Creative Innovation** Continuous improvement, Market orientation, Decentralisation, Entrepreneurial flair

3.7.2 Defining IM's Business Orientation

The aim of an Infrastructure Manager is to grant capacity to its client. Therefore a market oriented Infrastructure Company should be able to allocate capacity, in terms of quantity/quality, in order to match customer's requirements. Before attempting to cluster current practices, it is necessary to identify the key factors affecting the orientation towards the market for an Infrastructure manager. These **key elements/factors** concerning the assessment of the performance and the approach to the market of Infrastructure Managers are listed below:

1. **Ownership of Infrastructure:** This factor is analysed taking in consideration if the Infrastructure Manager is State-owned, Private/public-owned or totally private. This factor influences the level of government authority and explicit public policy redirection before Infrastructure Managers can react to the challenge of improving their competitiveness. A mixture of ownership is possible and often resulted as the best approach towards market orientation.

2. **Strategic dimension:** This factor is analysed identifying vertical integrated/separated or horizontal separated Infrastructure Managers. This affects the level of commercial incentives, cost and subsidies transparency, the level of EU Directive implementation, the management of capacity and of integrated timetables and the competitiveness. Separating users from infrastructure allows the infrastructure Managers to focus on only its core market.

3. **Market structure:** This factor is affected by the level of inter-modal or intra-modal competition (limited, for the market, in the market) and therefore the level of access of competitors to the railways infrastructure. The complete vertical separation or horizontal separation (or both in some cases) are the keys for a well defined market structure guaranteeing a proper and not discriminatory access to infrastructure. In case the vertical separation is not complete (separate accounts of operators and infrastructure manager but they are owned by the same holding) may cause bottlenecks in the open access to infrastructure (commercial operations are fully performed according to EU Directives but the market is structured as bilateral monopoly).

4. **Contractual regime:** This factor is affected by the level of subsidiaries/penalties and the relationship with Government (considered as customer). This is measured by the budget constraints (which guarantee social services) and from strict government constraints on tariff-setting. In such restricted situation, there are no significant incentives for the company to efficiently allocate internal resources in order to reduce the costs of providing services while maintaining quality standards. There is the possibility of mix of commercial and social services (e.g. commercial revenues are lower than 35%) or a total of commercial services. In the latter case rail services exclusively derived from the market (demand).

5. **Specialised infrastructure:** The existence of specialised infrastructure like High Speed services may be considered as factor affecting the operating systems and new investments, enhancing competition between different market segments (i.e. regional, long distance, etc). – intra - modal competition towards the network segmentation.

6. **Interoperability:** The level of interoperability is correlated to the harmonisation of network operating system, rolling stock, signalling, telecommunications, etc. and in terms of interoperable timetable and parking lines. A high level of interoperability may reduce operating, system and production costs.

7. **Managerial Performance objectives:** Fixing strategic performance objectives for Infrastructure Managers is considered as a lift towards better an innovative strategy is needed, based on staff motivation and a management style that is geared to the railways, but inherited from private enterprise. The managerial performance of Infrastructure Managers can be measured by a

transparent monitoring system composed be a set of key indicators that are not overly intrusive or complex. This factor is strongly affected by the typology of performance objectives, if any. Three levels of approach to this aspect could be identified:

- no evidence of formal procedure for measuring performance objectives (and in some cases no performance objectives are fixed). In this case the level of managerial performance is not linked to specific objectives, this means that there is a neutral approach towards the new market share attraction being managerial strategies only focused on increasing network productivity.
- performance objectives are focused on operational-commercial gains not specifically aimed at increasing market share.
- there is a detailed set of managerial objectives and strategies aiming at increase revenue with non-core business activities (ancillary services) and indirectly addressed to customer satisfaction and high level of service performance

8. **Strategies for increasing revenue:** A first approach to the market orientation may be found in the creation of a dedicated new business unit, a more focused attention towards the implementation of a better network interoperability and the optimisation of network capacity. A further step, which may be considered an indicator of orientation to the market, is the strategy for identifying sources of revenue of how cost and revenue projections are developed for financial planning purposes, selection and projection of new sources of revenue and make performance of sensitivity analyses.

9. **Regulatory framework :** Governments should institute a national regulatory authority in each country with powers to prevent anti-competitive practices and enforce compliance with the applicable laws. Independence of the regulatory bodies is important to give new entrants confidence to enter the market. This factor depends on whether the railway activities characterized by economies of scale and scope are shielded from other sources of competition in the relevant market, and whether there are protective barriers to entry (level of price regulation). The introduction of competition via access requires a strong regulation. A strong price regulatory intervention is to be focused only on those markets in which rail could be said to have a dominant position (respect to other modes of transport).

10. **Strategies towards new customers:** This factor has been analysed taking in consideration the relationship/interaction between infrastructure managers and their clients. The production of a strategic business plan for “grasp new market slices” may be considered as a way towards the market. This plan can become the basis of a shared commitment to transform the organization.

11. **Investment typology:** Better customer services and keener prices bring more business. Continuous improvement by service providers, within a framework of economic incentives provided by the regulator, and a clear set of public policy objectives from governments is the way towards market. In a monopolistic situation the infrastructure manager has specific constraints, such as reduction of expenses, rationalisation of network capacity. In a more competitive regime (e.g. vertical separation) there is the need of optimisation of infrastructure use (i.e. minimise segmentation of paths) ensuring a full network capacity (commercial performance). Now there is a clear recognition of the need for a partnership approach between public sector and the private sector in dealing with major investment and in setting the wider agenda and priorities for delivering social benefit. Moreover investment in new technology (with particular attention to customer needs) is becoming one of the strengthen lever for self-promoting railway sector.

With these key factors, infrastructure managers can be categorised in three groups according their orientation towards:

- Production
- Commercial aspects
- Market

Production oriented

The traditional approach considered the railway entity as an integrated body owning and operating its own facilities and vehicles. Typically, this typology lacks financial incentives and desegregated information on profitability, is (at best) production-oriented and inelastic to market demands for services.

Commercial oriented

Perhaps the most significant restructuring involved the commercial reorientation of the company. Shortly after the restructuring, were clarified the profit objectives outlined by each infrastructure manager board and established a management incentive system to reinforce these objectives. The approach is aimed at transforming company cultures (new business development become managerial performance objectives). As a result of consistent management efforts to increase the customer awareness of board, the quality of services gradually improves. For example, the network capacity optimization in specialised corridors increased; the quality of station facilities improved; and automated ticketing helped to reduce queues.

The regulatory direct influence of government is progressively reduced in favour of a mix of commercial and political/social objectives. This category of infrastructure manager limit the access to the market to the main national railway undertaking and are typically horizontally integrated (the market is not fully developed).

Market oriented

The market responsive-sensitive infrastructure managers aims at increasing revenue (enhancing also the non core business activities) to lower cost having as precise objective encouraging both intermodal and intra-modal competition. In this case the regulatory framework is characterised by a market price and strong interrelationship between infrastructure managers and customers (e.g. sharing of investments).

The following table shows the key factors for each type of orientation identified

Table 3 - *Key Factors Underpinning IM Business Orientation*

CATEGORY / *KEY FACTOR*	PRODUCTION ORIENTED	COMMERCIALLY ORIENTED	MARKET ORIENTED
1. Ownership of Infrastructure	State owned	State owned	Public-private ownership or fully private
2. Strategic dimension	Monopoly	Vertical separation – bilateral monopoly (horizontal integration)	Vertical or Horizontal separation – competitive access
3. Market structure	No competition	Limited competition	Full competition for market share
4. Contractual regime	High level of public subsidiaries (public services obligations – PSO)	Mix of social and commercial services	High level of commercial services
5. Specialised Infrastructure	Not necessarily	Specialised connection or dedicated networks (e.g. High speed services, freight services)	Specialised connection or dedicated networks (e.g. High speed services, freight services)
6. Interoperability	No interoperability	Good level of network interoperability	High level of interoperability (i.e. network, timetable)
7. Managerial performance objectives	No evidence of formal procedures and no managerial business objectives – increase network productivity	Operational gains Commercial gains Ensuring economic efficiency Service quality monitoring	Appropriate asset management Ensuring safety and reliable condition of the network Increasing performance to lower cost Optimisation of network capacity Increase revenue with non-core business activities Customer satisfaction Increase intermodal competition
8. Strategies for increasing revenue	No particular strategies	Better interoperability Creation of New Business Unit	Increase interoperability (e.g. parking lines for RUs) Renewal of inactive railway spaces Dismissal of low profitability railway spaces to office centres Ensuring a high performance of the network (these affect safety-reliability) Creation of New Business Unit
9. Regulatory Framework	Extensive price regulation	Regulated price	Market price
10. Strategies towards new customers	No special methods – no standard access contract	Systematic interactions with clients (e.g. information systems and meetings) – standard access contract	Development of strategic market plans
11. Invest ments typology	Balance constraints: reduction of expenses human resource rationalise existing capacity	Long-term investment programme Human resources Investment in main corridors Reducing punctual bottlenecks Optimisation of infrastructure use (i.e. minimise segmentation of paths) Customer satisfaction for indirect customers	Ensuring improvement of maintenance/renewal Investment in strategic corridors Reducing punctual bottlenecks Optimisation of infrastructure use (i.e. minimise segmentation of paths) New technology implementation Interrelationship between IM and Operators (sharing of investments) Customer satisfaction survey (for both direct and indirect customers Human resources management Creation of New Business unit

3.7.3 Contributions of BPR to the Improvement of IM's Organisation

In general, the benefits that should be derived from the BPR in IM are:

- Simplification of process work flows
- Elimination of whole steps in processes
- Improved cross-functional communication
- Enhancement of the integration of supplier's role in the improvement process effort
- Elimination of non-value-added costs throughout corporate-wide business process
- Reduction of deviations form service standards improve quality and reliability.

Infrastructure managers operate in an environment that has clear differences from the normal, commercial world at which the BPR texts are aimed. Examples of the differences are:

- Safety being paramount
- A public-service perspective and often ownership
- Regulatory and legislative framework
- European Commission directives
- A requirement to liase with, and take account of, external organisations e.g. passenger committees

Therefore re-engineering has to take place with these factors in mind. Some processes are embedded in an IM in order to comply with safety legislation, or safety Best Practice; these areas, whilst not impossible to re-engineer, require special consideration of these external factors.

3.7.4 Required steps for undertaking BPR in Railway Infrastructure Managers

IM's rarely if ever deal with something that could be called a product, though of course it has customers requiring services. These customers can be either direct customers such as passenger or freight train operators or end-user customers (the passengers and station-users, or freight customers) Having these restrictions in mind, the IM can move forward to consider the next step in implementing the BPR system – the seven "Process Improvement Steps"[4].

Those steps, presented here in a general practical context, are:

Step 1 Set the stage for process change
Step 2 Select candidate process for improvement
Step 3 Understand and map the process
Step 4 Standardise the process
Step 5 Improve the process
Step 6 Continue to improve the process
Step 7 Assess process improvement performances

An analysis of each step follows.

[4] Schact and Mansir "An Introduction to the continuous Improvement Process – Principles and Practices" (originally developed for the military who operate under some broadly comparable structures to IM's)

Step I: Set the stage for process change

This requires a board-level understanding, acceptance and commitment to BPR, and an organisation-wide awareness campaign to prepare the employees for the impact of BPR. The more communication regarding BPR the less resistance to change is likely to occur. Nominated senior managers should be designated the BPR leadership team, to oversee the work. A working team can also be prepared for instituting the re-engineering (though further members will be added in Step 2). These individuals will require training in what Hunt calls “process simplification tools”, the methods by which the planned process improvements will take place and a comprehension of how these changes will benefit the IM overall.

Step 2: Select candidate process for improvement

The leadership team selects the process or processes to be the subject of the BPR. This should be (during the first applications of BPR at least) a process that, consensually, requires improvement. This can be identified and measured via traditional benchmarking and input/output ratios (an analysis is done within WP2 of IMPROVERAIL). Targets for achievement are selected and the major obstacles (and the required level of change) identified, in order to generate performance measures, such as response time, work rate, person-hours, etc.

Step 3: Understand and map your processes

The next task is to define the work ahead as clearly and exhaustively as possible. This should be viewed from the "customer's" perspective - in IM terms, this can be the direct customer (passenger or freight operator), the final customer (freight user or passenger), or perhaps stakeholder (e.g. the regulator or State). Once the customer's needs have been identified in relation to the process the current method of delivering that need should be documented thoroughly. This should enable the team to identify the scope and nature of the changes required. The documentation (nearly always incorporating both process maps and written descriptions) should be comprehensive and consistent and will help in indicating if vital areas have been missed in the previous step.

Step 4: Standardise the Process

This phase sets down the preferred, standardised method of performing the process. It will also naturally lead to new, improved tools for evaluating both the process itself and the personnel involved. The team should assist in training the relevant staff in the new process and thereby use the opportunity to demonstrate the advantages of the new process compared to the old one. Performance measures should be taken at this stage and compared to the measures before the re-engineering.

Step 5: Improve the Process

Following from the definition of the process standard the team should seek to optimise it in light of the feedback from the "real world" applications of Steps 3 and 4. It should also re-evaluate the process against its stated aims and requirements and confirm that the re-engineered process encourages process simplification and has removed redundant activity. Any information about related processes and how they could be enhanced should be gathered and fed back to the steering group.

Step 6: Continuous Improvement

The team now follows the Plan-Do-Check-Act cycle to ensure that the culture of process improvement becomes embedded in the organisation's culture. This involves further support and encouragement from the board level down, in developing ongoing solutions that address the IM's requirements and improvements goals.

Step 7: Assess Process Improvement Performance

At this point the process improvement initiative is measured against its stated aims and achievements via an analysis of performance improvement in re-engineered processes. Those new processes that achieve the goals of the IM should be kept, and made part of the organisation's culture and working practices; those that, on study, do not move the IM forward should pass through another iteration of the seven steps.

Additionally, the team should keep an accessible (in style and communication) record to allow others to understand and benefit from the lessons learned during the BPR process. This will assist other departments, regions, etc. in replicating the effort made by the team and facilitate faster and better re-engineering, even by the same team.

3.7.5 Dealing with Railway Business Regulatory Environment

In order to implement BPR, the Infrastructure Managers need to explore the rail business and the regulatory environment firstly, assessing its current position within the business context. Thus, it is of utmost importance for the IM to gain awareness of the competitive environment, the railways dynamics, the challenge and opportunities and the impacts of the new regulations in the railway industry.

As a result the IM will be in a position to influence the positioning of the railway company in the context of current and historic railways development, understanding the major trends shaping the future of railway. This requires self-assessment concerns gaining an insight on the current positioning often the first obstacle as comparative analysis at European level is prevailingly levelled. In fact few IM's denote clear chances for learning opportunities in a changing process that is mostly in its youth. For this reason it has been the objective of the research undertaken in IMPROVERAIL to show also what has been done outside Europe in terms of innovative thinking in managing railway. Realising that different organisational and sectoral structures exist, help IM's to reach a decision about the most effective, efficient, and feasible structure for the railway company, given the forthcoming consequences of EU directives and each country's unique legal, economic, political, and social environment.

The basic step to this respect is detailed below:

Step 1 – Reconnaissance

The reconnaissance step comprises the background analysis on the theme where the IM fits in the current context of railway business and regulatory environment. The goal of this initial step is to place IMs in the right context of current practices. Thus, the IM should gain an appreciation of:

1.1 The competitive environment/landscape facing railway infrastructure managers.
1.2 The railway dynamics of today
1.3 The challenges and opportunities
1.4 The impacts of new regulation in the railway industry

Sub-Step 1.1. **Study of the competitive environment/landscape**

Before any attempt to place the IM in the current practices, its stakeholders need to have an idea of the forces that will interact to shape the competitive environment/landscape for infrastructure managers. For this purpose a need arises to carry out studies, if not already available, to identify how specific forces will impact their railway companies. These forces are mainly the rivalry among modal competitors and bargaining power of railway users and train operators.

Sub-Step 1.2. The railway dynamics of today

After gaining an understanding of the competitive environment, the dynamics of the railway sector should be assessed from the view point of a liberalized market "player". This will judge the IM's position in the current situation and will provide a first notion of the emerging opportunities in view of the forthcoming changes in the railway industry.

Sub-Step 1.3. The challenges and opportunities

Findings of the previous step will help identify the changes that present opportunities to IMs for new ways of doing business (particularly with private enterprises). This means that the issue of attractiveness to the private sector has to be addressed.

Sub-Step 1.4. The impacts of new regulation in the railway industry

This should be scrutinised in view of the consequences that recent EU and national legislation and policies have on European railways (at national and/or international level). This will assess the impacts that general regulatory frameworks (transport deregulation, privatisation, etc.) and changes in railways legislation (specific EU Directives, etc.) are expected to have on IMs.

3.7.6 Setting Objectives and Reaching a Balanced Structure

Business Process Re-engineering is only to be undertaken after a full and complete assessment of IM objectives. Organisational reform along with private sector involvement should represent a mean to achieve specific and well-defined objectives. IM should further check whether the KPI (Key Performance Indicators) values (see Benchmarking Chapter) indicate conflicting objectives or strategies. In order to define the objectives and strategies IM should exert the following aspects:

- **Objectives for the improvement of performance**
- **Consistency of the objectives by examining the underlying strategies**

Railways must increase their market share as transport demand expands and regulatory policies change. According to market opportunities railway companies' business strategies aim at competition with national and international transport operators or cross-border cooperation partnerships between market actors. In practice railways need to improve their service levels to those available in other transport modes. While the transport industry is becoming more international and deregulated, rail transport in Europe is too often based more on national considerations than on customer needs. Business strategies require the availability and use of information technologies and the sharing of common goals and technical infrastructures between all railways, which may imply the option of dedicated joint ventures with other transport modes leading to the provision of new and attractive services.

There are benefits to having the dominant user retain control over infrastructure. First, the performance of the incremental users is clarified and, assuming reasonable access fees, their operations strengthened. Second, the potential risk of disruption due to coordination problems between infrastructure provider and dominant operator is reduced – important when the dominant operator plays a significant role in the country's transport. In most of the involved Countries, strategic decisions are taken by Governmental bodies (e.g. Ministries) or internally to IM by the Board of Managing Director, supported by dedicated staff (e.g. in Italy there is the Dept. of "Strategy and quality of systems").

Most of interviewed IM realize that innovation and maintenance in rolling stock and infrastructure can lead to an increased perceived quality, comfort and safety and in terms of performance. Innovation in fixed installations (infrastructure and signalling) should lead to a perceived enhanced volume and quality of services and system safety levels. These are considered as common organisation strategies. Integrating planning, outsourcing and partnering are current examples of the industry's efforts in building good relations with the railway operators.

Information on the building and operation processes is necessary for these efforts to be successful. The industry is willing to take on its responsibilities in fields such as design, customer support and research.

Which Structure

There are several structures that might be possible after the application of BPR for IM. However, they must fall within the general structure envisaged by the regulatory frameworks in Europe. Hence, an assessment of the organizational structure of European IMs should be made to gain insight into the organizations' adaptability to change. To a considerable extent the regulatory frameworks are set by the state, which dictates the way in which the railway industry (sector) in a country organizes itself. This in turn dictates the initial stage or the starting point from which the IM re-engineering process should begin. This phase will identify a continuum of:

- **Sectoral structure**
- **Organisational structure**

A - Sectoral structure

The methodological framework identified the territory of possible railway sector structures, using a scenarios approach. Thus, the IM should try to identify where in this range of possible structure operates or will operate.

Most structures considered may be framed within the following standard descriptions and designations:

- **Regulated Structure**: railway is completely dominated by the State, which usually implies vertically integrated structures, state ownership, production oriented strategies and minimum adjustment to initiatives towards liberalization. The main principles of this structure are:
    - ***State Regulated*** (Low productivity, Low asset utilisation, High subsidy, High level of network coverage, High cost)
    - ***Production-Oriented*** (Low service quality, Low asset utilisation, negligible profits or loss, Low growth & learning, Medium cost)
    - ***High Integration*** (High cost, Low growth & learning)
    - ***Low Change Level*** (Low productivity, Low growth & learning)
- **Limited-competition Structures**: similar as above, but with some recognition of market competition forces. A typical, but not exclusive, example includes public ownership and in some cases private participation, commercial orientation and reactive behaviour towards liberalization initiatives. The main principles are:
    - ***Part-Privatised*** (Low productivity, Low asset utilisation, negligible profit)
    - ***Commercially-Oriented*** (Medium service quality, Low asset utilisation, High profits, Low growth & learning, Low cost)
    - ***Medium Integration*** (Average cost, Average growth & learning)
    - ***Medium Change Level*** (Average productivity, Average growth & learning)

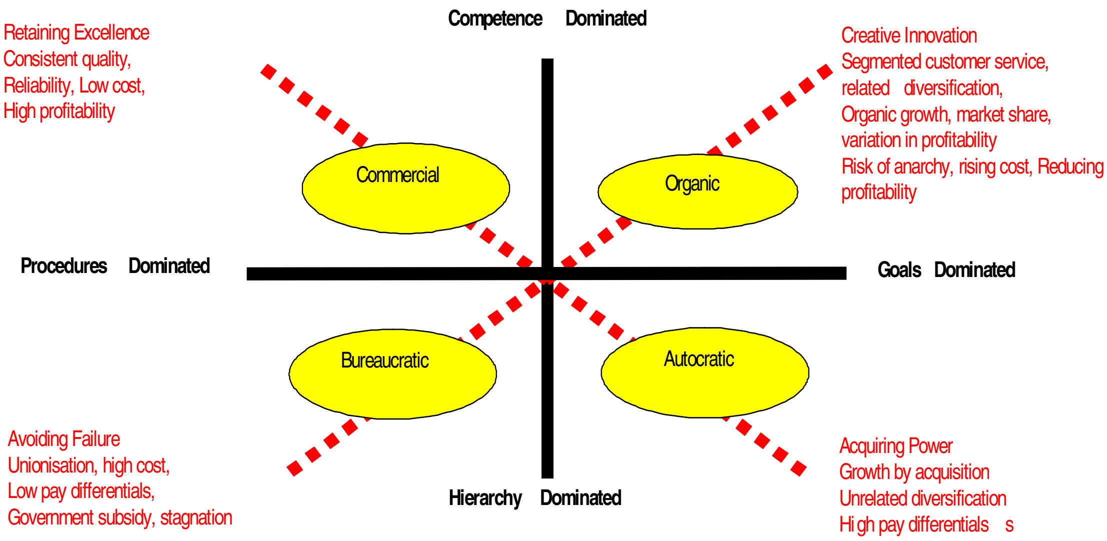
- **Deregulated structure**: the regulated functions are replaced by mechanisms, which are sensitive and responsive to market forces. The railway sector becomes responsive to the market and customer satisfaction turns out to be the primary objective. The main principles are:
    - ***Deregulated / Private*** (High productivity, High asset utilisation, Medium to high profits, Low level of network coverage)
    - ***Market-Oriented*** (High service quality, High asset utilisation, High profits, High growth & learning, Medium cost)
    - ***Low Integration*** (Low cost, High growth & learning)
    - ***High Change Level*** (High productivity, High growth & learning)

Definition of (desired) changes in railway sector

In addition to the analysis of railway's current structure, the IMs needs to define the desired structure of the railway sector, in which their companies would have better means to operate. There are two main drivers in this process, each one leading to a different direction:

- Excessive government control
- Complete absence of government involvement, which might lead to overexploitation and reduction of reliability.

B - Organisational structure



The next step in the methodological framework is the definition of the IM organizational structure. Concisely these structures are:

1. **Bureaucratic Structure**: IM is driven completely by Government, sometimes as a branch of the civil service, with a very rigid line of command, objectives based on output statistics, major strategies and policies defined by Government and little freedom to operate outside these tight parameters.

2. **Autocratic Structure**: similar, but with more emphasis in acquiring power and growth by acquisition (integration). Reduction of regulation is usually an objective, which sometimes is associated with incentives for top management.

3. **Commercial Structure**: is characterized by IM's recognition of the market introduced at the lower levels. Objectives incorporate business targets, within Government strategies and policies such as quality and consistency. The management will have some freedom on marketing activities. There are fewer levels of management, leading to reduced bureaucracy and accelerated decision-making.

4. **Organic Structure**: the production functions are replaced by business sectors. Government objectives are based on financial and service delivery parameters and will be more closely related to business targets set within the railway organization.

Based on the identification of the placement of the current IM's structure, two steps are taken for further analysis:

1 - Definition of (desired) changes in company's model

This step requires an assessment of the desired organizational structure of the IM, in order to identify appropriate change paths. To do so one needs to gain insight into the organization's resistance to change and understand the mechanisms that increase the change force. Hence, an assessment of the organization's current performance is needed, through benchmarking and market research. Resistance is proportional to how close an IM is to traditional command structures. Change force is reversibly proportional to how active or consistent the IM has been in progressively adopting more advanced organisational models. It is noticed that inactive organisations (usually bureaucratic) need radical solutions to catch up.

2 - Changing paths

Having specified the above, the next step is to find the change path that is more likely to facilitate the process of organisational change. The most common change paths are Bottom Up experimentation, Top Down experiment, Radical Leadership, Goal cascading, Core Process Reengineering, Organisation Realignment, Rapid Adaptation, Autonomous restructuring, Downsizing and restructuring.

In support of this guiding information, we suggest detailed reading of Deliverable 4, Chapters 8 and 9.

3.7.7 Selecting Core Business Processes for Reengineering

In order to get the most benefit from BPR it is important to select appropriate processes for re-engineering and to decide in which order to re-engineer them. There are three main criteria used to help in the selection of the key processes for re-engineering:

1. *Where in the organisation are the most serious problems?*
2. *Which are the most important processes to the successful running of the company?*
3. *Which processes provide the best opportunities for successful redesign?*

In addition to these three criteria, the processes to be chosen for analysis should also satisfy a further set of criteria. Due to the reality of the European railway industry today there are two "umbrella" factors which should be borne in mind at all times, to ensure that any theoretical analysis of BPR or the processes it is used to improve are anchored in the reality of the market. These should be considered when setting out the opportunities and methodologies in the context of an IM and the railway industry:

- adherence to EU directives
- better organisational and business performance of the IM (and railway industry as a whole)

In IMPROVERAIL project, it has been proposed to select three processes for BPR analysis Therefore it was decided to first identify processes which met the requirements of the project and then from this set of processes to identify those with the best fit to the standard BPR criteria. Once these processes had been selected it would be necessary to analyse them within the context of the two "umbrella" factors.

1 - Decision to select a process representing each of the 3 categories

IMPROVERAIL WP2, "Benchmarking business processes and methodologies" was undertaken concurrently in support of the specific analyses carried out in each of the other major work packages. It is subdivided into three discrete areas for assessment: operational performance, managerial performance and commercial performance. These three themes have ran throughout the rest of the IMPROVERAIL project. Therefore it was proposed to select three process for BPR analysis, which fit one into each of these categories:

- **Operational -** involved with the day to day operation of the railway
- **Commercial -** interactions with external organisations and bodies
- **Managerial -** role and effects of corporate organisation

2 - Relevance and differentiation between railways of different market orientation

A key output has been an analysis of how IMs at different stages of market orientation can best adapt and use BPR in their environment. They will gain the most advantage by implementing BPR in an appropriate way for their current business environment. Therefore it is important to select processes which are carried out by all the railways in question, so that the differences can be analysed.

Table 4 - Identification of core processes

Processes	Step 1	Step 2	Step 3
Strategy	Managerial	*	□
Financing	Managerial	*	
Control of operations	Operational	**	
Asset management	Operational	***	□
Capacity optimisation	Operational	**	□
Charging	Commercial	**	□
Network enhancement	Operational	*	
Business development	Commercial	*	
Procurement	Managerial	***	□
Admin/Ancillary	Managerial	***	

This simple analysis allowed three high level business processes to be identified as the processes which could be used as examples within this report, subject to the three BPR criteria.

➔ **ASSET MANAGEMENT** - Track maintenance possessions management was identified as a process for reengineering.

➔ **CHARGING** - the allocation of slots to freight operators was selected.

➔ **PROCUREMENT**

However, the identification of Core Processes is extremely industry-dependent. In the case of IMs it is vital to look beyond the usual subjects of (more commercially-driven) company BPR, and focus on those areas that define how the IM achieves success in the context of its operational, political, and social purpose. This must be done from a "top-down" view, so that important areas of interface between the IM and its stakeholders are covered comprehensively.

4 MARKET ORIENTED INFRASTRUCTURE MANAGEMENT

4.1 Introduction

Due to political trends as well as to a general growth of transport market, the traffic on main European railways corridor is constantly increasing. As a consequence, many rail infrastructure owners face capacity bottlenecks on their network.

Saturated railways sections raise two contradictory issues: the maintainability and the availability of the infrastructure. Several railways companies put a very high importance to the availability of their network and tend to reduce traffic interruptions for infrastructure maintenance activities, inducing either lacks of maintenance or a drift of maintenance costs. On the other hand, some infrastructure owners mainly consider the maintainability of their infrastructure and allow extended traffic interruptions, neglecting the quality of the service provided to operators and end-customers. Usually, both of the behaviour are the consequences of a lack of efficient strategy evaluation methods or are inheritance from the history.

This calls the attention to the fact that to carry out a lean railway business requires adopting careful long term (**strategic**) planning of both network capacity investments and infrastructure M&R, as railways investments often require several years between planning activities and deployment of the hardware. The defiance of strategic management level refers to adjusting network's capacity as close as possible to demand, taking into account M&R needs.

At the medium/short term level (**tactical and operational**) infrastructure managers also face challenges. Here the concern is the optimisation of the use of resources, keeping up with the strategic objectives set for infrastructure M&R, while securing the network availability contracted with operators without incurring in contractual compensations at the cost of both financial and image loss.

Hereafter the word infrastructure refers to the physical system constituting the railway's network. The word capacity refers to the maximal number of marketable train-paths that can be operated during a given time span, on a network, on a line, or a node, under given conditions and quality of service.

The handbook's part on market oriented infrastructure management presents three theoretical paragraphs explaining our view on infrastructure management. Another paragraphs synthesises the results of IMPROVERAIL.

4.2 The system "railway infrastructure"

The system "railway infrastructure" is described by three basic constituents: the capacity of the network, the substance and the quality of infrastructure. The capacity can be expressed in train-paths during a certain time span. The substance of infrastructure refers to the average remaining life time of its components, a high substance meaning then a young infrastructure. Finally, the quality of infrastructure represents track's geometry quality and infrastructure components quality. Capacity, substance and quality may be represented trough the following figure.

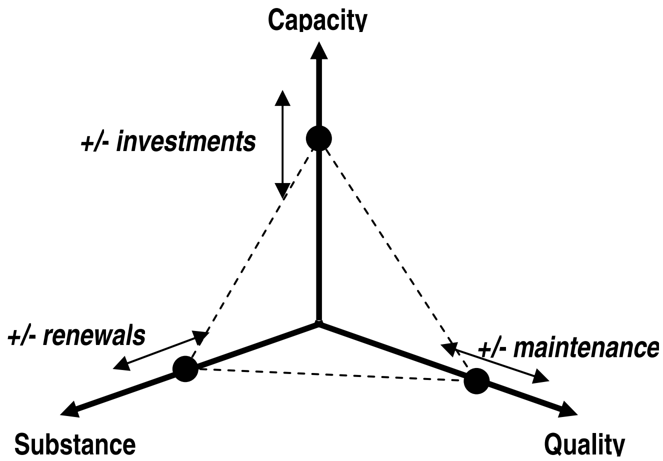


Figure 2: System "Railway infrastructure"

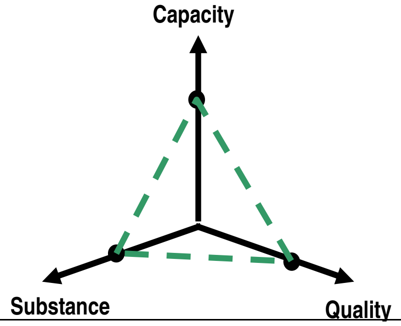
Managing infrastructure it amounts to the same to setting the three parameters at the most appropriate level, in order to maximize the efficiency of the whole system. Capacity can be adjusted through adapting investment policies. Infrastructure substance can be tuned through a suitable renewal policy and quality can be adjusted with the maintenance policy.

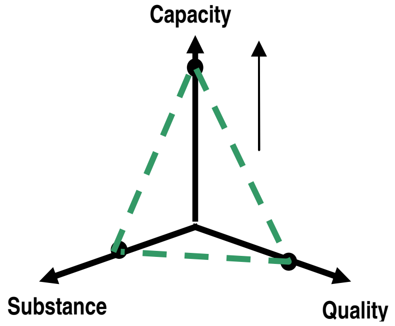
However, adjusting these three parameters require planning on various timescale, as illustrated by the table below.

Parameters	Planning horizon	Adjustment means
Capacity	From 5 to more than 20 years	• Hard investment : construction of a new line or an additional track • Hard disinvestment : dismantlement of a line or a track • Soft investment : upgrade of signalling system (decrease of headways)
Substance	From 2 to 5 years	More or less renewal of components (sub-layer, ballast, sleepers and rails)
Quality	From 1 to 5 years	More or less track maintenance (rails grinding and ballast tamping)

This outlines the importance of a sound strategy for capacity investments. Indeed, a bad policy for capacity evolution is unrecoverable on the short run and is likely to hamper railway infrastructure efficiency for many years. This is shown by Figure 3 below.

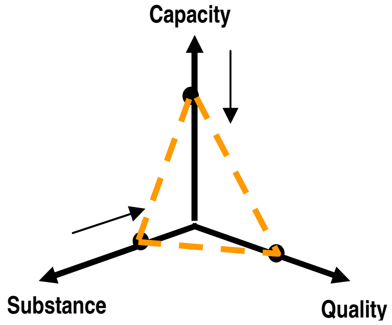
Moreover, capacity, substance and quality of a network are tightly related together. Next paragraph refers to these dependencies.

<table>
<tr><td>
</td><td>Initial situation – YEAR 0

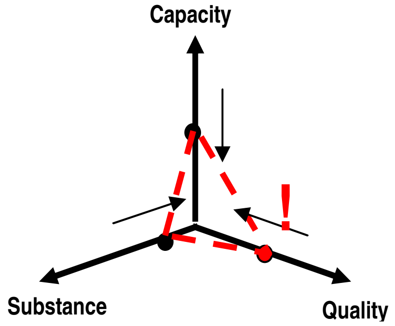
Infrastructure is in a good state. The quality is high enough to guarantee the expected level of service quality.</td></tr>
<tr><td>
</td><td>First step – YEAR +1 / +2

Limitation of budget for renewal actions or decrease of available intervals for renewal.

The consequences of such a policy are not yet visible as the infrastructure has enough substance.

More capacity is available</td></tr>
<tr><td>
</td><td>Second step – YEAR +3 / +4

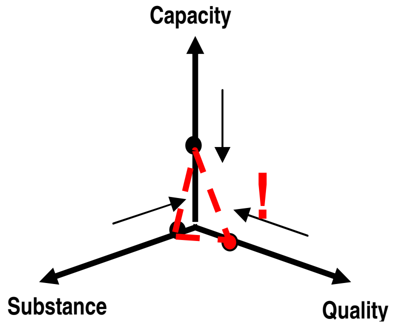
In order to keep quality standards, more maintenance has to be done. The infrastructure grows older and needs more maintenance actions.

The availability of capacity decreases too.</td></tr>
<tr><td>
</td><td>Third step – YEAR +6 / +8

It becomes hard to keep quality standards as needs in maintenance grow very quickly.

There aren't enough resources to achieve the maintenance.

Speed restrictions have to be set in order to guarantee the safety of the traffic.

There is a significant decrease of available capacity.</td></tr>
<tr><td>
</td><td>Final step – YEAR +10/+…

The system "infrastructure" is totally instable.

Maintenance costs are out of control, the quality decreases. There is a significant lack of capacity.

Massive renewal actions have to be launched in order to inverse the trend and to bring the network to its balance. These renewal actions require high investments and works lasts several years, years during which railways operators experience serious difficulties to offer an acceptable service.</td></tr>
</table>

Figure 3: Loss of the rail infrastructure due to insufficient budgets

4.3 Dependence between railway infrastructure capacity, substance and quality

4.3.1 First dependence: capacity vs. M&R

An increase of traffic induces an escalation of infrastructure deterioration and consequently an expansion of needs in its maintenance and renewal (hereafter M&R). Related M&R engineering works induce then an increase of track possessions, worsening so the saturation rate of the network. If engineering works are not undertaken, condition of the infrastructure will sooner or later deteriorate and generate permanent speed restrictions or safety lacks. The figure below illustrates the problem.

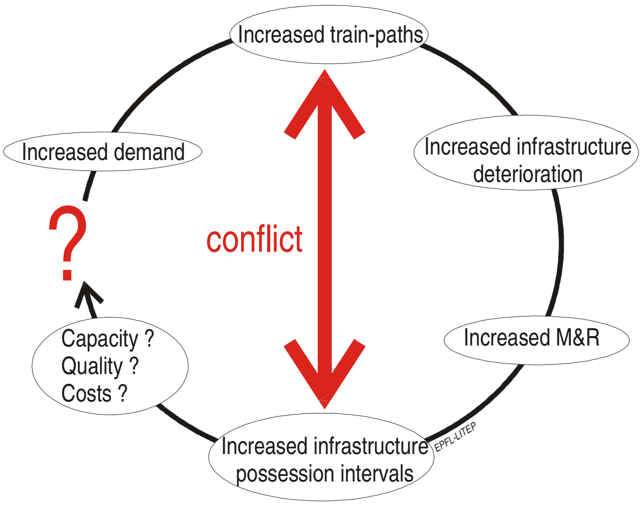


Figure 4: Technical interrelation between capacity and M&R

The dependence between capacity and M&R occurs not only on the technical side of infrastructure management but obviously also on the economical field. The marketing department's goal is to sell as many slots as possible to satisfy customer demand. The maintenance department's task on the other hand is to keep the infrastructure on a defined quality level. M&R works have to be carried out at the lowest possible costs, which imply the use of heavy machinery and large track possessions inherently consuming capacity, hereby reducing marketable train-paths (see figure below).

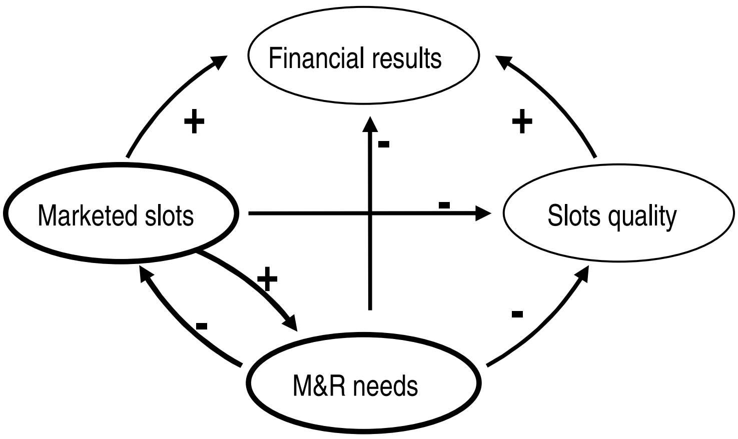


Figure 5: Economical interactions between capacity and M&R

4.3.2 Second dependence: quality vs. substance

By far the most significant factor contributing to infrastructure deterioration is the dynamic load of trains running on the track. The dynamic load is directly related to the axle load and track geometry. The two elements are closely linked in the complex process of deterioration:

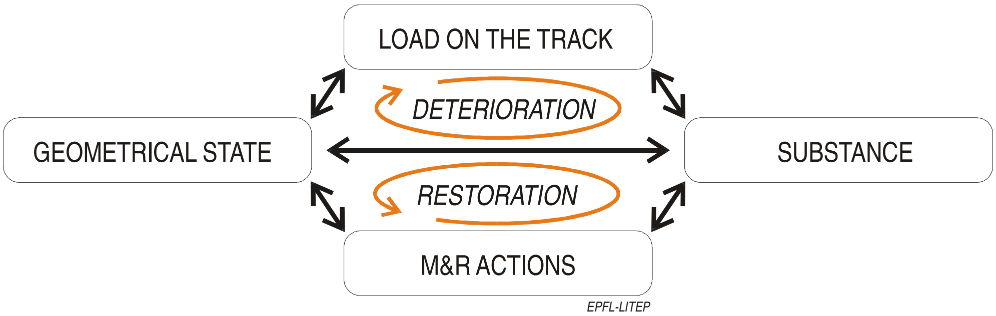


Figure 6: Restoration and deterioration processes.

The bad state or quality of material contributes significantly to the deterioration of the track geometry. Bad track geometry produces higher dynamic loads on the material, which accelerates the degradation of the material, and thus significantly reducing the substance.

Beside this, the life of such components can be divided into three distinctive parts: the youth, the intermediate life and the old age. During the youth, the component experiences substantial deterioration due to track settlements. After a while, the importance of degradations diminishes and the component starts its intermediate life. When reaching the end of its lifetime, the component undergoes higher degradations: the old age period. Thus, a network characterised by a poor substance of its infrastructure will require much more maintenance.

The degradation curve of a generic railways track component is shown by the figure below.

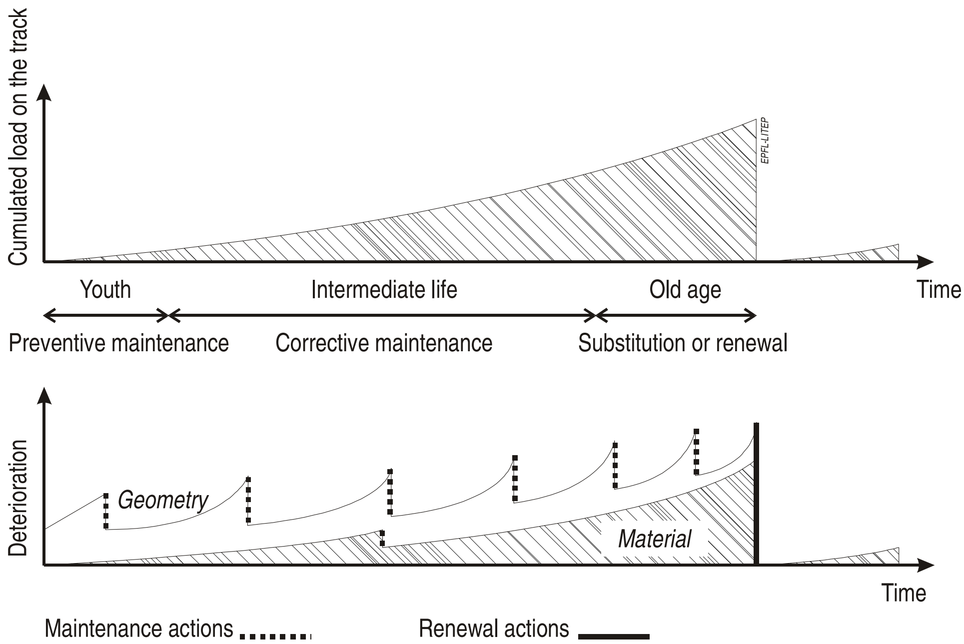


Figure 7: Degradation and restoration processes of railways infrastructure

4.4 Managing the system rail infrastructure

Railway infrastructure is the physical system constituting the railway network. As stated in previous paragraphs, the system "railway infrastructure" is characterized by the following points.

Capacity (maximal number of operable and marketable train-paths in a given time span, on a given part of the network), **substance** (average remaining life time of infrastructure components) and **quality** (quality of track's geometry and of components) are three constitutive parameters of the system rail infra.

Capacity, substance and quality are **interrelated parameters** and **must jointly be adjusted**.

Adjusting capacity, substance and quality requires planning activities at **various time horizons**.

IMPROVERAIL proposes methods for capacity and resources management for railways infrastructure, at the network level. Therefore, as first step, a structuring of the system "railway infrastructure" has been undertaken. Next figure describes the generic management concept of railways infrastructure.

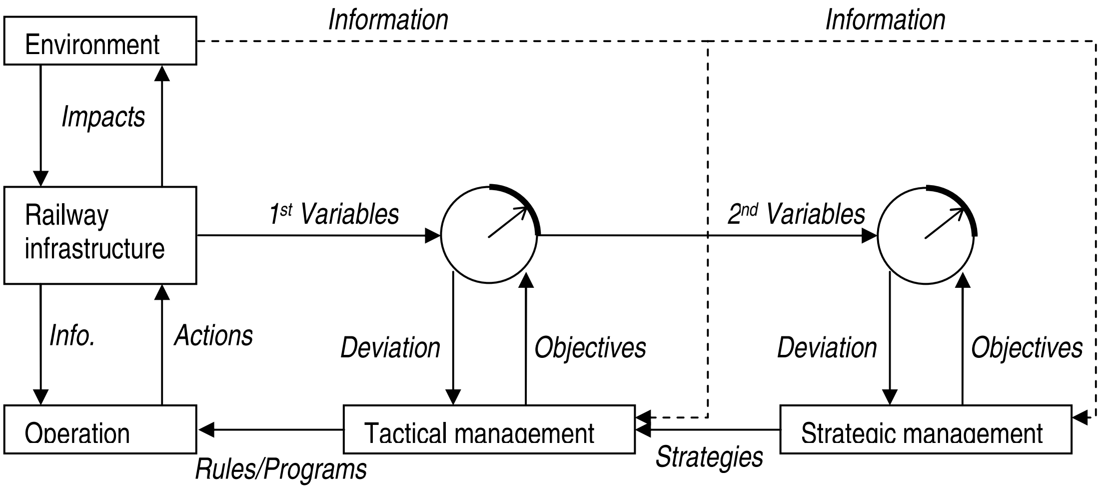


Figure 8: Management of the system rail infrastructure

- The system constantly interacts with its environment (society in general, meteorology, …)
- The operational structure runs the system through a panel of actions. Actions depend on information provided by the system. Type and amplitude of steering actions rely on operational rules or programs. For instance, a timetable is a rule that sets the pattern of capacity operation, M&R plan is a program that sets the pattern for undertaking engineering works on the network.
- The tactical management draws operational rules and programs. Rules and programs are adjusted according strategic goals of the company and according the deviation between variables measured on the system and tactical objectives, final objective being the most efficient operation. As example, the average train's delay may be too high on a given network. Thus, the punctuality objectives are not reached and some operational rules or programs must be adjusted (more timetable margin, better train-paths management, different track possessions scheme…) Information related to the environment also enters in the tactical management process.
- The strategic management defines strategies that guide the evolution of the rail infrastructure. These strategies are elaborated on the basis of an accurate analysis of the environment (evolution of the society, technological breakthroughs …) as well as on feed-backs collected from the tactical management (2nd variables). For instance, M&R tactical planners may experience difficulties to sufficiently maintain the geometry of their infrastructure because the latter is too old on average. The

renewal strategy must then be adjusted in order to reach a more accurate substance of the infrastructure.

Based on this structuring of rail infrastructure management, IMPROVERAIL presents methods, models and recommendations on capacity and resources management for rail infrastructure. Results of research works are presented below.

4.5 Toward a market oriented infrastructure management: outcomes of IMPROVERAIL

Research works led to various conclusions on infrastructure management topics and to seven rough models, more or less elaborate. These are:

Strategic management (long-term):

- Transformation of a rough demand O-D matrix into train-paths.
- Capacity estimation of a network, in the long term (without specific timetable).
- Saturation costs estimation of a network (saturation due to capacity bottlenecks and track possessions).
- Optimal track possession interval calculation.
- Strategic infrastructure M&R policy elaboration.

Tactic/operation management (medium/ short-term)

- Definition of static work zones on a link.
- Minimisation of timetable degradation due to track maintenance (by optimisation of short-term worksites scheduling)

Beside this, various existing planning tools are described and put into the context of infrastructure management.

For a better intelligibility of research outcomes, presented results are centered on basic topics related to long term (strategy) and medium-short term (tactic and operation) management levels.

STRATEGY RELATED TOPICS
A – EVALUATION OF FUTURE DEMAND FOR NETWORK CAPACITY
B – EVALUATION OF FUTURE NETWORK CAPACITY
C – SIMULATION OF A MAINTENANCE AND RENEWAL STRATEGIC POLICY
D – CAPACITY INVESTMENTS SCENARIOS TAKING INTO ACCOUNT M&R

TACTIC/OPERATION RELATED TOPICS
E – TACTICAL M&R DECISION SUPPORT TOOLS
F – PRIORITISE AND PLANNING M&R ACTIVIES
G – SCHEDULE WORKS AND ALLOCATE M&R POSSESSIONS
H – IMPLICATIONS OF OUTSOURCING TRACK WORKS

A – EVALUATION OF FUTURE DEMAND FOR NETWORK CAPACITY

For managing the network, infrastructure managers need to have knowledge about the current market situation and forecast, partially relying on information from operators.

From O-D matrices to train-paths

Adjusting infrastructure to match capacity needs (new lines, extensions, upgrade …) is a process which takes years or even decades. The infrastructure manager, up to a certain extent, wants to accommodate future demand for capacity as well as possible. Just because of the long development time the infrastructure manager needs a long-term forecast on how much capacity is needed on his network. The required network capacity is dependent on two main factors: the demand for transport and how this demand is translated into capacity usage. There are several models for estimating future demand for transport. Usually such models also incorporate some evaluation of alternatives (scenarios). Typical output for models like these is an Origin-Destination-matrix (O/D matrix) differentiated along several dimensions. IMPROVERAIL does not deal with this type of models and assume that relevant O/D matrices are given. IMPROVERAIL only copes with the translation of transport demand, expressed in tons or passengers, into capacity demand, expressed in train-paths.

"Fixed supply" of train paths

In various countries passenger timetables are not simply the result of projecting the demand on the network, translated into the in number of trains per day. Therefore, the data that has to be used cannot be in the form of an O/D matrix, but already in the form of capacity (number of train per day on every line or section) of the considered network. In fact, when transport authorities wish to offer the population a public service that is a real alternative to car transportation, they dictate a minimal supply fixed by the law. This is generally voluntary and is planned relatively early (for instance, up to 20 years ahead for Switzerland). This time allows infrastructure managers and train operators to plan their needs sufficiently early concerning infrastructure and rolling stock in order to meet the wishes of the authorities. In the same way, some offered paths don't correspond directly to a demand, but allow to meet certain needs or services (local freight trains bringing every day a few wagons from the shunting yard to branch enterprises) or to realise a political goal (e.g. trans-Alpine piggy-back trains, carrying lorries). In these cases data in the form of an O/D matrix are not usable either.

Market segmentation

As the process leading to the number of train-paths might vary from one market segment to the other, it is important to define which market segments should be included. Independently of the methodology or the particular model to be used, market segmentation should also be compatible with the availability of statistical data. Actually, disintegration of data may not be always possible, at least not to the detailed level required to take into account every relevant criterion. The segmentation proposed below takes into account this fact and is based on available statistical data.

a) Passengers

Four following segments are proposed :

1. International traffic
2. Long-distance national traffic
3. Inter-regional traffic
4. Urban and regional traffic

Depending on the size of the geographical area, segments 1 and 2 may be grouped.

b) Freight

Based on a PhD thesis[5] conducted at LITEP by Dr. Paolo Guglielminetti, IMPROVERAIL proposes to segment freight traffic according to 10 market segments defined by the NST/R[6] typology. This is valid for all but combined transport, for which there is no segmentation according to the type of transported product. To take into account the specific characteristics of combined transport, Dr. Guglielminetti introduced 2 specific segments:

- Freight loaded in land-transport intermodal units (land-transport containers, …)
- Freight loaded in maritime containers

The reason for that is that rail-road combined transport requires a fast and reliable service, as it is exposed to direct competition with road transport, whereas sea-rail and sea-inland maritime combined transport is usually carried out over longer distances and with less stringent speed requirements.

It is therefore proposed to split rail freight demand into 12 segments, defined upon the type of product or the loading unit. The next table summarises the traffic volumes for those 12 segments for the years 1994 and 2007 (which correspond to the basis-year and the planned target-year used in Dr Guglielminetti's study). The value per hour of transportation for each of those segments is given next. These have been assessed roughly on the basis of the average value of products and on the evaluations and indications given by shippers concerning requirements of service quality. Two points should be raised concerning taking the value of transportation time into account when modelling:

- Different values must be considered for every segment in order to be able to distinguish the various " reactions " facing a more or less fast (notably in case of rerouting of a part of the traffic in order to get around a bottleneck);
- The estimated value of time is evidently an approximation. Therefore, a sensitivity analysis will be necessary to test the response of the model to a variation of this parameter.

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5 Thesis EPFL #2394, § 3.2.2 (Id [115] in WP1's database)

6 NST stands for "Nomenclature Statistique pour les Transports". (i.e. Standard Goods Classification for Transport Statistics); see also http://www.ires.ucl.ac.be/BASE_DE_DONNEES/Nomenclatures/transports/NST_R_3.en.html

Segments			Rail transalpine traffic in 1994	Average value[7]	Potential for rail transalpine traffic in 2007	
			(tons)	(€ / ton)	(tons)	(%)
Intermodal Freight	1	Land-based combined freight traffic	5 518 218	n.d.	7 813 811	16.4%
	2	Maritime-based combined freight traffic	2 353 188	n.d.	4 719 344	9.9%
Conventional rail freight	3	Agricultural Products (NST 0)	2 491 390	194	3 225 391	6.8%
	4	Foodstuffs And Animal Fodder (NST1)	628 753	2070	860 534	1.8%
	5	Solid Mineral Fuels (NST 2)	123 914	131	129 411	0.3%
	6	Petroleum Products (NST 3)	779 145	196	927 019	1.9%
	7	Ores and Metal Waste (NST 4)	1 783 166	147	2 078 754	4.4%
	8	Metal Products (NST 5)	4 130 384	422	5 241 236	11.0%
	9	Crude and Building Materials (NST 6)	3 111 192	76	4 100 890	8.6%
	10	Fertilisers (NST 7)	71 668	162	85 415	0.2%
	11	Chemicals (NST 8)	1 437 184	692	1 983 606	4.2%
	12	Manufactured Articles (NST 9)	11 594 059	4801	16 509 946	34.6%
		Total	**34 022 261**		**47 675 356**	**100.0%**

Table 5– Segmentation of transalpine freight traffic developed for model application

Input – Output

With the demand being expressed by O/D matrices in tonnes or in number of passengers, the objective is to make these data compatible with the needs of other processes, being trains circulating on the network. However, it is necessary for freight traffic to also know the number of wagons, because trains are not always constituted of the same number of wagons, depending on itineraries. Therefore, a" tons2trains " process must allow first of all to transform the freight O/D matrix (tonnes daily) into another O/D matrix (number of wagons to transport per day). In a second step, this process must give a "law of train composition", permitting to transform a number of wagons into a number of trains. The input of this process includes the O/D matrices on the one hand and on the other hand, some features of the network (permitted loads, sizes, track length etc…) and the types of train that can circulate on the network. Outputs must match to the objective, on the one hand a new O/D matrix expressed in number of wagons by segment of market, and on the other hand a rule allowing to transform a number of wagons into number of trains.

Existing Methods and Tools

Several railway companies have models to transform demand in terms of tonnes into demand for capacity. As an example we've included explanation of the approach of the Dutch Rail Infra Manager. Generally speaking, models like this use abstract rules to calculate the number of trains per section. Routing of these trains is done with expert knowledge. Behind the rules and the setting of parameters there's a lot of business logic. This implies that experts in the field of rail traffic should use such models.

[7] Those values are established using data on Italian foreign trade (which is the source of the major part of transalpine freight traffic). Data are provided by ISTAT (the Italian Institute for Statistics), as the Swiss statistical sources bear no indication on the value of the transported goods.

In Guglielminetti (2001): *Optimisation des performances du transport ferroviaire de marchandises,* .it is presented an optimisation model for rail freight transport planning. Effective infrastructure use and customer orientation are its key characteristics. On the basis of a preliminary estimation of the demand, the model determines the frequencies of the freight trains and the routes of the freight flows that minimise a total generalised cost function. Capacity limits of lines, nodes and trains are the constraints of this optimisation problem. As opposed to the model mentioned above, this model routes wagons and only transforms wagons into trains after the route of the wagons is known.

Proposed approach: Tons2Trains

This paragraph identifies the main steps in the process of converting transport demand into capacity demand. We will only deal with demand for freight and take the future demand for passenger trains for granted. The number of passenger trains is (beside transport demand) highly dependent on factors beyond the control of the infrastructure manager. In particular so-called Public Service Obligations and commercial considerations (e.g. regularity of timetables) disconnect the demand for transport from the demand for train paths.

A list and description of the steps leading from defined inputs to the expected result is given here:

- *Clustering*

The O/D matrix we start with is typically very detailed. In order to feed the model significant streams we clustered nodes from the O/D matrix. Some zones (origins, destinations) are grouped with a railway perspective in mind. Likewise the number of commodities is reduced, i.e. commodities are grouped together.

- *Conversion tonnes-to-wagons*

For every cargo type a relevant wagon type is selected. The conversion to wagons is now a simple division of the number of tonnes per year by the average payload of this wagon. This results in a number of wagons per year (for every cargo type and every origin-destination-pair considered).

- *Adjusting for peak factor*

The demand for transport is expected to have some fluctuations. There may be a seasonal pattern in which there is more demand than average during part of the year. There may also be variations between days within such periods. As we are interested in the capacity needed in practice we raise the figures from the previous step by some peak factor.

- *Allocation to part of days*

The unit wagons/year doesn't suit the units of the infrastructure manager. According to the number of working days, we transfer to wagons / day. In certain countries we should even go further and talk about wagons / hour where we differentiate between hours at night, rush hours and normal daytime hours. Here we can adjust for a certain number of hours needed for maintenance of infrastructure (and therefore not available for operations).

In the implementation of the model we can group these last three steps (so tonnes / year is converted in one step to wagons / hour), however a user should specify the characteristics (wagons, peak factor, spread over day) separately.

- *Rules for conversion of wagons (per hour) to trains (per hour)*

For every origin-destination-pair we have to decide which are the possible routes. This may be cargo type dependent as some commodities are time-critical and therefore do not allow large deviations. For every route we have to establish rules based on infrastructure characteristics on how wagons are converted to trains, i.e. we calculate the maximum number of wagons per train.

- *Output*

The output of our model is a number of wagons for every combination of cargo type, origin and destination. Beside that, we give the route-dependent rules on how wagons can be converted to trains.

The elaborated model is shown by the figure below.

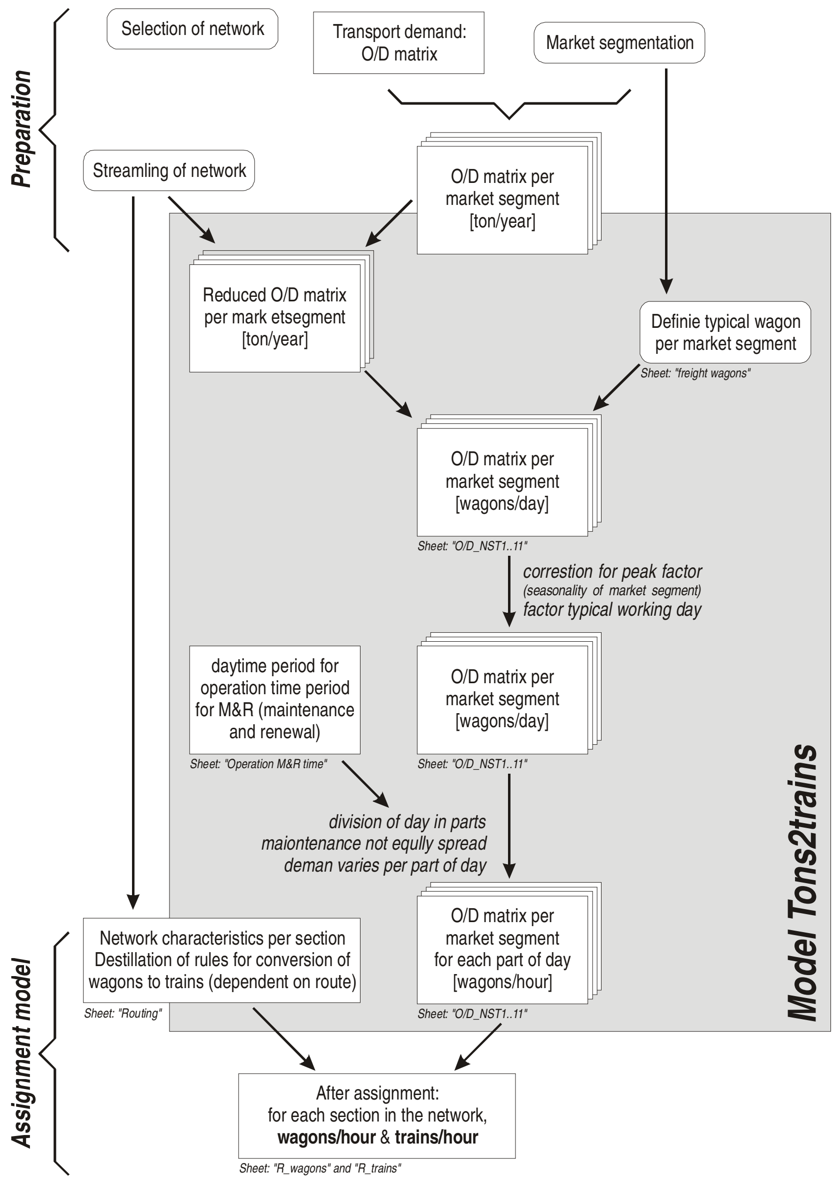


Figure 9 : Concept of the model "tons to trains"

For further details, see D6, Chapter 2.4, "FROM AN O-D TO A NUMBER OF TRAINS", page 15.

B – EVALUATION OF FUTURE NETWORK CAPACITY

IMPROVERAIL tackles the evaluation of future capacity in a two steps approach. IMPROVERAIL firstly proposes a capacity assessment model. Secondly it suggests an approach for routing trains that is to say to allocate the demand. The latter is expressed in train-paths and may be the output of the TONS2TRAINS model presented in the previous chapter. The demand allocation allows as well the costing of track possessions for M&R engineering works.

Capacity calculation for long-term planning

The IMPROVERAIL capacity model proposes evaluating capacity by identifying bottlenecks The calculation of used capacity as a percentage of the maximal capacity will give a saturation indicator of the analysed section. It is to be applied in long-term planning without information about the timetable. The sequence of trains is not required; only the number of trains of each train category is required to calculate the expected sequence of trains, taking into account infrastructure characteristics and network effects.

The CAPACITY model is based on the UIC formula, with the most significant difference being in the formula to calculate the mean time span at minimal sequence of trains. Without the timetable being defined, it is not possible to count the number of sequence cases of one train category following another train category (n_{ij}). This parameter n_{ij}, is replaced by the expected number of sequence cases taking in account the known number of trains running in a given time span for each train category and can be computed by:

$$n_{ij[\text{slots}]} = \frac{n_i \cdot n_j}{N}$$

With:

n_i	number of trains running in period T of category i
$N = \sum_i n_i$	total number of trains running in period T as defined above

These expected numbers of sequence cases (n_{ij}) are not exact. Nevertheless, it gives an approximate value with a decreasing error with the increase of N. Some experiences return an average error of 0.05 trains with a maximum of 0.2 trains with 21 trains distributed in 6 train categories.

With this assumption, the capacity will be defined by:

$$L_{[slots]} = \frac{T_{[\text{min}]}}{t_{fm[\text{min/slot}]}} \times C_{ut} \times V$$

with:

L	capacity of a section in number of trains in period T
T	considered time span
t_{fm}	expected mean of time span at minimal sequence of trains
C_{ut}	% of maximal usable capacity
V	number of tracks

Where the mean of time span at minimal sequence of trains will be computed by:

$$t_{fm[\frac{\text{min}}{slot}]} = \frac{t_{ftot}}{N}$$

with:

t_{ftot} the expected total occupation time strictly necessary to handle with the total planned trains N for the period T

N total of planned trains for the period T

And the total occupation time t_{ftot} is given by:

$$t_{ftot[\min]} = \sum \left(t_{fij} \cdot n_{ij}\right)$$

with:

t_{fij} the minimal time gap between trains, when one train of category j follows one train of category i

n_{ij} expected number of sequence cases of one train from category j following one train from category i

The calculation of the time gap between the sequence of train category i and train category j (t_{fij}) can be computed in different ways to take into account different security systems implemented in network, or different definitions of regularity margins (e.g. in % of time instead of additional time between stations). One possible process is given by:

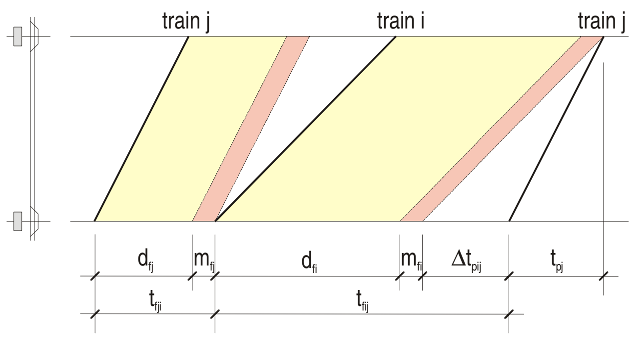
$$t_{fij[\frac{\min}{slot}]} = d_{fi} + m_{fi} + Max\{t_{pi} - t_{pj}; 0\}$$

with:

t_{pi} running time of train i

d_{fi} train spacing (headway buffer time)

m_{fi} regularity margin (additional time between stations to cover potential delays)



<u>Allocation of demand and traffic interruption costing</u>

The propose of the allocation model is to allocate the demand, returned from the Tons2Trains model, to the railway network taking into account the capacity restrictions; additional delay cost due to network saturation; and, if necessary, re-routing trains to longer paths, with an objective of service degradation cost minimisation.

In the case of capacity restrictions, the models CAP1 and CAP2 described above allow capacity evaluation, taking into account the mix of trains without the knowledge of the timetable.

Train Delay

Train delay can introduce additional costs to the infrastructure manager and it is well known that it is correlated with the level of saturation in each section. To take this cost into account, the run time of a train in a path will be increased by a percentage of additional run time in each section as a function of saturation on that section.

The additional run time due to section saturation must be defined for each network or sub-network. Figure 10 shows the graph of the used function that must be adapted to each network with relevant statistic data.

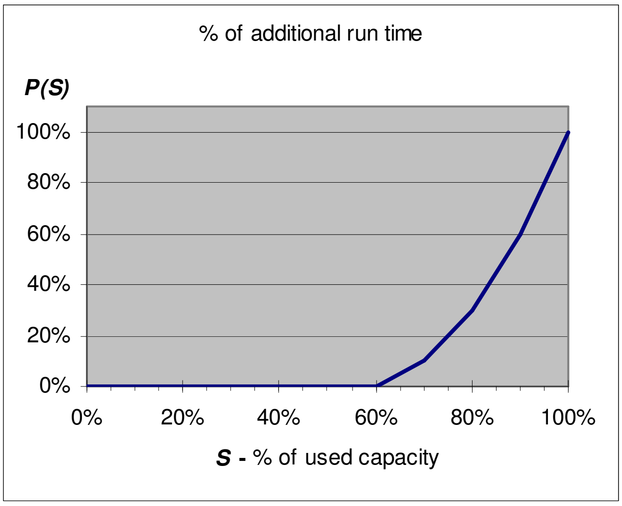


Figure 10: additional run time due to section saturation

The total run time of a train-path will be given by:

$$t_{tot} = \sum_i [1 + P(S_i)] \cdot t_i$$

where:

t_{tot}	total run time for the train-path
t_i	run time of train in section i
S_i	percentage of saturation in section i
$P(S)$	percentage of additional run time function

Re-routing

To increase network capacity trains can be re-routed to a longer alternative path, not for any path but only for a specific set of paths selected by the user as alternative paths.

For each origin-destination pair of the O/D matrix a previous analysis of the network, or the application of the k-shortest paths algorithm, will return a set of alternative paths other than the ideal one, normally the shortest one in time or length. In this selection of alternative paths for re-routing all paths that not fully satisfy train category characteristics (e.g. maximum axle load or profile) should be discarded. The result should be a set of paths that can be used in each market segment for each origin-destination pair.

Service Degradation Cost

Service degradation cost of a train is defined as the cost of train delay due to congestion or re-routing. Given the value of time for each market segment, the service degradation cost of one train will be that value multiplied by the total delay, the difference between travel time and ideal travel time using the shortest-path (in time) with a zero saturation level in the network.

For each train-path, service degradation cost can be computed by:

$$c_m \cdot \left(t_{im} - t_m^*\right)$$

where:

- c_m time value per hour of a train for market segment m (/h)
- t_{im} travel time on train-path i for market segment m taking into account the level of saturation in the network (€/h)
- t^*_m ideal travel time of one train for market segment m using the shortest path without delays due network saturation (saturation level equal to zero for all sections of the network).

The travel time t_{im} is computed by

$$t_{im} = \sum_k a_{ik} \cdot \left(1 + P\left(S_k\right)\right) \cdot t_{km}^*$$

with

- a_{ik} is a binary value that defines if section k of network is used by train-path i (a_{ik}=1 if section k of network is used by train-path i , a_{ik}=0 if not used).
- t^*_{km} ideal travel time of one train for market segment m in section k without delays that are due to network saturation (saturation level equal to zero for all sections of the network).
- $P(x)$ percentage of additional run time for a train to travel in a section in function of saturation level in the section (x).
- S_k saturation level of section k measured by the ratio of the assigned number of trains by the capacity for the given mix of trains, or by the ratio of used time by the considered time span, given by:

$$S_k = \frac{\sum_m \sum_i a_{ik} \cdot x_{im}}{L_k\left(x_{im}\right)} = \frac{1 - P_{0k}}{T}$$

  - x_{im} mix of trains defined by the number of trains of market segment m that follow train-path i
  - $L_k(x_{im})$ capacity in number of trains for a given mix of trains (see previous chapter)
  - $P_{0k}(x_{im})$ is the free time of section k for a given set of train mix (x_{im}) (see previous chapter)
  - T time span

And the ideal travel time t^*_m that is fixed in the problem can be computed by:

$$t_m^* = \underset{i}{Min}\left\{\sum_k a_{ik} \cdot t_{km}^*\right\}$$

Basic Formulation

Taking as decision variables for the allocation problem the number of trains following path *i* that run from the origin to destination of *m* (x_{im} , – number of trains following path *i* for market segment *m*), the allocation problem can be formulated by:

$$Min \quad SDC_T = \sum_m \sum_i \left[c_m \cdot \left(t_{im} - t_m^* \right) \cdot x_{im} \right]$$

$$\sum_m \sum_i a_{ik} \cdot x_{im} \leq L_k \left(x_{im} \right)$$

$$\sum_i x_{im} = D_m$$

$$x_{im} \in \mathrm{N}$$

where:

$$t_{im} = \sum_k a_{ik} \cdot \left(1 + P\left(S_k \right) \right) \cdot t_{km}^*$$

$$S_k = \frac{1 - P_{ok}\left(x_{im} \right)}{T}$$

with:

- *m* — index representing one market segment from one origin to one destiny, with each index m representing one cell of the OD matrix for each market segment (e.g with 4 market segments each one with 4 origins and for destinations, the number of index *m* used will be 4x4x(4-1)). This index *m* can be replaced by three indexes *mod* where *m* represents the market segment, and *o* and *d* represents the origin and destination of OD matrix without any consequences in the formulation presented.
- x_{im} — number of trains following path *i* for market segment *m*.
- SDC_T — global service degradation cost on the whole network for the assigned demand
- D_m — Demand for market segment m in number of train-paths required

The objective is to find a solution for demand allocation that minimises the global service degradation cost of allocated demand. The first set of restrictions (one for each section *k*) ensures capacity limits due to the mix of trains, while the second set (one for each market segment) covers the demand.

Allocation Algorithm

To solve the allocation problem an algorithm was developed with four main steps:

1) Allocate demand taking into account priority indexes and capacity restrictions
2) If not all demand was assigned, search for bottlenecks on unassigned demand, and try to release capacity by rerouting trains from other market segments.
3) For each market segment, try to use rerouting to improve the solution
4) For each market segment, search for a second market segment and try to reroute both market segments to improve the solution.

Next picture shows a cost evolution as a function of possession time in a given specific section. Values shown represent service degradation cost (SDC) in the whole network and corresponding components of delay cost (DC) and reroute cost (RC) $SDC_I = DC_I + RC_i$.

This graph will have the same value at origin, in this sample EUR 310000, for any section of the network representing the service degradation cost due to network saturation or existing bottlenecks. With the increase of possession time in hours/day, the corresponding capacity reduces with two types of solutions: an increase of delays in the analysed section with consequentially lead to an increase of DC (no change in re-routing RC); or reroute some trains, releasing some capacity for possession with an increase of train-paths on alternative paths resulting in an increase of RC and DC on the sections used for rerouting.

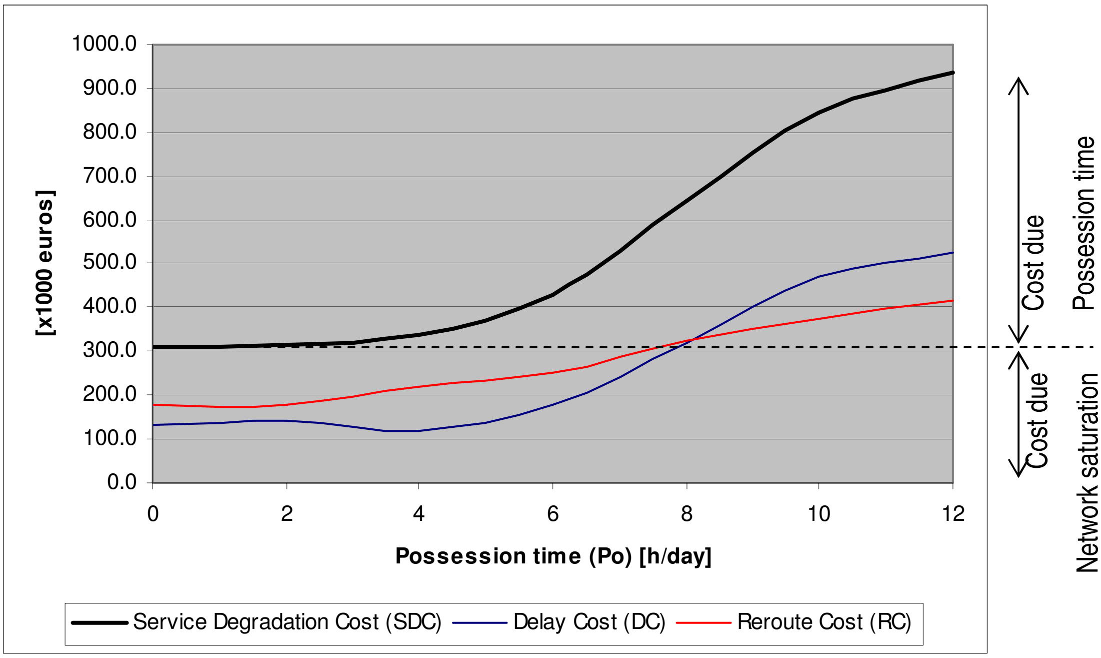


Figure 11: possession time cost function

For further details, see D6, Chapter 2.7, "Introduction to IMPROVERAIL capacity evaluation model", page 35, proposes a capacity evaluation model. This model does not take into account a specific timetable and is suitable for long term analyses. This model is detailed in Chapter 2.8, "Proposed Capacity Model", page 41.

C – SIMULATION OF A MAINTENANCE AND RENEWAL STRATEGIC POLICY

Importance of a M&R strategic policy

Main objective of successful M&R strategic policy is to define maintenance and renewal rules leading to a sustainable balance between the magnitudes of the three main decisive variables of the system "rail infrastructure": capacity, substance and quality (see introductory paragraph, above).

A long term M&R policy must provide a decision framework for the medium term M&R work planning (tactical level). This framework consists of several rules that are guidelines leading the medium-term management to achieving a minimal infrastructure cost over the life cycle. Major rules that constitute decision guidelines should be:

- Average thresholds for renewal actions, leading to the adjustment of the substance,
- type of material to use at the time of renewals,
- quality level of infrastructure,…

These rules should either be defined by strategic business goals (e.g.: quality level of the infrastructure) or be adjusted through an optimisation process (e.g.: average thresholds for renewal actions). The latter must be optimised on the long term so as to minimise the total cost of the infrastructure over its lifetime. The medium-term management can then rely on guidelines that ensure a coherent evolution of the quality and the substance of the network and a minimal cost of the infrastructure over its life cycle.

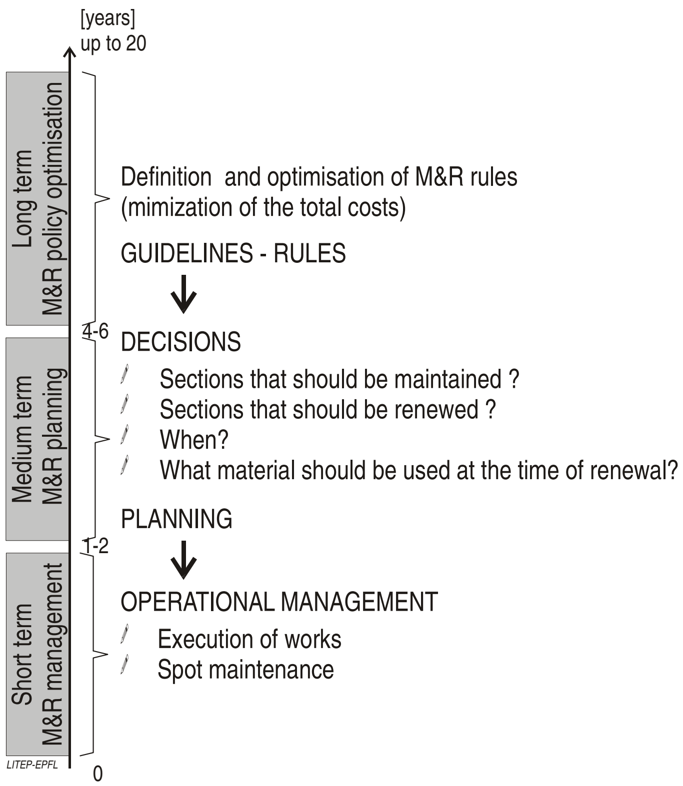


Figure 12: Role of a long-term M&R policy in the M&R process

Proposed approach, concept of the M&R simulation process

The following figure illustrates the concept of the M&R simulation process:

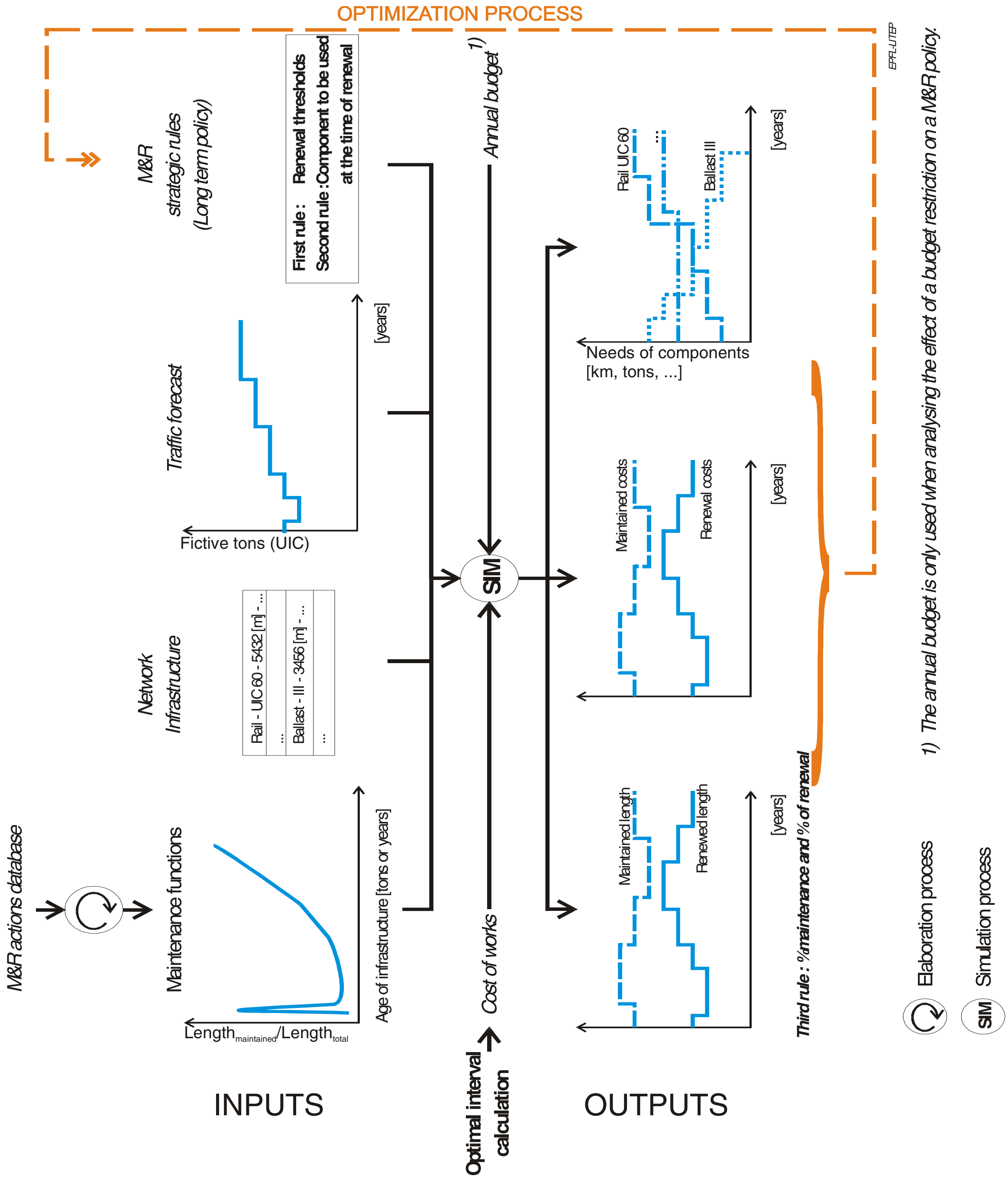


Figure 13: Concept of the M&R simulation model

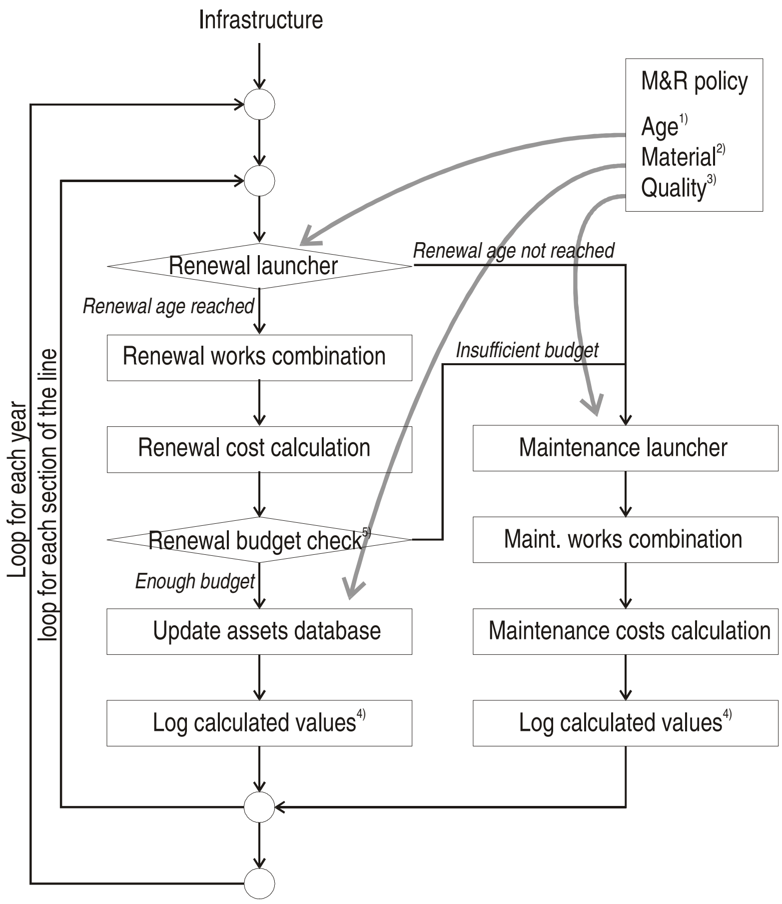
The process simulates the maintenance and renewal actions engendered by the wearing of the infrastructure due to traffic. These actions correspond to a maintenance and renewal policy that is defined according to the know-how of the infrastructure manager.

In a second phase, maintenance and renewal actions are again simulated but with adapted maintenance and renewal policies. This step-by-step adaptation constitutes the optimisation process of the policy elaboration. The best maintenance and renewal policy minimises the costs over the long-term planning period but ensures the required level of quality of the infrastructure.

Below are described the key steps of this simulation process:

1. Application of the first M&R policy rule : the limit age threshold. This allows to steer the average age of the infrastructure, in other words, the substance of the infrastructure. The age, here expressed in cumulated gross train tonnage (or UIC cumulated fictive load) of components are compared with limits set by the policy. If a component has reached the threshold, its renewal is launched.
2. Then, a work combination takes place (time coherency). The process checks if other components have reached or nearly reached their respective thresholds. This is done through the use of a margin, which is added to the current accumulated load, and the comparison of this sum to the respective thresholds. This allows the time coherence of renewal actions, avoiding for instance, that a ballast renewal is launched one year only after a rail renewal. Once the combination done, the process chooses which kind of action should be undertaken (integral renewal, rail renewal,…).
3. The process repeats the two above-mentioned steps until the end of an engineering section is reached. Then, the model sums the lengths of launched renewal and generates worksites (spatial coherency). If the total length of sections that must be renewed is bigger than a certain threshold, it is divided into more worksites. This step is crucial as the cost of worksites strongly depends on its length.
4. The renewal cost calculation is undertaken on the basis of these generated worksites.
5. If there is a budget restriction and the budget isn't sufficient, renewal actions on the engineering section are cancelled.
6. If there is enough budget or there is no budget restriction, the "renewal is achieved", in other words, the assets' database is updated, according the second M&R rule, the type of component to use at the time of renewal.
7. If no renewal has been launched, the process calculates the length of track to be maintained, using the third M&R rule: the quality of the infrastructure, through the use of maintenance functions. The length is determined for each homogeneous section, as the product of the section length and the maintenance probability given by the related maintenance function. These maintenance lengths are summed for each engineering section and aggregated into worksites (with the same principle as 3).
8. Then, the model calculates maintenance costs.
9. Finally, after every engineering section, calculated values are stored in a table. The latter will be used by queries and routines to build the outputs.

The following figure shows the simulation concept.



1) Expressed in cumulated gross train tonnages or UIC fictive tons
2) Type of rails, type of sleepers, type of ballast
3) Quality thresholds (geometry). These thresholds are considered through maintenance functions
4) For each link, for each year : length and cost of M&R actions, average age of infrastructure,...
5) Optional

Figure 14: Maintenance and renewal policy simulation: steps.

Maintenance functions

The maintenance function characterises the influence of the traffic (load) on the maintenance actions that should be undertaken on the infrastructure. The more traffic a section gets, the more maintenance should be done on it. Maintenance functions are expressed as a percentage of length to be maintained in function of the accumulated load or the age of the considered component :

$$L_M = \sum_{comp\_type} \alpha_{comp\_type}(age\_cat) \cdot L_{comp\_type, age\_cat}$$

with L_M : length to maintain, $\alpha(age\_cat)$ maintenance function for one type of component of a certain age category and L the total lengh of track composed by a certain type of component of a certain age category.

These functions allow the calculation of a trade-off between renewal and maintenance expenditures. Logically, the less a network is renewed, the more it should be maintained, in order to keep a constant quality. So, one could expect that decreased renewal costs implies increased maintenance costs as the average networks category of age depends on the renewal policy. Somewhere in between there must be an optimal ratio.

But above all, maintenance functions reflect the quality policy applied by the infrastructure manager. If quality standards are high (for instance geometric faults tolerance are small), it is foreseeable that, for a given infrastructure, more maintenance should be done. Therefore, maintenance functions contain the information of the quality of the infrastructure.

These maintenance functions should be extracted from the history of maintenance interventions of the infrastructure. Thus, they reflect the M&R policy that has been used during the past on the considered network.

$$\alpha_{comp\_type} = \frac{\sum_{network} Lm_{comp\_type,age\_cat}}{\sum_{network} L_{comp\_type,age\_cat}}$$

with *Lm* : maintained length of track, composed by a certain type of component of a certain age category. This analysis should be done on a large sample (several years) and aggregated.

Network Infrastructure

The network is divided into homogeneous sections (for instance: homogeneous rail + sleepers + ballast triplet). The same division is kept for the whole simulation process.

The age of the infrastructure is represented by UIC fictive load or gross train tonnage. The task 5.3 real case illustration uses gross train tonnages.

The **load of traffic** is represented by the annual UIC fictive load of the traffic running on the considered section. The UIC fictive load takes into account the real load of trains, the aggressiveness of the rolling stock over the track, the speed of the traffic, etc.

A basic tool has been developed to demonstrate the concept proposed. The tool is based on Access® and has been developed for the three following components:

- Rails
- Sleepers
- Ballast.

The tool is divided in three parts: the user interface, tables containing simulation parameters and the infrastructure and simulation databases. User interfaces and parameters tables control the simulation (macro Visual Basic®) that subsequently uses the infrastructure database and fills the simulation database. The simulation goes through every year on every homogeneous section.

The paper proposes a modelling approach based on components life time and on maintenance functions to evaluate M&R needs in the long term. Chapter 3.14, "Second stage: simulation of the long term M&R policy", page 105, describes the approach. Moreover, the reader might also read the whole chapter 3, where theoretical railways infrastructure M&R aspects are tackled.

D – CAPACITY INVESTMENTS SCENARIOS TAKING INTO ACCOUNT M&R

As stated in theoretical chapters above, an efficient infrastructure management should be relying on strategies including capacity demand aspects as well as M&R needs. IMPROVERAIL introduces an approach using capacity evaluation/allocation and M&R policy elaboration models developed during the first part of the project. IMPROVERAIL proposes a real case illustration based on the North-South corridor of the Swiss Network.

The real case illustration is based on three scenarios where the demand in capacity and the structure of the network vary. The first parameter reflects the state of the market while the second represents the effects of capacity investments made on the considered network.

Firstly, each scenario undergoes a three steps capacity analysis (capacity evaluation models):

1. An ideal traffic assignment is done (without capacity constraints) and is used as a routing costs reference for the assignment with capacity constraints. Thus, any routing scenario can be compared with the ideal situation.
2. The traffic is then assigned, considering capacity constraints, giving then real routing costs.
3. The last step is repeated for varying track possession interval on each link. This allows the elaboration a capacity cost curve that is function of the duration of the track possession.

The second step consists in following stages (M&R policy models) :

1. The long term infrastructure M&R policy (consisting in decision rules for tactic planners) is simulated, using as input the traffic assignment and the costs of service degradation, provided by the capacity analysis model. The simulation provides then the costs of M&R for the considered infrastructure, over the strategic planning period.
2. The last stage is repeated with three M&R policies, allowing then the choice of the most efficient one, that is to say the one characterized by the lowest cost, for a given infrastructure quality standard.

M&R policy assessment is undertaken only for the Gotthard corridor (~200 km) as the collection of data for the whole network would have taken too much time.

Available data on the load of infrastructure is expressed in gross train tonnages. The transformation into UIC fictive tons would have been too hazardous. Therefore, the real case illustration uses gross train tonnages as "age" unit.

The methodology is illustrated by the figure below. The real case illustration gives interesting results showing the value of the approach. These results are available in the report D6.

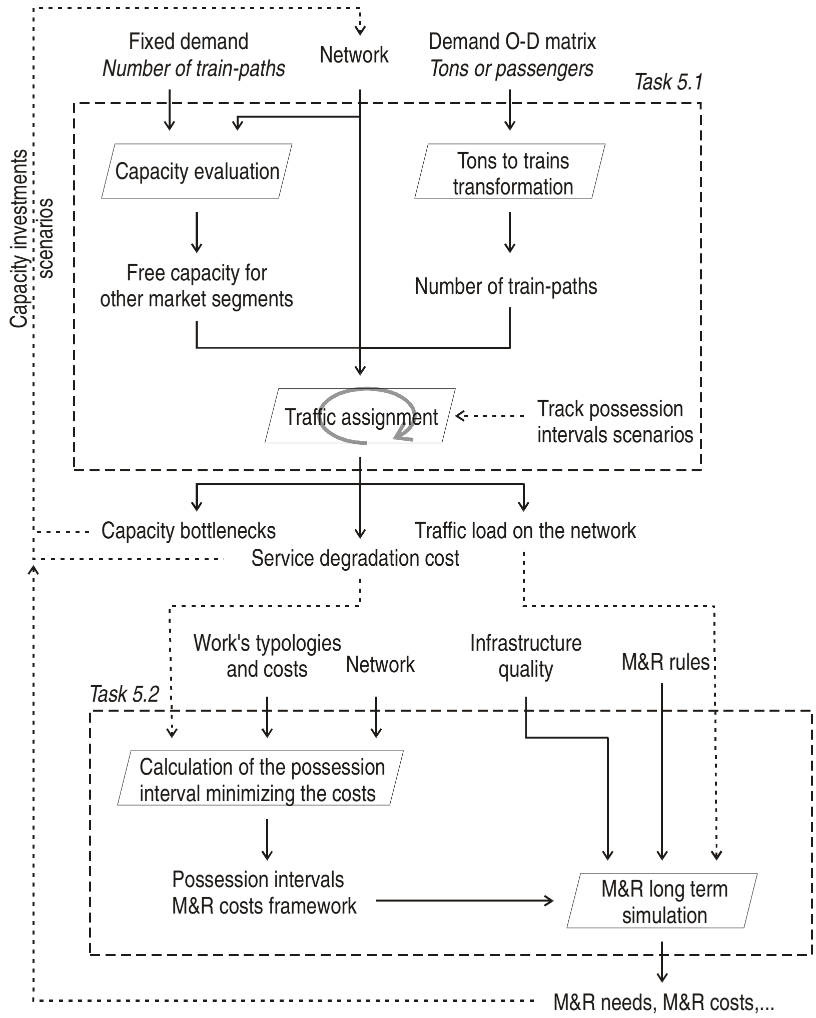


Figure 15 : Capacity investments scenarios: methodology for real case illustrations

The proposed IMPROVERAIL model deals with this fact trough the calculation of an optimal possession interval, minimising the costs of capacity (rerouting of trains, delays, service cancellation) and the cost of works. On heavy-loaded lines, the optimal interval will be rather small and the cost of works rather high.

Therefore, the model takes into account the value of capacity when simulating the M&R policy on the network. On saturated links, the optimal policy should foresee more renewal (and thus less maintenance) in order to decrease the number of interventions on the line.

A detailed optimal interval calculation is rather complex as several factors influence the costs. These factors are related to the type of intervention, to the mechanisation rate, to local conditions. Furthermore, the quantification of capacity costs is hard to undertake thoroughly. Some of these aspects don't fit with the long-term planning activities, characterised by a high degree of uncertainty. Therefore, the model concluded for the use of a simplified approach for capacity costing.

For Further details, please see Chapter 2.9, "Possession interval costing", page 50, presenting a methodology providing the cost of a possession interval. Beside this, optimal possession interval calculation and M&R policy simulation are described in chapter 3.13, "Proposed approach for modelling", page 91. Finally, a real case illustration shows an example of M&R policies evaluation and is available in chapter 4, "TASK 5.3: LONG TERM DEPENDANCE BETWEEN M&R AND CAPACITY", page 111.

E – TACTICAL M&R DECISION SUPPORT TOOLS

A review of existing methods and tools have been undertaken, notably trough a questionnaire filled in by various infrastructure managers in Europe. Synthesis of answers is available in report D6.

Medium-term budget determination and quality prediction

The main tool in this respect is the decision support system Ecotrack, which is briefly discussed in this section. One should bear in mind that Ecotrack only covers rail, not switches, catenary system or other parts. An extension into these directions should therefore be useful.

At the time of the launching of IMPROVERAIL (2001), Ecotrack was the only DSS dealing with track deterioration models. Nowadays, there are at least one other tool, called IRIS, that should cover similar field as Ecotrack

But Ecotrack is one of the major decision support systems for planning track maintenance and renewal in Europe. It was developed in project D187 of the European Rail Research Institute (ERRI-in Utrecht, The Netherlands) and finalized in March 1998. It provides solution to the problem of maintaining track at the required quality level for minimum cost. Ecotrack is described in [Esveld (2001)] and [Jovanovic *et al.* (2000a, 2000b)]

The general idea of developing Ecotrack was to solve the most complex track management task, namely taking decisions about the maintenance and renewal work plan.

Structure of ECOTRACK

Ecotrack provides an environment for organizing and storing track data and decision tools for producing maintenance and renewal plans using this data. It is structured as a five level system, each level representing a planning activity, see Figure 3. The levels have the following functions:

Level 1 – *Initial diagnosis* – it determines M&R work needs per track component. For each track segment, the system, based on the decision rules, undertakes a fully automatic diagnostic procedure and sets out the basic requirements for the additional data required for the more detailed diagnosis of track segments needing M&R works

Level 2 – *Detailed diagnosis*- it is based on the additional data that the user should have provided and additional decision rules. The plan produced at this level is interactive, i.e. the user can examine and modify the decisions proposed by the system. The outcome is a Preliminary M&R Work Plan.

Level 3 – *Coherence of the elementary M&R work* – The works necessary according to the previous level are subjected to a fully automatic coherence analysis based on decision rules. The works of the same type are combined together if they were planned close enough, both in time and in location. Renewal works of different types planned on the same track section and close in time are grouped together as well. For instance sleeper and fastening renewal and ballast cleaning/renewal, or sleeper and fastening renewal and rail renewal, or rail renewal and ballast cleaning/renewal. The outcome is a final M&R Work Plan proposition.

Level 4 – *Optimization of resource allocation* – it enables the user to carry out optimization when the available resources are limited. This level is based on man-machine interaction. The cost plan is estimated and the selected track M&R work is optimized in long-term planning. Costs of continuous and spot maintenance and renewal works are included as well. The user chooses the best alternative in accordance with the railway's M&R practice.

Level 5 – *Overall network management* – it provides a set of tools required by the planner to achieve the optimal management of M&R works on the whole network. This level includes database tools, like displaying various thematic maps and statistics, e.g. the distribution and history of M&R works performed in the past, etc. There are some 36 parameters that can be statistically analyzed and presented to the user in various forms.

Project prioritisation

The allocation of projects to time periods can be modelled as an integer programming problem, and solved using state-of-the-art solvers, like CPLEX 7.0 In the model given below, we assume, for ease of clarity, that all time buckets are equal. It is rather straightforward to adapt the model for unequal time buckets. Note that the model is a variant of the multi-resource multi-project model [(ref Pinedo)]:

(PP) Min $\sum_{r\in R} \alpha_r z_r$

s.t. $\sum_{t\in T} x_{pt} = D_p \qquad \forall p\in P,$ (1)

$x_{pt} = 0 \qquad \forall p\in P, t\in T, (ES_p > t)\ or\ (LF_p < t),$ (2)

$x_{pt} + \sum_{t+D_p \le t_1 \le LE_p} x_{pt_1} \le 1$

$\forall p\in P, t\in T, (ES_p > t)\ or\ (LF_p < t),$ (3)

$\sum_{t_1 \le t} x_{p_2 t_1} \le D_p (1 - x_{p_1 t}) \qquad \forall p_1 \in P, p_2 \in P, (S_{p_1 p_2} = 1),$ (4)

$\sum_{p\in P} x_{pt} \cdot V_{ptr} \le z_r \qquad \forall t\in T, r\in R$ (5)

$\sum_{p\in P} x_{pt} \cdot V_{ptr} \le A_{tr} \qquad \forall t\in T, r\in R$ (6)

$x_{pt} \in \{0,1\} \qquad \forall p\in P, t\in T,$ (7)

where the decision variables of Model (PP) are:

x_{pt} binary variable that denotes whether project *p* is assigned to period *t* ($x_{pt} = 1$), $p\in P$, $t\in T$, or not ($x_{pt} = 0$),

z_r maximum load w.r.t. resource *r*.

The input parameters of Model (PP) are:

P the set of all renewal projects,
T periods (e.g. months),
R resources,
α_r objective coefficients w.r.t. maximal needed for each resource *r*, $r\in R$,
D_p duration of project *p*, $p\in P$,

ES_p	earliest starting period for project *p*, $p \in P$,
LE_p	latest end period for project *p*, $p \in P$,
$S_{p_1 p_2}$	binary parameter that denotes the precedence relations, i.e. whether project p_2 is a successor of project p_1 ($S_{p_1 p_2} = 1$), or not ($S_{p_1 p_2} = 0$), $p_1, p_2 \in P$,
V_{ptr}	amount of resource *r* needed by project *p* when scheduled in period *t*, $p \in P$, $t \in T$, $r \in R$,
A_{tr}	amount of resource *r* available in period *t*, $t \in T$, $r \in R$.

Constraint (1) ensures that all projects are assigned to the right number of periods. Constraint (2) ensures that the periods before the earliest start period and after the latest end period are forbidden.

Constraint (3) ensures that projects are carried out in subsequent periods. Constraint (4) ensures the precedence relations. Constraint (5) determines the maximum resource consumption over all periods, which is used in the objective. Constraint (7) ensures that the decision variables for the assignment are binary. The objective is to minimize the maximum (of a linear combination) of the resource consumption.

Finally we note, that if there are conflicts, i.e. problem (PP) is unfeasible, then the user can change e.g. the earliest start period or the latest end period to get a feasible solution.

For further details, see Chapter 5.3.5, "Project prioritisation", page 170, presenting methods used on various European countries. A decision support system is provided on page 177 by chapter 5.4.2.

F – PRIORITISE AND PLANNING M&R ACTIVITIES

When M&R projects have been identified and defined upon a diagnosis phase, a rough indication for when the projects should be carried out has to be made. As a step of the 'prioritisation' phase, a rough maintenance and renewal plan has to be developed. This means that the projects should be allocated in time, in such a way that all constraints with respect to resources and priorities are satisfied. It should be noticed that this step does not determine exactly which days or nights the renewal projects will be carried out. This step neither determines which projects will be carried out at the same time. All these exact dates are determined in the next step: the track possession step. Reasons for this are that firstly often the project prioritisation is carried out per region. For the regions it is impossible to take nuisance into account, since that heavily interacts with the plans of the other regions, and thus should be taken into account nationally. Therefore the nuisance to the train operators is not taken into account in this phase. Another reason is that it is not logical to be very precise in timing the projects for several years ahead.

The time bucket may vary over the years. Example given, the time bucket for the next year (N+1) is in weeks, for N+2 in months, for N+2/3 in quarters, for N+4/5 in half years. Below is provided a model formulation of this problem. To our knowledge no such model has been implemented in any IM to date:

Given are:

- A list of all projects with the following characteristics:
    - Earliest start period
    - Latest end period
    - Need for resources, e.g.:
        - man-hours w.r.t. the contractors
        - man-hours w.r.t. railinframanagement
        - scarce machines
        - available budget
    - Project duration
    - Precedence relations
- A list of all available resources (per period).
- A planning horizon of several (say 5) years, divided in time buckets (which may vary over the years).

The aim could be to find a rough maintenance and renewal plan such that all constraints are satisfied and e.g. the workload or the budget load is as balanced as possible.

G – SCHEDULE WORKS AND ALLOCATE M&R POSSESSIONS

Medium or short term work scheduling represents the most concrete link between the network operational management and the infrastructure M&R management. This stage often reveals long term or medium term planning deficiencies, when there is a lack of coordination between the capacity development of the network and the evolution of its infrastructure quality and substance.

In most countries routine maintenance is carried out during train service. In the existing train timetable possible possession allocations are sought for routine maintenance such that it will not affect the regular train service. In e.g. The Netherlands it is however almost impossible to carry out all routine maintenance during train service, due to the fact that there is too much traffic on the rail network and the timetable uses a repetitive basic hour pattern, in which no time for maintenance possession is incorporated. Moreover, due to severe accidents in the past, it was decided that when track workers are carrying out maintenance that particular track should be taken out of service to ensure their safety. Since during daytime the network is overloaded, routine maintenance is carried out mostly during the night in the Netherlands.

Fixed maintenance roster for routine maintenance

Taking Netherlands as an example we have seen that a fixed maintenance roster for routine maintenance is used. The reason for this is perhaps that in other countries it is possible to find possession allocations in the existing train timetable even at daytime. This way of working and the methods developed are perhaps also useful for those countries that have a high traffic density on the railroads (e.g. parts of UK and Switzerland). PRORAIL has divided into so-called working zones. Each working zone should be maintained every four weeks. Therefore, a working zone is taken out of service every four weeks. For most of working zones maintenance is carried out during the night. Contractors get a 5-hour track possession for each working zone. Based on the working zones, a maintenance schedule has been made. This schedule tells exactly which working zones will be out of service during a specific night. This schedule is made such that the nuisance for the train operators is minimal and the workload for the contractors is levelled over the nights.

The advantages of such a fixed roster and fixed working zones are:

- It gives clarity to the train operators. Every four weeks the possession allocations are the same. This also avoids mistakes made by the train driver, and thereby contributes to increase safety levels.
- It gives clarity to the track worker, since every four weeks they work in the same working zones. This also contributes to safety.
- A fixed schedule (for one or more years) saves much planning time. Also the necessary adaptations to the regular timetable of the trains can be copied for each four-week period!
- Fixed working zones save a lot of time in developing tailor-made safety instructions. Now, standard safety instructions can be developed for each working zone only once.
- No need to know all specific maintenance activities that will be carried out and when.

The disadvantages of such a fixed roster are:

- Much maintenance during night is clearly a disadvantage for track workers, will lead to higher maintenance costs, besides raising the possibility of conflict law (environmental, labour legislation).
- Sometimes and for some working zones less or more time is needed than the fixed time for each working zone in each period.

In all other countries the maintenance activities are planned in the free times or the times of less impact to the operations.

Clustering

In many countries, routine maintenance is clustered as much as possible. This is done either manually or using the computer. In UK and the Netherlands, this clustering is done by the contractors, since maintenance is fully contracted out. Several countries (NL, CH) also cluster the renewal (and new-to-build) projects as much as possible. In the Netherlands the timeslots assigned for routine maintenance are also used for renewal projects, when possible. This reduces the need for extra track possession. Of course in all countries nuisance to the train operators is (implicitly or explicitly) an important criterion. In the Netherlands also the workload for the contractors is taken into account.

Decision level

In the Netherlands this stage is carried out at a national level. This is necessary since here the track possession allocation may have national effects. In Switzerland, e.g., this stage is carried out by regional units, except for the co-ordination, which is done at the national level. This is possible since the possession allocation is done such that the running times do not exceed timetable margins (almost no nuisance to train operators). Other countries seem to use a similar structure. Such a structure is possible since the maintenance activities are planned in the free times or the times of less impact to the operations. It is therefore possible to do most of the allocation work at a regional level. For developing the fixed schedule for routine maintenance, both a method for dividing the rail infrastructure into working zones and for developing the schedule itself should be developed. In many countries timetabling software is used (e.g. Viriato, Opentrack) to find free times or times with less impact to the operations. In [Higgins (1997)] and [Ferreira (1997)] an optimisation method is described and applied for the Australian situation, to find possible allocations in the existing train timetable.

Short term maintenance scheduling

In UK and NL the scheduling for routine maintenance is carried out ad-hoc. This method combines finding possible track possessions and scheduling the routine maintenance activities. In Switzerland a computer-based scheduling tool is used for detailed planning to optimise all kind of resources (staff, machines, etc.). Concerning planned maintenance and renewal projects in several countries more or less standard project planning software is used to support the scheduling of all activities per project.

Problems Observed

A complicating factor in e.g. the UK is that several operators are using the track, with different possession priorities and which may veto possession. This has led to too little time for maintenance in the UK for Railtrack. In the Netherlands, on the contrary, there are also two major transporters parties involved (passengers and cargo) with conflicting objectives, but in good co-operation and using optimisation tools and methods they were able to reach an agreement. Clustering renewal and new-to-build projects is done manually, supported by a database. There is a need for a computer model to carry out dynamic possession planning for renewal projects.

For further details, see Chapter 5.3.6, "Possession allocation and timetabling of track possession", page 171, and 5.3.7 "Short term maintenance scheduling", page 174, relate current methods applied by various infrastructure managers in Europe. Finally, a model applied in Netherlands is detailed from page 184 on, by chapters 5.4.4, "Possession planning" and 5.4.5, "Routine maintenance scheduling".

H – IMPLICACTIONS OF OUTSOURCING TRACK WORKS IN M&R STRATEGIES

In some countries (UK, NL) routine maintenance is fully contracted out. In the Netherlands for example this maintenance is contracted out to contractors by so-called “output process contracts”. In these co-maker ship contracts a precise description is given of what is wanted with respect to quality. Contractors are responsible to achieve this quality. The Dutch rail infrastructure manager does not tell the contractors how to carry out the maintenance, but evaluates the quality by several modern measuring instruments, and by monitoring and analysing disturbances. This means that in these countries the contractors are responsible for the diagnosis of routine maintenance.

The **advantages o**f fully contracting out routine maintenance are:

- It makes the job of the contractors more challenging and compels them to think in quality, instead of just carrying out the pre-described maintenance activities. This stimulates the creativity of the contractors to come with alternative and better maintenance possibilities at lower costs.
- It avoids carrying out maintenance that is perhaps mentioned in the contract but does not contribute to the quality.
- The rail infrastructure manager can focus on his task: what are the quality levels we need such that safety if guaranteed, disturbances are minimised and the maintenance costs are not too high?

The **disadvantages** are:

- The infrastructure manager may loose control over maintenance. It is easier to check that certain maintenance works have been carried out, than to check whether certain quality levels are achieved. In UK this disadvantage has led to big problems. In the Netherlands modern measure instruments are used among others to check the quality so as to overcome this disadvantage.
- Less (reliable) information on the status of the objects via the contractors is obtained. There is more need to use an independent third party to determine the quality and the status of the objects.
- The rail infrastructure manager may loose a feeling for the costs. Since routine maintenance is contracted out, it is unclear for the rail infrastructure manager what exactly the costs for the contractors are, to realize the contracted quality levels. This makes the negotiations more difficult.

4.6 Conclusions and recommendations

4.6.1 Strategic network management : results of the project

This paragraph provides some overall comments of the real case illustration.

First of all, the approach allows having a clearer idea on various strategic aspects of network management. The method provides precious information on the long term impact of a traffic growth on global infrastructure costs. It underlines variations of track possessions costs, maintenance and renewal costs and, finally, basic saturation costs (without any M&R track possessions).

These costs play a key role at the time of capacity investment decision making. Once capacity investment scenarios elaborated, one can simulate the traffic routing on "updated" networks and estimate M&R and saturation costs. This may be the base of a cost-benefit analysis.

Finally, the approach provides a mean to estimate long term effects of renewal budget restriction on the substance of the infrastructure as well as on maintenance costs. This might be interesting to show to national decision makers at the time of state budget allocation.

However, the proposed approach, as presented in this document, is subject to various limitations:

Possession strategies:

The approach only deals with daily traffic interruptions shorter than 12 hours. Thus, any engineering works requiring more than 12 hours need to be split over several days. Many infrastructure managers use (or at least start to consider to) extended track possession intervals, lasting several days or several weeks. Therefore, the service degradation calculation model (task 5.1) as well as the optimal possession calculation model should be extended. However, the methodology should still be applicable.

Maintenance functions:

Maintenance functions – functions linking the age of the infrastructure (expressed in cumulated gross tons) to the needs in maintenance works – represent the core of the M&R policy simulation tool. They are therefore very important.

The paper bases the elaboration of those maintenance functions on statistical analyses. That implies the availability of coherent, rather elaborate complete registers containing an accurate log of works undertaken in the past as well as an assets database. The latter should also keep track of the infrastructure in the past.

The real case illustration is based on maintenance functions elaborated on a basis of an assets database only providing the state of the infrastructure in 2001. Thus, maintenance works carried on between 1980 and 2000 couldn't be compared with the age of the corresponding infrastructure. Therefore, maintenance functions have been elaborated only on year 2001 data. This implied that maintenance functions had to be generalized. That is to say, there is one maintenance function for all type of a component as samples were too small to get credible functions.

Infrastructure managers should be aware of the importance of keeping track of the evolution of their assets as well as of past M&R actions. This is the only way to efficiently set up and control a M&R policy.

Calibration of models

Once a model elaborated, it should be carefully calibrated in order to fit to the context where it is used. As the calibration of a rather complex approach takes a considerable time, the real case illustration couldn't include a proper model calibration. However, some calibration simulations have been executed and allowed a first tuning of the model.

4.6.2 Strategic network management: some recommendations

When devising to undertake demand forecasts to anticipate the long term evolution of the network, the top management will have to choose a development strategy for the infrastructure, questioning whether the network dimension will be able to cope with the most likely scenarios in a horizon of a decade or two. This is crucial in result of the time gap between decision making and actual implementation of the solutions, which in turn will have a global effect on M&R strategies. In that sense, the following recommendations come in support of those involved in the long term planning of the infrastructure development, by providing guidance throughout the planning path.

- When planning Market orientated Investments in long term it is necessary to consider designing and providing adequate services, accounting for market segmentation, each segment (of final clients) having different weights for the various service attributes.
- It is necessary to develop infrastructure so that various market segments can be served efficiently, even if weight of those segments may vary over time. All this should be accomplished while avoiding excessive investment.
- Flexibility rather than “perfect fit” to each client type should be envisaged.
- Systematic review of market evolution, in dimension and requirement of the various segments. In turn the correct judgement on investments relies on adequate charging systems that are also discussed within IMPROVERAIL.
- Close monitoring of operation, identifying bottlenecks and other sources (physical & organizational) of loss of efficiency.
- Good linkage between processes of planning and operations (forward and backward implications) are key in this context, which aspects cannot be detached from the implementation of effective information systems and comprehensive asset registers for network management

4.6.3 Short/Medium Term Planning: results of the project and some recommendations

To implement efficient decision support tools to find the best tactic balancing M&R and capacity needs requires dealing with the permanent conflict between the maintenance and the marketing departments. This means that the realm of short and medium term planning is perceived to be much closer to day-to-day actions and therefore often deserve more focus from responsibles. To that end, we provide hereunder a number of conclusions on key issues related to the topic. These come in support of those involved in the short / medium term planning of the infrastructure M&R, by providing guidance throughout the planning path. For further details on technical aspects we provide a reading guide for related matters in Deliverable 6.

Overall, and from the research undertaken, it may be concluded that there is quite some variety between the companies, both in sophistication and in the concepts they apply. The answers in this report should be considered in the perspective that the authors had much access to particular infrastructure companies, like the Dutch RIB and the Swiss one.

Some key conclusions are:

- There is no overall embracing database system containing information on the state of all the elements of the railway system. Instead information is scattered over many systems. The main information system seems to be SAP, but that has mainly an accounting role and is not linked to quality information systems. Several attempts are being made and it is an essential, yet difficult, task if maintenance planning is to be done in a thorough way.
- There is no possibility to link the present state of the infrastructure with deterioration models, except for Ecotrack and IRIS cases. A proper maintenance planning systems requires such a link.

- There are no good overall quality indicators, giving insight into the average state of the infrastructure and which can be used in budget determination. To day, budgets seem to be based on ad-hoc processes rather than on a thorough analysis on what is needed in the long-run.
- The possession planning seems to be in many countries a manual based process which can be improved using concepts developed with RIB in the Netherlands.

5 PLANNING INFRASTRUCTURE INVESTMENTS SUPPORTED BY LIFECYCLE COSTING DECISION TOOLS

5.1 Introduction

A review of studies undertaken both by railway associations and in the scope of EU research projects, have shown that Railways use of LCC techniques is not something new, having been initiated more than 20 years ago. However both the recent vertical separation of the railway business and the need to optimise cost management, has led to increased interest in LCC methodologies, as Railway Undertakers and Infrastructure managers are faced with the ever-increasing pressure to reduce costs.

The initial uses of LCC techniques in the railways were mainly to check whether availability and maintenance costs met the requirements of the contract. Its adoption allowed monitoring of maintenance costs and the modification of maintenance schedules and a methodology to minimise maintenance costs

Although these types of studies of costs have long been of central interest in the transportation industry, it has only recently become a major issue in railway mostly driven by sectorial deregulation and wide social economy concerns. In such context, information about transportation costs has played a central role e.g. in the attempt to develop fair charging systems, as researchers sought to find out whether transportation markets were structurally more like natural monopolies or like markets that could be self sustainable. In order to support the optimisation of the business decisions and options regarding services offered and the fair prices to be charged for those services, more accurate information on costs was required.

The importance of LCC lies on the fact that investment decisions are hard to reverse once implemented as overhead costs are fairly high in railway projects. Therefore the long-lasting impact on transport operations must be accounted prior to the project's implementation phase, in the attempt to optimise the trade-off between infrastructure quality, safety and costs, assessing the life cycle costs of infrastructure. In support of this rationale, Decision Support tools should be used for estimating the optimum scenario for life cycle cost in varying operational as well as exogenous conditions, such as:

- Construction and maintenance conditions, e.g. market prices for labour, materials and machines, safety and noise regulations, the performance quality, and the duration of maintenance works;
- The financial environment, e.g. budget limits, budget allocation between investments and maintenance, the performance regime, and interest rates;
- The physical environment, e.g. quality of the substructure, alignment, climate, and site accessibility;
- The transportation concept, e.g. layout of the tracks, vehicle-infrastructure interaction (distribution of train speeds and axle-loads, quality of the rolling stock, traffic intensities, and braking and acceleration capabilities). (Zoeteman, 2000)

The above-mentioned conditions have an impact on the quality decline of the track structure, the traffic disruption caused, the productivity rates for new construction and maintenance, and of course the financing costs.

The LCC methodology suggested, not only accounts for the traditional costs, related to investment, maintenance and renewal costs, but also for other less commonly considered but most relevant "lifelong" cost elements, such as commercial, accident and environments costs. To this extent it should be made clear those falling within the responsibilities of the infrastructure manager in result of the railway "separation of roles".

5.2 The LCC Concept

Life cycle costing is the process of economic analysis to assess the total cost of acquisition and ownership of a product. Several definitions of Lifecycle Cost (hereinafter designated as "LCC") exist. A short way of explaining this concept is perhaps to say that the life cycle cost of an item is the sum of all funds expended in support of the item from its conception and fabrication through its operation to the end of the useful life. Thus, the LCC of a physical asset begins when its acquisition is first considered, and ends when it is finally taken out of service for disposal or redeployment. As a professional cost prognosis, the method of life cycle costing has been widely accepted in the field of transport during the last years. This type of cost analysis provides important inputs in the decision making process with regard to product design, development and use, evaluating operating and maintenance strategies to optimise long term investment.

5.3 LCC in the Railway Context

As European railways faced declining market shares and increasing financial problems, disappointing and limited effective progress was made towards reforming the European railway sector and bringing the sector into the European single market. Conversely, several other European network industries such as energy and telecommunications have been restructured with some success, towards improving their efficiency and profitability. However, and for some time now, railway started being considered by policy makers as an important part of the overall transportation system, in particular looking at its potential for bringing increased sustainability to the system itself. This is reflected by the adopted Transportation Policy, where railways are considered much promising as an alternative for congested and polluting road traffic, one of the key transport and economy related issues, these days.

To this end, Railway's performance must be improved on key aspects such as availability, reliability, cost-effectiveness, safety and comfort. In support of such goals, Policy makers have chosen to adopt a new framework to railway business, the full separation of railway operations from the infrastructure management being perhaps the most visible of the measures adopted. This 'vertical separation' along with prospects for the future privatisation of at least parts of the system, should allow distinguishing responsibilities more clearly, fostering competition in the rail transport market.

To this extent, the European Commission has proposed a series of railway restructuring measures (known as the "infrastructure packages"), looking at separating train operation from infrastructure management, further helping eliminating unsustainable financial and political obligations on national railways, granting individual railway companies the commercial freedom to run new international rail freight services.

Although the railway industry is following this process of organisational changes, to effectively realise the expected benefits of such reform requires not only the reorganisation and reengineering of the provision of railway service but also, and along with it, improved understanding of cost structures in support of private sector rationale when it comes to day to day management and to analysis of railway investments.

This new context also implies that the expected costs for different levels of performance and availability are made explicit, e.g. for making pluri-annual agreements with the central government. Hence, a supported investment, maintenance and renewal cost balance is necessary for the long-term success of Railway. This is where Life cycle Costing methodology, already practised to a reasonable extent in railway rolling stock production, enters the scene regarding the railway infrastructure, driving its improved economical performance. This means that an effective management of the physical assets that form the basic infrastructure of railway businesses is necessary, making planning and monitoring of assets absolutely necessary throughout their entire life cycle. This is designated as **Life Cycle Cost Analysis** or **Life Cycle Costing (LCC)**. Such approach, which is the subject of this WP6, is deemed necessary for the successful modernisation of the railway business, helping to turn it in to an industry less dependent on subsidies for its financing.

The resources to undertake any new investments, required in response to this new context, are scarce. A competitive business environment, declining resources and an ever-increasing need to obtain value for money, set up the framework for optimising use of available resources. Similarly to the re-engineering of the business processes undertook in the private industry sector (see WP4 of IMPROVERAIL, Deliverable 4), LCC have also became a crucial issue for railways. Also similarly to BPR (Business Process Reengineering), railway companies do recognise that the introduction of LCC is a long-term process that is costly and that requires changes within company structures and cultures to be effective. Therefore, it is reasonable to say that BPR and LCC are complementary core vectors of the undergoing change in railways. All these aspects should be further analysed at the light of new pan-European concerns, going beyond traditional individual Member States' concerns, as construction, maintenance, renewal and upgrading of the infrastructure must now be framed within such context.

All in all, we have seen that the LCC systematic approach is required for managing the network assets in the best possible manner, optimising resource allocation while ensuring pre-defined levels of performance and availability. The major hindrance to its adoption, besides the technical obstacles is perhaps that such approach has few roots in the past of these organisations, whereas maintenance and renewal have long been planned and executed according to historical practices, personal experience and, most of the times with little budget restrictions.

In order to establish a continuous high performance level of the infrastructure for the future in a context of budget optimisation, it is therefore important to systematically consider the long-term effects of today's decisions, by means of consistent life cycle cost assessments.

The key for the development of economically sustainable strategies in railway, besides considerations upon other vectors some of which also analysed within IMPROVERAIL, seem to lie also on adopting suitable and harmonised LCC methods, looking at the optimisation of costs of maintaining the infrastructure in suitable operating conditions, without overlooking crucial aspects such as safety requirements.

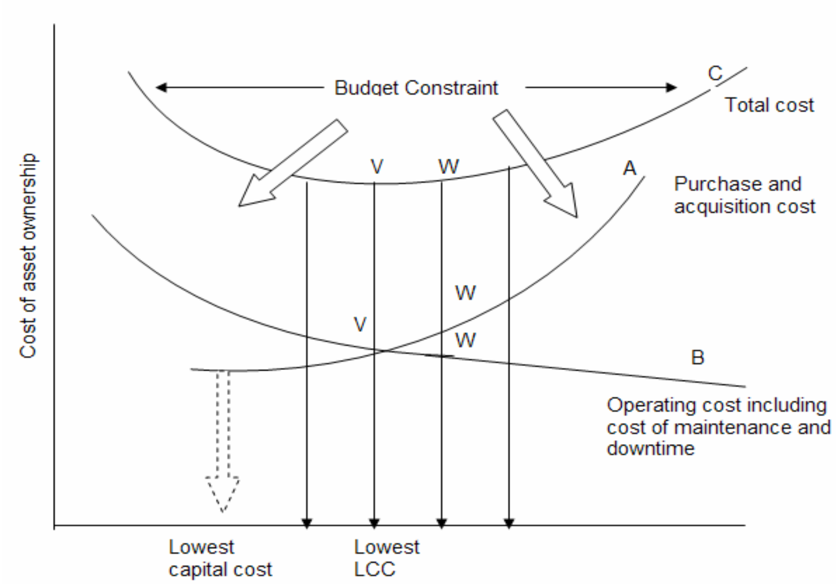
This final report for the Workpackage 6 of the IMPROVERAIL project aimed at contributing to this aim, by providing to the Infrastructure Managers an overview of current panorama on LCC methodologies, highlighting the relevance of such technique applied to railway infrastructure management, further identifying possible obstacles to its implementation, proposing a conceptual methodology for Life Cycle Cost calculation.

5.4 Costs Borne by the Infrastructure Manager

As it happens with most of the infrastructure-based industries, Railways suffer from the fact that a large proportion of costs incurred are related to the initial investments, tending to be considered as sunk costs and therefore are hardly related to the level of activity. In fact, the financial target for a transport system is usually to be able to keep up with operational costs, as infrastructure tends to be considered as a public entitlement and is not usually subject to consideration for charging purposes or even return on investment.

The importance of the previous remark lies on the need to adapt the trade off between High Initial Costs / Lower Running Costs to the expected demand for additional supply. If this aspect is overlooked, it may well result on a misleadingly low lifecycle cost while in fact it the decision to invest may be proved wrong, since e.g. opportunity costs then would become a dead weight. Resources are naturally scarce and should therefore be used in the best way possible. Therefore, considering the trade off between the decision to invest and to perform maintenance or renewal works is one of the underlying principles of a LCC analysis. The possibility of trading – off initial enhanced capital against subsequent maintenance savings is one of the underlying principles of a LCC analysis. This aspect is illustrated in the next figure:

Cost trade-offs in asset ownership



Source: Woodward, 1997

The costs borne by the infrastructure managers namely those related to Investment, Maintenance and Renewal have been addressed in this report. These costs include direct labour, direct materials, direct expenses, indirect labour, indirect materials and establishment costs related to the provision of the infrastructure. It was seen that M&R (Maintenance and Renewal) strategies among infrastructure organisations differ significantly. Also national accounting rules and varying availability of budgets make a consistent interpretation difficult. In essence "superficial comparisons" are of little use, unless a combined view on all long-term expenditures of existing networks is adopted.

Indeed, railways operate under different circumstances, with strong effects on cost of their infrastructure, plus the fact that the criteria used to determine the IM costs in result of the account separation is not totally standardised. This lack of harmonisation prevents the adoption of any straightforward methodology and therefore calls for a “common denominator” in order to develop suitable methodologies fitting the IM’s in general.

However, railways costs more than in any other mode have several specificities hindering, up to some extent, its accurate assessment, when accounting for real cost drivers. This is mainly due to the fact that only some costs are directly and unambiguously attributed to the production of services, whereas most costs are shared in the aggregate supply of service. Furthermore only recently costs associated to the infrastructure alone became relevant as the railway business moved towards separate operation and infrastructure provision. This led to significant changes in the business approach, in which infrastructure cost management has become a major issue, as IM’s try to reduce deficits. This latter aspect turned out to be particularly relevant at the light of the tragic events in the UK, unveiling the crucial need to have reliable methodologies to understand asset conditions and behaviour of the infrastructure as a function of the costs related to maintenance and renewal.

A regular, planned, preventive maintenance policy allows reducing downtime costs. The “run it until it breaks” approach, although reducing maintenance expenditures increases the downtime loss and does not promote high safety standards. At the same time, technical and operational knowledge which was traditionally in the heads of practitioners and meanwhile tends to get lost is not formulated in an adequate way that makes it manageable. In turn the Commercial Assessment of technical and operational issues is often neglected. Few practical decisions are really taken on well-informed commercial grounds. Therefore a comprehensive lifecycle cost balance should be undertaken, contributing to overcome many of these constraints. The cost elements to select are the expenditures that occur during or are related to the life of the asset. These should include all expenditures related to the assets, from acquisition until disposal at the end of life. Further defining the cost structure involves grouping costs so as to identify potential trade-offs, thereby to achieve optimal LCC. The nature of the cost structure defined will depend on the requirements of the LCC study. For that purpose, a cost structure is proposed in this report.

Railway LCC calculations are made on a yearly basis. Depreciation annual cost flow can derive both from initial investment and periodic renewals or long-term enhancements. It was seen that for a given network asset, train control and maintenance represent the core processes that drive the current costs for the infrastructure commercial usage.

Collection of infrastructure real cost data has proved to be a difficult endeavour, thus the research undertaken has focused on comprehensive data collections and statistical elements in support of LCC calculation, with regard to relevant cost items.

5.5 The External Costs components in LCC

Although mostly at the Research levels such as in the EU Projects, LCC procedures have been extended to include externalities such as Accident and Environmental costs. Therefore, it is not strange that all the reviewed LCC models, or attempts of LCC analysis, incorporate costs such as acquisition, investment, maintenance, delay and disposal but not always accident and environmental costs. External LCC analysis is useful in an investment decision framework, as it offers a more complete comparison of different alternatives, in terms of their short and long-term impacts, both internal and external. Once the latter are correctly included in the evaluation of costs and benefits together with “internal costs”, the investor is provided with a clearer view of the options available and can make a better choice. Without the inclusion of external costs in the LCC procedure some “cost interaction scenarios” will be neglected and therefore result in non-optimum investment choice for the infrastructure, which in turn can lead to a non-optimum/non-viable charging mechanism for the use of the infrastructure.

Basically the connection between LCC policies and accident/environmental cost lies on the modification of the costing mechanism of railway infrastructure in order to achieve internalisation of such external costs imposed by means of the charging mechanism.

The following expression for calculating LCC related to environmental side effects should be adapted in the LCC DSS models.

$$\mathbf{LCC_{EA} = IE \times VIP + IA \times VIA + PV[\,E(T) \times VT] + PV[P_t \times V] + PV[RME+RMA]}$$

- IE –Initial Environmental impacts – Impacts in the first period of the Life Cycle. The typical example is landscape effects
- VIP is the valuation of the initial environmental impacts
- IA – Initial Accident impacts – If there are extra accident risks related to the provision of infrastructure these effects should be included
- VIA – Valuation of the initial accident impacts
- PV – present value: The figures in brackets are discounted to the base year
- E – Expectation value of the figures in parenthesis.
- T – Traffic, the c represents different characteristics of the traffic composition, Bold letters indicates that this could be a vector or a matrix
- VT – Valuation of the different impacts of traffic related to both environmental and accident costs. Bold letters indicates that this could be a vector or a matrix
- [Pt x V]–account for time-dependent but not activity-dependent cost factors. Normally, these costs are ignored, or added as average unit costs that are calculated per vkm. This expression can include e.g. pollution from infrastructure that is solely a function of time. The two factors P and V opens up for changing valuation/ preferences over time
- RME – Remaining value of environmental costs
- RMA – Remaining value of accident costs

Hence, any LCC methodology should not only account for the traditional costs, broadly related to investment, maintenance and renewal costs, but also for other less commonly considered but also relevant cost elements, such as commercial, accident and environments costs. Moreover, it should be further distinguish those falling within the responsibilities of the infrastructure manager in result of the business “vertical separation” context, requiring the application of additional criteria for separating cost responsibility.

5.6 Scarcity and Delay Costs

Scarcity Costs

Scarcity represents the inability of an operator to obtain a given path, in terms of departure time, stopping pattern or speed. Therefore, in the presence of a capacity constraint, the value of any train seen as the loss of corresponding charging fee, as a result of lack of capacity, should be added to other costs, such as track damage. To this respect, the High Level Group on Transport Infrastructure Pricing identified scarcity, rather than congestion, as the dominant consequence of existing capacity constraints on the existing rail network (CEC, 1999).

Since rail infrastructure managers control access to the network on a planned basis, rail congestion manifests itself in a different form. Indeed, it is useful to distinguish between two effects of shortages of capacity - congestion and scarcity. Congestion represents the expected delays resulting from the transmission of delays from one train to another. These become worse at high levels of capacity utilisation, since there is a lack of spare capacity to recover from any delays, (Gibson, 2000). Congestion costs are the costs associated with these expected delays.

Both in the case of congestion and scarcity, it may be argued that there is only a genuine external cost imposed when the effect is on the time of another operator. However, the issue arises of whether the cost perceived by the operator fully reflects the cost imposed on the final users. Only in the event of perfect price discrimination is this likely to be true. Congestion and scarcity costs are usually examined together and include the increased management costs and the costs of extra time spent travelling as a result of another train entering the traffic flow, an accident or infrastructure maintenance. The categories of costs should focus on location (inner/outer city, urban, interurban rural), road type and time of travel (peak hour, inter peak, off peak). Cost varies with the length of time spent travelling, traffic mix, flows and speeds, accidents and road maintenance. Obvious examples of cause include vehicles joining peak hour road traffic flows and delayed trains and planes.

Scarcity Cost Estimation Methods

The approach undertaken to estimate such costs is the additional costs imposed on society by the use of the infrastructure by an additional train. For rail the volume of traffic is directly controlled by the allocation of slots, so capacity should never be exceeded. Nevertheless, as traffic approaches capacity, delays become more frequent. For rail, use of the system is controlled through the allocation of slots and the main consequence of full capacity is the inability to run the train when desired. The costs of congestion and scarcity are only external when imposed by one train operator on another. External costs of scarcity – like congestion and accidents - should be valued using willingness to pay approaches and it is essential that the internal element that the user already ‘pays’ be separated from the price-relevant external element. The scarcity value of train paths may in principle be found by auctioning paths off, but in practice there are many difficulties with this approach. The most workable alternative is to permit negotiation of path allocation and prices between service providers and infrastructure managers. The complexities of rail systems are such that no simple formula can be found to estimate scarcity values of slots for a variety of typical circumstances. It is recommended that penalties for non-availability, is the best way to reveal scarcity values of rail slots

For comparison purposes, let us analyse what should happen when the delay caused by an operator has a cascade impact on other operators. In this case, compensation may be paid directly for increased costs and passengers' time, provided that adequate records are kept of amounts and causes of delay. This is a feature of the 'performance regime' embodied in track access agreements in Great Britain. However, this is only likely to measure the delays directly caused by the train in question. Simulation modelling, using a model such as the MERIT model used by Railtrack, which simulates a large number of days operations using probability distributions of the various causes of delay, will only estimate the full effect of running additional trains, including the worsening of delays from other causes by the reduction of the recovery margin in the system.

In the case of railway infrastructure managers, as with other types of transport infrastructure where specific slots are allocated to particular users, the major issue is not so much congestion as the scarcity value of slots; when the infrastructure approaches capacity, other users are unable to obtain the slot they want; when they want it; they have to run their trains at times, and possibly speeds, different to their preferred alternative, or to give up the journey. Infrastructure might approach capacity for various different reasons. In principle the reasons can be categorised under three broad headings.

A - INFRASTRUCTURE/ENGINEERING

- **Superstructure (track) technical attributes**: like block length, design speed, acceleration and deceleration properties as well as maximum acceptable axle load and finally materials quality.
- **Stations technical attribute**: platform length, groundwork length and sidetrack length.
- **Structures (tunnels, bridges) technical attribute**: tunnels and bridges lengths and height
- **Equipments**: (existence of) catenaries, signalling and telecom installations

B - OPERATIONAL/ADMINISTRATIVE

- **Maintenance**: the way maintenance is done: maintenance intervals, time of day, duration, materials used, insufficient maintenance
- **Operation**: operation of telecom installations and signalling systems, lack of operating / administration personnel

C - VEHICLE/TRAFFIC

- **Vehicle technical characteristics**: Length, axle weight, speed and type (freight, passenger, fast slow, interurban, rural etc.) of train.
- **Traffic characteristics**: Mixture of trains

The following considerations are very relevant and should be carefully accounted for when approaching delay/scarcity costs:

- The categories of costs should focus on location (inner/outer city, urban, interurban rural), line type and time of travel (peak hour, inter peak, off peak). Cost varies with the length of time spent travelling, traffic mix, flows and speeds, accidents and maintenance.
- The minimum headway between trains, which depend on speed, signalling and block lengths which greatly affect the capacity of the track.
- Station areas which function as crossing lines for trains, often have speed limits. Some stations are just served by local trains, while regional trains do not stop. This will reduce the total capacity of the section, compared with a section without such stations.

- Slow and fast going trains on the same track reduces the number of trains that is able to operate within the same hour.
- The carrying capacity of a railway link is the maximum number of physical transport units which can use the link, and can be expressed as a function of the number of tracks in a section, average train speeds, geometry, signalling and safety systems, section lengths, length of trains, etc. (Rothengatter et al, 1996).

However, over and above all these factors, the mix of train speeds and the precise order in which trains are run is crucial. For instance, on a predominantly high-speed line an additional slow freight train may remove the paths of several high-speed passenger trains; on a heavy freight route the reverse may be true. Capacity is also maximised by grouping trains of like speeds, so that a 'flight' of fast passenger trains is followed by a 'flight' of slow freights and vice versa. However, this is conflicting with the provision of a good service of well-spaced trains at regular intervals for the public. More complicated still is the interaction of trains on different routes or between different origins and destinations; as with roads, junctions and other bottlenecks (e.g. speed restrictions) are key factors determining capacity.

The result of all these considerations is that it is impossible to come to a ready definition of the capacity of a rail route. More seriously, the impact of an additional train of a particular type on the paths available to other trains will differ enormously according to the precise mix of traffic on the line. At the same time, the value of a slot to other commercial operators or to government bodies providing social services will also differ enormously in time and space. Therefore, it does not seem straightforward to come to a general methodology to estimate scarcity values for rail slots in a variety of typical circumstances. However, there are other ways of seeking to derive scarcity values. One is by competitive bidding for the slots. However, in rail systems capacity can be used in such a wide variety of ways to produce different mixes of trains of different types, origins and destinations that any bidding exercise is likely to be very complex. Moreover the value of a particular slot depends very much on what other slots are obtained, in order to put together a commercially attractive service. We see some scope for bidding processes for alternative packages of slots in a pre-planned timetable, but in general we do not consider bidding processes as a practical way of revealing scarcity values. It does raise fears that the infrastructure manager or the larger train operating companies may exert undue monopoly power over the process (particularly when the two are part of the same organization), and calls for an independent regulator to intervene where that happens. However, in a situation in which there is no ideal solution, it does appear to be the best way forward.

Delay Costs

The delay cost considerations produced hereby are related to the delay costs than contractually may pass to the Infrastructure Manager. A review of the different delay concepts is undertaken and measurement methods are mentioned.

Table 6 - Technical terms of delay

	Definition	Measurement
Indigenous delay	delays coming up in the sub-network	measurement at any part of the network (interesting for the question if the delay will increase or decrease)
Final station delay	delays of break-in trains ending at their final station in the sub-network	measurement of ending trains at their final station
Break-in delay	all delays coming from outside of the sub-network	measurement at the border of the sub-network
Outgoing delay	delay of a train while leaving the sub-network	measurement at the border of the sub-network
Consecutive delay	delay of proximate trains due to the delay of the preceding train	measurement at any part of the network

A train is delayed when it arrives too late at a station where an operational stop is scheduled. The frame of reference is the current valid time schedule. The definition of delay is different from railway to railway. For passenger trains in the Netherlands a delay is detected for trains being more than 3 minutes late at a station, on the network of the DB Netz AG the critical value is 5 minute and for the Swiss it is 3-4 minutes.

Consequently for comparing delays the basis of comparison has to be equal. Important for a time table is its stability, meaning its ability to reduce the amount of consecutive delays originated by indigenous and break-in delays (Pachl 00, page 208). The relation is as following:

(Outgoing + final station delay) ≤ (break-in + indigenous delay)

Delay Cost Estimation Methods

There are many acknowledged gaps up to now on this respect, especially the aspects related to specific energy consumption and commercial costs and customer reaction (passengers, freight forwarders). Both are barely quantified at this time. While the part of the energy costs can be estimated using computer based tools, the knowledge about customer reaction is very low, both for passenger and freight transport. With European wide deregulation of the transport markets including decreasing transport costs of air and road transport the aspect "commercial cost – customer reaction" shall deserve more attention than before.

According to the previous table, the delay can be tagged as:

- effective delay time
- relative delay (delay / total travel time of the train)

With the relative delay the user gets an idea about the influence of the total travel time (or travel distance) on the delay at the final station. The more interesting is the "effective delay time" at each planned stop of the train (passenger station, hub for combined transport, etc)
Many railway companies do this measurement automatically, for the DB AG the used system is called LeiBIT (Leitsystem Betriebliche Informationsverteilung). An interesting aspect is the question when the delay will come up and what are the effects on other trains. Major parameters which have negative effects on recovering delays are:

- size of buffers (time surcharges) in the timetable
- degree of the density of the railway network
- train mix on the used train path
- position in the train hierarchy

The next figure combines M&R and D&S cost calculation

Figure 16 - Combining M&R and D&S Cost calculation

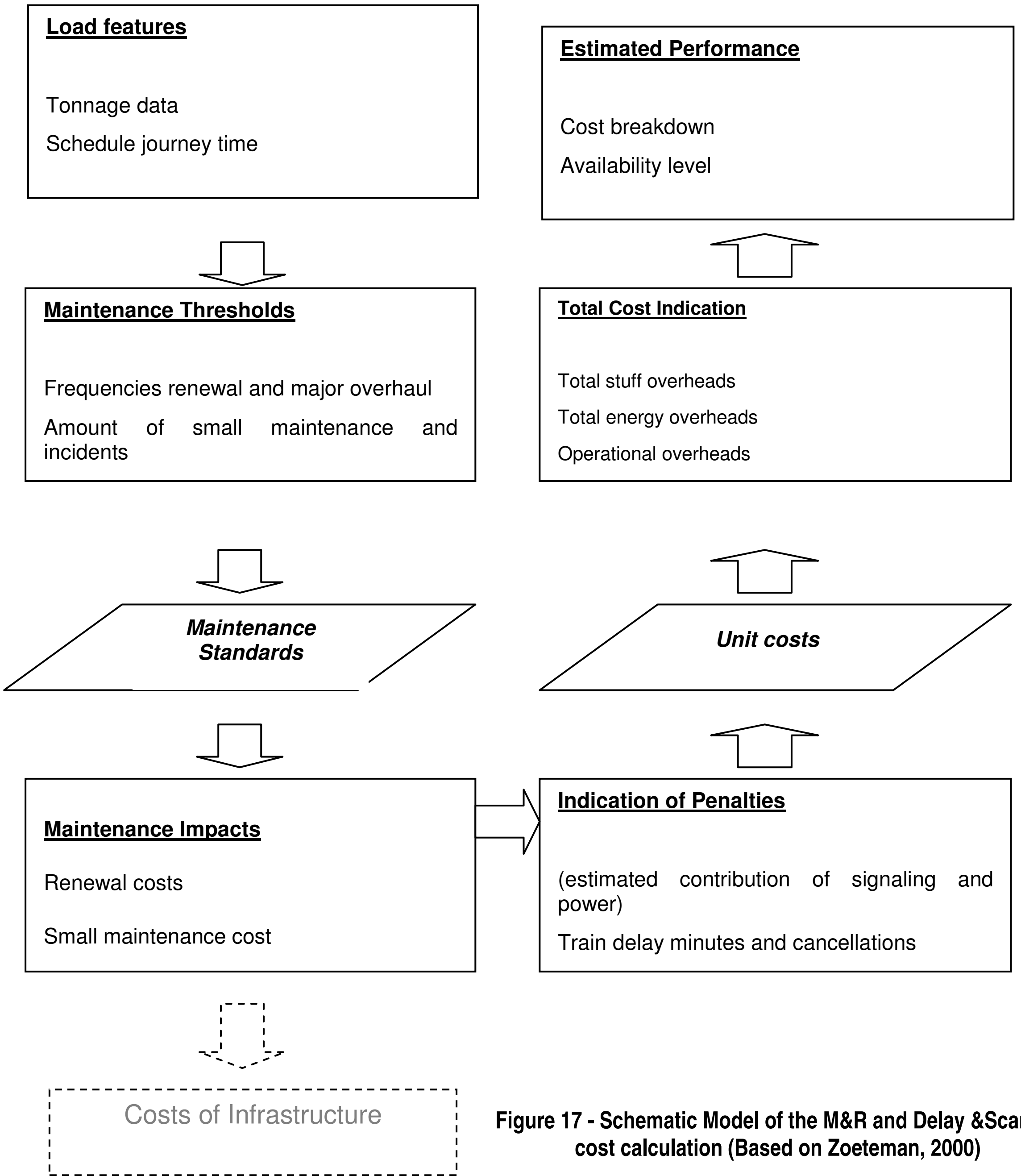


Figure 17 - Schematic Model of the M&R and Delay &Scarcity cost calculation (Based on Zoeteman, 2000)

5.7 Conclusions and Recommendations

A review of previous studies undertaken both by railway associations and in the scope of EU research projects, have shown that Railways use of LCC techniques is not something new, having been initiated more than 20 years ago. However both the recent vertical separation of the railway business and the need to optimise cost management, has led to increased interest in LCC methodologies, as both Railway Undertakers and Infrastructure managers are faced with the ever-increasing pressure to reduce costs. Although these types of studies of costs have long been of central interest in the transportation industry, it has only recently become a major issue in railway mostly driven by sectorial deregulation and wide social economy concerns. In such context, information about transportation costs has played a central role e.g. in the attempt to develop fair charging systems, as researchers sought to find out whether transportation markets were structurally more like natural monopolies or like markets that could be self sustainable. In order to support the optimisation of the business decisions and options regarding services offered and the fair prices to be charged for those services, more accurate information on costs was required.

The initial uses of LCC techniques in the railways were mainly to check whether availability and maintenance costs met the requirements of the contract. Its adoption allowed monitoring of maintenance costs and the modification of maintenance schedules and a methodology to minimise maintenance costs.

For new prestigious projects with well-controlled maintenance confined to few locations, the collection of data, its recording and process is not a major problem providing it is made available. However, the quality of the data on which designs and judgements have to be based on is often a critical issue. Free exchange of data between competing companies is mostly seen as being commercially sensible and therefore it is difficult to obtain elements of data with the required detailing for LCC. The initial uses of LCC in railway have identified some problems that relate largely to the RAMS (Reliability, Availability and Maintainability System) terminology and the financial analysis of the results. The deficiencies in the terminology definitions is being addressed through the development of CEN standards though care must be taken to ensure that there is consistency between the various groups working on the standards.

Currently, LCC should be seen as a development of older cost control processes that aim to give value against known specification parameters rather than a "best at a cost" approach.

5.7.1 Lessons Learnt from Existing LCC Models

A review of previous studies undertaken both by railway associations and in the scope of EU research projects, have shown that Railways use of LCC techniques is not something new, having been initiated more than 20 years ago. However both the recent vertical separation of the railway business and the need to optimise cost management, has led to increased interest in LCC methodologies, as both Railway Undertakers and Infrastructure managers are faced with the ever-increasing pressure to reduce costs. Although these types of studies of costs have long been of central interest in the transportation industry, it has only recently become a major issue in railway mostly driven by sectorial deregulation and wide social economy concerns. In such context, information about transportation costs has played a central role e.g. in the attempt to develop fair charging systems, as researchers sought to find out whether transportation markets were structurally more like natural monopolies or like markets that could be self sustainable. In order to support the optimisation of the business decisions and options regarding services offered and the fair prices to be charged for those services, more accurate information on costs was required.

The initial uses of LCC techniques in the railways were mainly to check whether availability and maintenance costs met the requirements of the contract. Its adoption allowed monitoring of maintenance costs and the modification of maintenance schedules and a methodology to minimise maintenance costs. For new prestigious projects with well-controlled maintenance confined to few locations, the collection of data, its recording and process is not a major problem providing it is made available. However, the quality of the data on which designs and judgements have to be based on is often a critical issue. Free exchange of data between competing companies is mostly seen as being commercially sensible and therefore it is difficult to obtain elements of data with the required detailing for LCC. The initial uses of LCC in railway have identified some problems that relate largely to the RAMS (Reliability, Availability and Maintainability System) terminology and the financial analysis of the results. The deficiencies in the terminology definitions is being addressed through the development of CEN standards though care must be taken to ensure that there is consistency between the various groups working on the standards.

Currently, LCC should be seen as a development of older cost control processes that aim to give value against known specification parameters rather than a "best at a cost" approach.

Numerous LCC calculation models exist for the assessment of railways rolling stock and almost each Railway Operator has its own model. However, this does not stand for the infrastructure side of the railway industry. For the past 20 years, most European Infrastructure Managers made efforts to develop and implement tools that are required for professional life cycle design and maintenance management. However, these tools are still in an early phase of development and examples of successful implementation in the decision-making processes are almost absent. In an effort to summarize all the progress done in Life Cycle Costing in Railways Infrastructure Management, a review of European Railways Procedures took place.

Out of all, only RIB showed specific attempts to introduce and eventually establish LCC techniques in the infrastructure management. Shortly after the establishment of *Railinfrabeheer (RIB)* the maintenance staffs were transferred to the three Dutch railway contractors. This means that the *Railinfrabeheer* plans and controls the maintenance activities, which are executed by the contractors. Responding to these demands *Railinfrabeheer* has initiated a number of programs in order to change its way of working. One of these programs was *Life cycle management*; a program aimed at the introduction of a structured approach for making design and maintenance decisions. Decisions are usually based on case-to-case judgments of regional maintenance managers and are financed through separate budgets. The reduction of government funds makes it necessary to reduce the total costs and to increase the accountability of costs. Strategies have to be analysed comprehensively on their maintenance and availability effects.

Since 1997, TU Delft has been elaborating a life cycle costing approach applied to decisions related to investments in railway infrastructure [Zoeteman, 1999]. Life cycle costing is an assessment of the total costs of ownership and operation of capital assets. Choices related to design (e.g. system redundancy) and maintenance strategy (e.g. location of maintenance depots) will have a long-lasting impact due to the long life span and the high acquisition costs of the assets. Although life cycle costing focuses primarily on costs, it is well possible to include performance aspects, such as asset availability, quality and safety.

The key of the approach is the development and use of a decision support system (DSS) for estimating life cycle costs. It presents information on the likely cost and performance levels of design and maintenance alternatives. It can be defined as a computer-based data processing system developed and used to improve the effectiveness and efficiency of decision-makers in performing semi structured tasks, which have partly a 'judgmental' character. In the cases performed until now, each DSS design was specifically fitted to the context. Although a decision might concern the same asset, the conditions for infrastructure management vary a lot (e.g. type of traffic, allocation of risks, and payment regime).

The application of the DSS to the design of a new high-speed line in the Netherlands showed that many factors influence the actual costs and performance. Uncertainties related to, for instance, the train operations and innovative technologies complicate the analysis. These uncertainties are enlarged due to the poor availability of historic maintenance data. A univocal expectation of infrastructure costs and performance is therefore missing. The possibilities for planning infrastructure costs and performance are limited, especially in a design phase, due to the above-mentioned reasons. This should be taken into account in the requirements put to the infrastructure management, especially in the case for projects, where private companies are assigned responsibilities in the design and maintenance.

The uncertainties related to the infrastructure management conditions are in principle not an obstacle; if possible risks during construction and operations are analysed well.

5.7.2 Selecting Infrastructure Cost Elements for LCC Analysis

Overall the cost elements of interest are all the expenditures that occur during the life of the asset (e.g. railway infrastructure). Whilst there is a general agreement that all costs should be included, opinion varies as to their precise identification. The cost elements of interest within the IMPROVERAIL framework are hereunder identified. These costs are borne by the infrastructure manager and are dependent on vehicle-infrastructure interaction.

A. INFRASTRUCTURE COSTS

On a LCC (Life Cycle Cost) basis, rail infrastructure cost structure comprises the following cost categories:

- **Investment**: Acquisition of assets - *Land purchase*, New Construction (buildings and railway lines), Railway lines extensions
- **Renewal**: Track renewal, Building renewal, Major maintenance (Tracks, Switches, Ballast, Stations, Bridges, Tunnels, Catenaries, Signalling installations, Telecom installations etc.), Consultancy costs (external advisors)
- **Maintenance and Repairs**: Repairs (Tracks, Switches, Ballast, Stations, Bridges, Tunnels, Catenaries, Signalling installations, telecom installations etc.), Seasonal maintenance, Cleaning/ Cutting, Check conditions
- **Operations, Servicing**: Servicing of bridge beddings, Traffic lights, Operation of signalling, traction current, power consumption (electricity)
- **Management/ Administration**: Administrative costs, Wages, Security-Police, Scheduling & Planning, Training costs for staff
- **Disposal**: Disposal of used materials

B. DELAY AND SCARCITY COSTS

- **Delay**: staff cost, energy consumption, vehicle capital cost, commercial costs – customer reaction
- **Scarcity**: Penalties for non-availability

C. ACCIDENT AND ENVIRONMENTAL COSTS

- **Accident**: Materials damage, Administration costs, Medical Costs, Production losses, Risk value
- **Environmental**: Air Pollution Cost, Noise Cost.

D. LIFESPAN OF INFRASTRUCTURE COMPONENTS: The average operational life expectancy for railway infrastructure components

E. THE DISCOUNT RATE: Choice of the appropriate discount rate, based on best practices, if not applied by the Infrastructure Manager.

The difference between Renewal and Maintenance should be clarified by defining each one. The following definitions are taken from the final report of WP5 (D6) of IMPROVERAIL.

SUBSTITUTION OR RENEWAL: At a certain moment these periodical works are no longer applicable, be it by technical limitations or by economical reasons. The component has to be partly or completely substituted, if the track no longer fulfils the quality level or needs too high maintenance expenses to achieve it.

MAINTENANCE:

a. Preventive maintenance: Just after the construction or a complete renewal, preventive works are executed to eliminate any defects resulting of bad construction, faulty material etc. This type of work is intended to avoid any premature degradation of the infrastructure.
b. Corrective maintenance: Later in the infrastructure lifetime periodical works are executed to restore the infrastructure to a predefined quality level. Referring to the track as the main component of railway infrastructure, this work type includes corrections of geometry, partly exchange of used or faulty material. This work aims to assure the security of train operations and to slow down the deterioration process of the track.

5.7.3 Developing LCC analysis in Railways Infrastructure Management

The costs incurred by the IMs are broadly related to the **initial capital costs** (depreciation and interests) for new investments. The **Initial Capital** costs include all the costs of buying/building the physical asset and bringing it into operation and may be divided into three sub-categories of cost, namely:

- Purchase costs include assessment of items such as land, infrastructure and superstructure, fees, furniture and equipment. Current costs may be estimated by obtaining quotations from suppliers.
- Finance costs include the cost effect of alternative sources of funds.
- Installation/commissioning/training costs: installation of equipments, construction of the infrastructure etc. and the costs of training personnel to operate the equipments and the infrastru

Running costs are related to **Maintenance**, **Management, Administration** and to **Asset Renewal.** The definition for the latter is particularly relevant in this scope given that replacement of assets should be associated to major upgrades in the existing infrastructure, rather than with investment in additional elements of infrastructure, which should fall in the **Capital Costs** category.

The **Maintenance Costs** include direct labour, materials, fuel/power, equipment and purchased services. Maintenance may be further broken down into smaller classifications such as:

- Regular planned maintenance
- Unplanned maintenance (responding to faults)
- Intermittent maintenance (for major refurbishment, other than renewals)

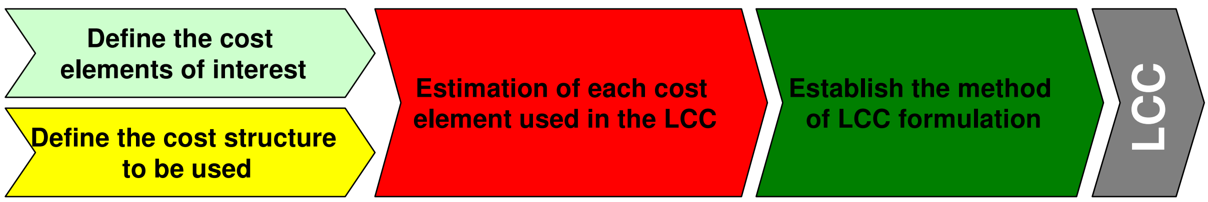
On a LCC (Life-Cycle Cost) basis, rail infrastructure cost structure comprises the following cost aggregations:

- Investment;
- Renewal;
- maintenance;
- operations;
- general costs;

The estimation of these costs is based on both predicted and actual experience of the performance of similar assets. Therefore, empirical information sources are usually the prevailing method adopted such as studies from the UIC (INFRACOST). The basic principle of the methodologies to apply is the calculation of these costs over a pre-defined time period, providing the means to incorporate different strategies for maintenance and assets renewal that are not possible with the approaches using only one reference year.

In general procedure for LCC analysis should be in line with scheme below:

Figure 18 - Life cycle costing procedure



The cost elements defined to be interesting are all the expenditures that occur during the life of the asset. These should include all expenditures related to the assets, from acquisition until disposal at the end of life. Further defining the cost structure involves grouping costs so as to identify potential trade-offs, thereby to achieve optimal LCC. The nature of the cost structure defined will depend on the requirements of the LCC study. For that purpose, a cost structure is proposed ahead. This list of cost elements should be seen as a top-level approach to the lifecycle cost analysis, envisaging developing suitable methodologies for its assessment. This following list presents the Rail infrastructure cost estimation and the allocation process based upon the HLG recommendations:

COST DEFINITION

Fixed costs:

- ➔ Land purchase
- ➔ Construction of new lines
- ➔ Upgrading/Enlargement of investments
- ➔ Overhead

Partly variable costs

- ➔ Replacement investments
- ➔ Construction maintenance
- ➔ Operation
- ➔ Servicing and on-going maintenance.

Pure variable costs:

- ➔ Security
- ➔ Scheduling/train planning

COST CATEGORIES

- ➔ Land purchase
- ➔ Construction of new lines
- ➔ Upgrading/Enlargement of investments
- ➔ Overhead
- ➔ Replacement investments
- ➔ Construction maintenance
- ➔ Operation
- ➔ Servicing and on-going maintenance
- ➔ Scheduling/train planning

COST ATTRIBUTION: According to *engineering relationships* - In this type of approach, total costs are disaggregated into sub-categories, and for each one of these categories, individualised analysis provides the technical relationship between inputs and output measures. Application of the engineering approach has been demonstrated for a range of modes, such as rail passenger transport (ECMT, 1998) and scheduled public transport in general (Jansson, 1984, 1997).

MONETARY VALUATION: Direct financial costs

COST DRIVERS:
Train categories: Freight trains (with sub-categories according to wagon load, combined transport, rolling road), Passenger trains (with sub-categories according to train type)
Network categories: Electrified main lines, Non-electrified main lines, Electrified minor lines, Non-electrified minor lines (with further categorization according to type of traffic)

Table 7 – List and Classification of Cost Elements Identified for Railway Infrastructure Providers (IMPROVERAIL)

<table>
<tr><th rowspan="2">Functional</th><th rowspan="2">Accounting</th><th rowspan="2">LCC</th><th rowspan="2">Cost Categories</th><th colspan="2">NATURE</th><th rowspan="2">ABC(*) Ability</th></tr>
<tr><th>Fixed</th><th>Variable</th></tr>
<tr><td rowspan="3">INVESTMENT</td><td rowspan="4">CAPITAL EXPENDITURES</td><td rowspan="3">PROJECT EXPENDITURES</td><td>Acquisition of assets – Land Purchase</td><td>☐</td><td></td><td>No</td></tr>
<tr><td>New Construction – Buildings and Lines</td><td>☐</td><td></td><td>No</td></tr>
<tr><td>Enlargement – Line Extensions</td><td>☐</td><td></td><td>No</td></tr>
<tr><td rowspan="5">RENEWAL</td><td rowspan="22">LIFECYCLE EXPENDITURES</td><td>Renewal - Tracks</td><td colspan="2">☐</td><td>No</td></tr>
<tr><td rowspan="21">OPERATING EXPENSES</td><td>Renewal - Buidings</td><td colspan="2">☐</td><td>No</td></tr>
<tr><td>Major Maintenance of Tracks, Switches, Balast, etc</td><td colspan="2">☐</td><td>No</td></tr>
<tr><td>Major Maintenance of Bridges, Tunnels, etc.</td><td colspan="2">☐</td><td>No</td></tr>
<tr><td>Consultancy costs (e.g. external advisors)</td><td colspan="2">☐</td><td>Yes</td></tr>
<tr><td rowspan="17">MAINTENANCE</td><td>Disposal costs – Disposal of used materials</td><td colspan="2">☐</td><td>Yes</td></tr>
<tr><td colspan="4">Maintenance and Repairs:</td></tr>
<tr><td>Repairs of Tracks, Switches, Balast compression, etc</td><td></td><td>☐</td><td></td></tr>
<tr><td>Repairs of Stations, Bridges, Tunnels, etc.</td><td></td><td>☐</td><td></td></tr>
<tr><td>Disposal costs – Disposal of used materials</td><td></td><td>☐</td><td></td></tr>
<tr><td colspan="4">Operation, Servicing:</td></tr>
<tr><td>Seasonal Maintenance</td><td>☐</td><td></td><td></td></tr>
<tr><td>Cleaning, Cutting</td><td>☐</td><td></td><td></td></tr>
<tr><td>Check conditions</td><td>☐</td><td></td><td></td></tr>
<tr><td>Servicing of Bridge Beddings, traffic lights</td><td>☐</td><td></td><td></td></tr>
<tr><td>Operation of Signalling</td><td></td><td>☐</td><td></td></tr>
<tr><td>Traction Current</td><td></td><td>☐</td><td></td></tr>
<tr><td>Overheads - Admnistrative Costs, Wages, etc.</td><td>☐</td><td></td><td></td></tr>
<tr><td>Security - Police</td><td></td><td>☐</td><td></td></tr>
<tr><td>Scheduling & Planning</td><td></td><td>☐</td><td></td></tr>
<tr><td>General Consumption (e.g. electricity, etc.)</td><td></td><td>☐</td><td></td></tr>
<tr><td>Training costs – Staff</td><td></td><td>☐</td><td></td></tr>
</table>

(*) - Activity Based Costing

5.7.4 Data Requirements in Support of LCC methodologies

The data requirements to produce a proper LCC analysis are extensive, and may depend upon an amalgam of information obtained both in house and from statistics and specific studies. It is advisable to have a checklist of all the aspects, which probably contribute to the cost-effectiveness of a particular asset.

A basic step in developing a LCC analysis Decision Support Tools (or DSS) will be the representation and management of this vast amount of information. Therefore, such DSS requires a database that captures and stores financial, time related and quality data associated with reliability, capacity utilization and maintenance procedures, leading to an understanding of the relationship between the capital costs of specification, design, acquisition and disposal and the costs of operation, and maintenance as well as the external costs (accidents, environmental). Depending on the importance and the cost of compiling LCC records, it may be worthing developing and integrating a database that provides the parameters (metrics) needed for the LCC models.

Establishing the method of LCC formulation involves choosing an appropriate methodological framework to evaluate the asset's LCC. The LCC Methodology formulation proposed is based on the seven-step approach indicated below and shown in the next figure:

- **Step 1**: The Management profile (MP) describes the periodic cycle of the asset, and indicates when such asset will, or alternatively will not, be working. It comprises the modes of start up, operating and shut down. At this step, relevant life-span data elements are collected
- **Step 2**: Asset registration. At this step – technical data will be collected
- **Step 3**: Asset cost elements; every cost element or area of cost must be identified. At this step - cost data will be collected.
- **Step 4**: All costs are first calculated at current prices
- **Step 5**: All costs need to be projected in the future, by applying the estimated rates of inflation and possibly expected change of specific price of some items(e.g. through new technology). The difficulty in projecting such figures should not be underestimated, since lack of precision here can lead to inaccuracy in the final calculations.
- **Step 6**: It should be recognised that money has a time value and the costs occurring in different time periods should be discounted back to the base period to ensure comparability. How to establish the appropriate discount rate is, of course, the subject of discussion. If available it will be applied, otherwise best practice will determine it.
- **Step 7**: Summing all the costs involved will enable the LCC of the asset to be established

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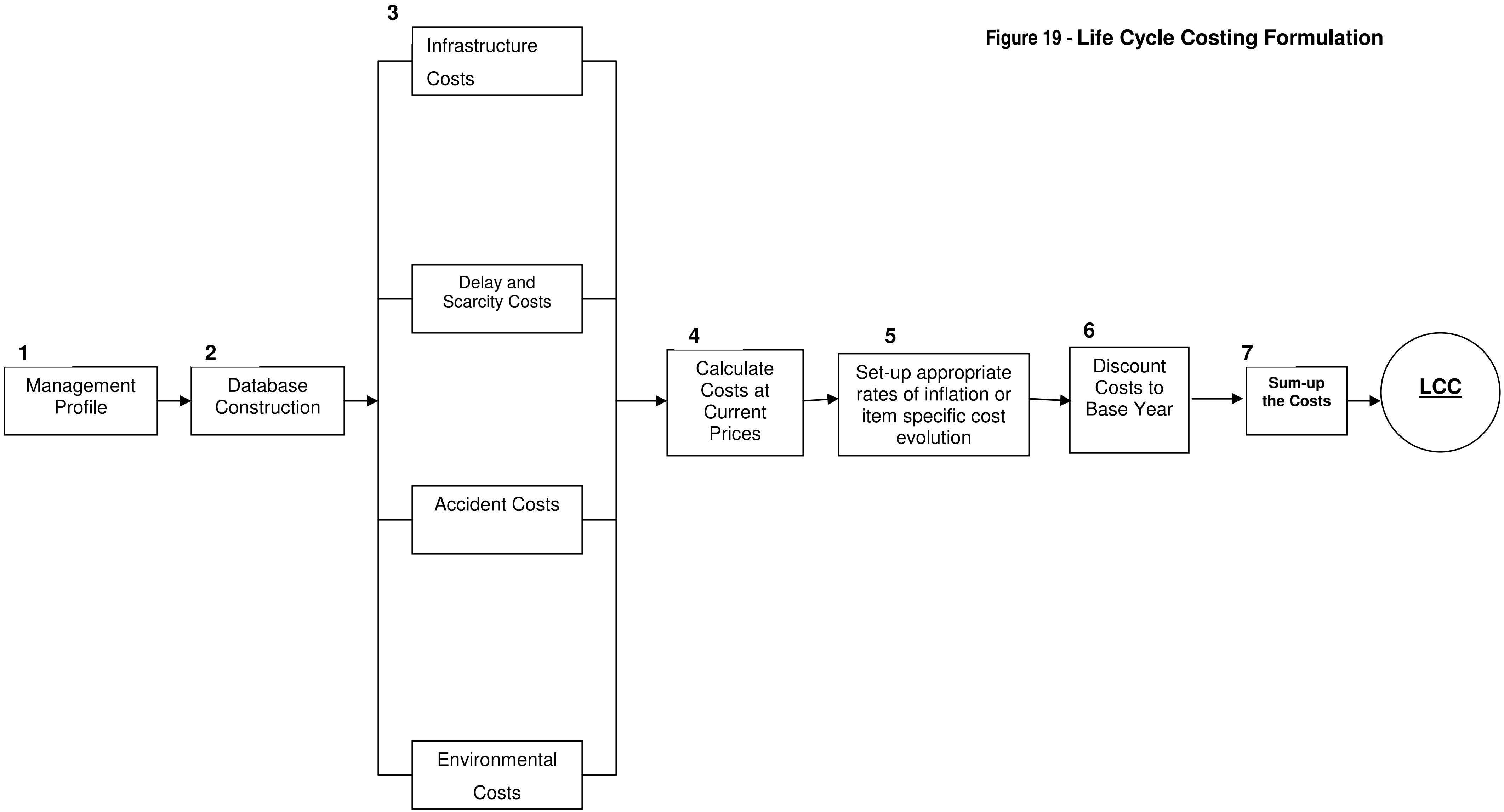
Figure 19 - **Life Cycle Costing Formulation**



6 SETTING UP EFFICIENT INFRASTRUCTURE CHARGING SYSTEMS

6.1 Introduction

As in railways the infrastructure is limited in each section to serve one or a few vehicles at the same time, the access to a sequence of sections of the infrastructure at a specific sequence of points in time is called a slot or a path. These two terms are used as synonyms in this context. But operators in a liberalised market will have a different willingness to pay for different slots, varying with the underlying demand function of the passengers and the characteristics of the operators.

For traffic running according to a timetable, real time pricing does not seem feasible. The slot pricing must be done in advance during the setting of the timetable and must be based on demand-supply relationship. Supply is closely related to how the infrastructure is divided in blocks. Making the blocks shorter, possibly by improved control and signalling installations, which may reduce the distance between consecutive trains, can increase supply. Demand is derived from the underlying demand for passenger and freight transport. Generally, demand is varying strongly over the day, and this will make the value of different slots very different.

According to the Directive 2001/14/EC, charges must be paid to the infrastructure managers and used to fund their business; in principle, the charge for the use of railway infrastructure equals the cost directly incurred as a result of operation of the trains; the infrastructure charge may include a sum reflecting the scarcity of capacity; and the infrastructure charge may be modified to take account of the cost of the environmental impact of operation of the trains.

Referring to the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification the EC Directive 2001/14 of the European Parliament and of the Council of 26 February 2001, says explicitly, "*the charging and capacity allocation schemes should permit equal and non-discriminating access for all undertakings and attempt as far as possible to meet the needs of all users and traffic types in a fair and non-discriminating manner*".

The directive 2001/14/EEC defends that the infrastructure charging schemes have to encourage the infrastructure manager to minimise disruption and improve the performance of the railway network. While respecting the management independence, the specific charging rules are established by the state member or the infrastructure manager. As already considered in the previous directive 91/440/EEC, the infrastructure manager determines and collects the charge for the use of infrastructure except if the infrastructure manager is not independent in its legal form, organization and decision-making from any railway undertaking.

In general, the charging systems that are analysed hereby allow clarifying the role of charging in promoting access to services facilities and supply of services, including the different capacity allocation strategies combined with the levying of the charges. A discussion on the adherence of Marginal Cost pricing principles to the recent EC Directives on this subject is also included, along with the importance of the charging systems in the relationships with the Railway Undertakers and in the promotion of cross border railway traffic.

6.2 The Context of Railway Charging

The separation between provision of train services and the infrastructure management has provided the basics for a new railway business concept, calling for a new approach regarding the relationship between network managers and new coming competing operators. Such cleft raises the need for feedback relations among railway stakeholders, fostering the rational production of the railway transport service. This means that it becomes necessary to implement a market structure based on financial flows, promoting the system's optimisation. Such structure should account for:

- **Welfare of end-users**. The provision of railway services should meet the end-users demands.
- **Cost structures**. Both internal and external costs should be reflected in the market. Cost efficient production should be a concern across the "production line".
- **Differences in companies' cost structures**. Relative differences in productivity among competing firms should lead to a situation where the most competitive firm wins contracts and is given opportunities to expand and evolve its production.
- **Intermodal competition**. The railway market should face the same external conditions as competing modes of transport
- **Flexibility** needed for adapting new traffic into the railway framework
- **Non-discrimination of operators**, freight -companies and passengers
- **Need for clear information flows** between operators and infrastructure managers to secure that decisions taken are rational and that the whole railway system is taken into account

Hence, infrastructure charging emerges as a crucial "part of the picture" required to fulfil the expectations that remain in railway transport with. Besides raising revenue, infrastructure charging provides also a valuable instrument to the policy maker in pursuing several objectives. But since some of them are contradictory, a clear hierarchy has to be established. Otherwise, some forms of decay can follow: congestion and delays, over- or under-investments, poor maintenance and so forth. A short list of the possible objectives of railways infrastructure pricing is hereby presented (Quinet 1990, NERA 1998, RFF 1998, Nash and *al.* 1999).

1. **Favour the best possible use of the rail network** from the standpoints of the management of priorities in operation (routes/slots) and economic efficiency criteria (economic surplus for example) and non-discrimination. The efficient tariff that reaches an optimal use of infrastructure is the additional cost that the use of infrastructure per additional unit of transport imposes on society. It is the short run marginal cost. These costs are attributed, in absence of scarcity of capacities, to the wear and tear of the tracks, the consumption of electricity for the traction, the costs of signal additional, the costs of management and administration additional (if truly marginal), congestion traffic (delays), accidents, noise, pollution and other externalities.
2. **Cover all or part of the operating and maintenance costs of the rail network.** This coverage may be achieved globally, or on the contrary for each section of the network, and this may be in identical or differentiated fashion. Setting the price at the short run marginal cost is insufficient to cover all costs that relates to infrastructure. In this case, the additional fees can be established in accordance to the Ramsey principle or to some multi-part tariff. These fee systems will introduce some distortions, but Ramsey-pricing will minimize the deadweight losses that the increased charges incur.
3. **Reflect the level of service provided to the carrier; service quality.** A typical quality variable that is in the hands of the IM is the length of the time interval for which a train can run. Increasing the length of this path in terms of minutes, reduces the risk for a train to be delayed because of other incidents on the track ,and the possibility for avoid large delays if the departure is falling a couple of minutes behind.
4. **Contribute to the costs of developing the rail network making investment fully or partly self-financing** This can be done by some kind of LTIC (Long-term incremental cost-function) or simply by one or more additive charges to the general infrastructure charges.
5. **Encourage the use of the rail transport in intermodal competition**, because of the insufficient harmonisation of the conditions of intermodal competition (external costs, social

costs). The fee system of rail infrastructure has to take into account the fees concerning other competing transport services. A particular problem is the pricing of the road infrastructure, because the users of roads generally directly pay only a part of the costs assigned to their use.

6. **Contribute to the balanced regional development**, through improving the accessibility of disadvantaged areas, for reasons of equity and solidarity. Earmarked public transfers, or regional levels of charges etc will in general follow such public objectives.

All of these objectives cannot be adopted simultaneously, and any pricing policy will have to reflect the ranking of objectives established in the compromise accepted. Each option decided upon must be able to be evaluated from the standpoint of efficiency on the one hand and equity on the other.

In order to better understand how charging can be a complex issue, it is however important to acknowledge that State owned Infrastructure Managers may lack a clear market orientation and may, to some extent, be further constrained by political control. For such reasons, the true implementation of efficient pricing becomes challenging, requiring a bit of a private sector rationale in view of the required optimisation of the infrastructure usage.

On the other hand, if a IM is a self-financing entity running on commercial terms, government must set up controlling mechanisms. Otherwise the IM will tend to maximise its own profit or revenues instead of securing the optimal railway activity. Calculations such as those related to maintenance costs should then be revised in order to secure that the costs are not exaggerated.

Thus the need for governmental control and surveillance of the railway sector increases when the IM is separated from public control. A profit-maximising IM is especially difficult to handle in a situation where the IM or one or more operators get public transfers. Then, the system must be controlled in detail in order to avoid monopolistic behaviour from the IM. Only if there is a certain level of production and the system as a whole is profitable without any public transfers, profit maximising IM may be seen as a viable approach.

Overall, the socio-economic success of a given approach on charging will always depend on the efficiency of regulation and on the degree of competition between Railway Undertakers (RU). To this respect, regulation should be able, not only to ensure the discrimination-free access to path capacity at earlier stages of implementation, but also to ensure the right incentives to the IM in order to promote efficiency.

According to the Directive 2001/14/EC, charges must be paid to the infrastructure managers and used to fund their business; in principle, the charge for the use of railway infrastructure equals the cost directly incurred as a result of operation of the trains; the infrastructure charge may include a sum reflecting the scarcity of capacity; and the infrastructure charge may be modified to take account of the cost of the environmental impact of operation of the trains.

Finally it is clear that charging procedures are crucial to enable building the right incentives for total railway production, and competition between operators and between railway transport and road and aviation transport, in the relevant segments.

6.3 Advantages and Pitfalls of SRMC Charging Principle in Railway

The core pricing principle discussed together with capacity allocation in IMPROVERAIL has been the short run marginal cost (SRMC). The short run marginal cost (SRMC) principle, measures the cost of increasing output when capital stock is regarded as fixed. Applied to rail infrastructure, the SRMC measures the cost of accommodating an additional train to the existing rail network.

In the long run we will have also the Long Run Marginal Cost (LRMC), measuring the cost of increasing output when all inputs can be varied. Applied to rail infrastructure, it measures the cost of accommodating an additional train service over a time period when the capacity of the network can be increased or decreased, that is: the capital stock can be changed.

Sometimes, another cost-measure is used: Long run average incremental cost (LRAIC), which is the average cost of accommodating trains over a time period. This is related to LRMC but diverges on the fact that LRAIC is an average measure related to an increase in the number of trains.

Although largely depending upon an effective information system, setting prices equal to short run marginal cost SRMC should encourage more efficient use of the network. At least theoretically, SRMC-pricing gives the operators the right prices to take into account the total costs that their services impose the network and society. Different SRMC calculated for different train paths, means that SRMC-pricing will also secure the correct allocation of train services per paths.

But to implement SRMC, cost elements such as Tear and wear of infrastructure caused by rolling stock must be calculated at a desirable high level of accuracy. And this is currently a major drawback for SRMC, as there will always be a great number of variables that affect these costs, and there will always be some inaccuracy and uncertainty in the calculations. The effort that is spent on these calculations are justified if the value of fine-tuning the methodology is equal or above the costs of estimation. Varying charges for different train-types if the underlying cost structure is different is recommendable. A top-down approach with a limited number of parameters seems however to suffice in most cases.

While reflecting on which charging principles to apply, it must be acknowledged that these should be complex enough to include the most important train types etc, but simple enough not to make the business decisions for the operators unnecessarily complex. In the approach to this trade-off, information systems where required data is retrieved, stored and ultimately processed is required.

6.4 Slot allocation and pricing of access to track

As both economically founded slot allocation and SRMC-pricing of track are techniques that have not been widely used and thus information about them is scarce, there is a need to explicitly draw some practical implications of the use of these methods.

An orthodox use of the SRMC-pricing principles will make the time costs in the track system an endogenous variable in the slot allocation procedure. An additional train will inflict higher time costs on other trains in the system, and the total SRMC-prices will not be visible before the final timetable is elaborated. For practical purposes this connection between time costs and slot allocation needs to be simplified.

One method that can be used is to define some categories, for which the external costs are treated as constant. As a few categories are needed for accident costs as well as environmental costs and time costs, there will exist multiple combinations of cost parameters and thus multiple levels of external cost payments (see WP6). It is important that the number of cost parameters do not make the slot allocation procedure too hard to compute. Given these categories, the operators as well as the infrastructure manager knows in advance the level of external cost pricing for any given train.

Assuming that the infrastructure access charge is correctly set so that the external costs in the actual market that has been created through some kind of slot allocation procedure, all revenues from the slot allocation procedure will be a transfer from the railway sector to the government. This will lower the producer's surplus and therefore reduce the operators' profitability. In an auction procedure with many operators competing for slots, the revenues from the slot allocation procedure might be substantial. It can be questioned whether this is problematic or not. Higher costs for the operators will normally lead to reduced activity, since the demand curve is downward sloping. This reduced activity can lead to reduced frequency of trains but at the same time increase the average speed of the trains in case of congestion. So the outcome of this is uncertain. In standard microeconomics a transfer between the private companies and public is neutral. This idea is often questioned by setting a cost on tax money.

The revenues from the slot allocation can be invested in the railways, or transferred back to the operators or the passengers through some subsidies. Private investments in the rail operating market depend on the expectation of profitability. An expensive auctioning round reducing the producers surplus dramatically, can effectively hinder private investors to enter the market. Barriers to entry e.g. by high investments costs increases the need for high profitability before potential operators are willing to enter the market (see discussion note for more on this topic).

Auctioning of track access rights seems more and more reasonable as the number of operators increases. With just a few bidders there is a risk of speculative cooperation. If auctioning is presented in multiple markets where a few big companies compete against each other regularly, there is a risk of agreements between the companies where the markets are divided between them, and thus the competition is destroyed. Some researchers suspect this to be the case in some aviation and bus markets. Cooperation may also be caused by economies of density and is therefore not always a negative property of a market. Another reason why there tend to be few competitors in such markets, is an economy of scale. In that case this trend can be regarded as the result of well-functioning markets. In the Nordic countries, and probably for many other European countries with medium or low population density, a situation with multiple operators in the passenger transport market seems highly unlikely. A situation of one to three operators seems more plausible. It is important that the slot allocation procedure can handle such a competition with few competitors. There are experiences from other sectors that can lead us to questioning the feasibility of an auctioning system. Learning from these experiences, should at least make us more prepared for finding good and feasible solutions.

6.5 Mechanisms for Efficient Slot Pricing in Railways

Before the separation of train and track, the national railways were able to carry out an integrated analysis of track allocation and costs and revenues from the operation of these trains. Revenue is of course closely linked to the demand side, and how well the willingness to pay is exploited. Upon the implementation of the EU-Directive 91/440, the actual allocation is in the hands of the infrastructure manager separated from the operators. The operators are left to concentrate on the cost/ revenue considerations. In an area of competition all operators are interested in running the most profitable routes. Other routes at other times of the day may be less lucrative, and some routes may not be profitable at all and no operator will ask for these slots without some public funding.

Competition on track demands a way to allocate the railway capacity among different train providers. There are many ways of doing this. In order to find the best way of allocating capacity we need to consider the following criteria:

- Efficiency
- Fairness in allocation, equity
- Financial objectives

The railway system (network) in a country is divided into lines and blocks. Blocks are defined as a distance of the track that can be occupied by only one train. As there never can be more than one train in each block, the problem of timetabling is to prioritise which trains that shall be granted the right to run in each block at a special point in time.

As the signalling and safety systems are improved the length of the blocks may be shorter and thus increasing the capacity of the track. These blocks, formerly a fixed constraint associated to the physical segmentation of the network have since evolved in to a more dynamic concept by which a certain length before and after the train is reserved for the train according to its speed allowing for increased slot management flexibility.

This concept called "'moving' blocks" has been introduced in several countries. This concept indicates that blocks move with the trains. This is a result of the introduction of new safety systems.

Given these facts and rules, finding a way to translate economical rules for optimal provision of railway capacity and train capacity into a feasible and manageable system becomes the important issue.

On the supply side the basic concepts are:

- **Capacity**: the capacity is a limited resource in two dimensions: time and space. The constraints are in practice not physical constraints, but constraints related to some security measure.
- **Safety** is linked to the density of trains on track, and the technology both on infrastructure and trains. Railway administrations distinguish between the two concepts called theoretical and practical capacity. The first is connected to the maximum level of traffic that can run on the track given the current state of the infrastructure (curvature, signalling etc), and the latter related to what is regarded as practicable given the existing train material, the current mixture of local slow train and high speed Inter City traffic, and current operational practice.

The **demand** for railway services can, in turn, be explained by a regular demand function including income and prices, but varies greatly in the two dimensions time and space. Demand varies with time in at least two ways. The obvious one is the actual needs of the consumer.

If the working period generally starts at 9 am, obviously the willingness to pay (WTP) for a train arriving 9.30 is low. As adaptation to a new timetable has some costs for the passenger, and most daily passengers are using some kind of periodic card, the changes in demand due to changes in the timetable are slow. Furthermore, passengers dislike frequently changing timetables.

Reliability, **Punctuality** and **Quality** are important concepts, which are affecting demand, and closely connected to the density of trains on the tracks. If the capacity limits are trespassed, the effect on the total traffic of a delay of one single train may be great.

The allocation procedure will need to consider all these elements in order to find some optimal allocation rule. Once this allocation is done, a timetable is fixed for a certain time e.g. one or two years. The routes will for certain areas and time of the day be fully exploited by the operators, but for other areas and time of the day there may be free capacity, giving room for additional traffic.

Relating slot allocation and pricing of access to track

As both economically founded slot allocation and SRMC-pricing of track are techniques that have not been widely used and thus information about them is scarce there is a need to explicitly draw some practical implications of the use of these methods.

An orthodox use of the SRMC-pricing principles will make the time costs in the track system an endogenous variable in the slot allocation procedure. An additional train will inflict higher time costs on other trains in the system, and the total SRMC-prices will not be visible before the final timetable is elaborated. For practical purposes this connection between time costs and slot allocation needs to be simplified. One method that can be used, is to define some categories, for which the external costs are treated as constant. As a few categories are needed for accident costs as well as environmental costs and time costs, there will exist multiple combinations of cost parameters and thus multiple levels of external cost payments. It is thus important that the number of cost parameters do not make the slot allocation procedure too hard to compute. Given these categories, the operators as well as the infrastructure manager knows in advance the level of external cost pricing for any given train.

Assuming that the infrastructure access charge is correctly set so that the external costs in the actual market that has been created through some kind of slot allocation procedure, all revenues from the slot allocation procedure will be a transfer from the railway sector to the government. This will lower the producer's surplus and therefore reduce the operators' profitability.

In an auction procedure with many operators competing for slots, the revenues from the slot allocation procedure might be substantial. It can be questioned whether this is problematic or not. Higher costs for the operators will normally lead to reduced activity, since the demand curve is downward sloping. This reduced activity can lead to reduced frequency of trains but at the same time increase the average speed of the trains in case of congestion. So the outcome of this is uncertain.

Auctioning of track access rights seems increasingly reasonable as the number of operators increases. With just a few bidders there is a risk of speculative cooperation. If auctioning is presented in multiple markets where a few big companies compete against each other regularly, there is a risk of agreements between the companies where the markets are divided between them, and thus the competition is destroyed, that some researchers suspect to be the case in some aviation and bus markets. Cooperation may also be caused by economies of density and is therefore not always a negative property of a market. Another reason why there tend to be few competitors in such markets, is an economy of scale. In that case this trend can be regarded as the result of well-functioning markets.

In the Nordic countries, and probably for many other European countries with medium or low population density, a situation with multiple operators in the passenger transport market seems highly unlikely. But a situation of one to three operators seems more plausible. It is therefore important that the slot allocation procedure can handle such a competition with few competitors..

Different ways of allocate track capacity between operators

This section will analyse how track can be allocated between different operators by setting an access price on the track.

Following the earlier works of Dupuis and Pigou, Walters (1968) is among the first to show that rationing access to roads (or infrastructure in general) experiencing congestion can be welfare enhancing. The principle of access pricing is easy to understand. In congested situations there is no way to separate urgent traffic (except for emergency cars and lanes for public transport), from the weekend-motorist. A congestion charge, making the traffic travelling during peaks of the day paying a higher price, can do just this. This will reduce traffic jams, and spread traffic more evenly across time. The EU-commission has made several reports indicating that they see this as the future solution to cope with growing congestion around the major European cities.

For roads this principle is called road pricing, and can be seen as a real-time traffic control problem. The prices are dependent on the road and time of the day. For aviation or railroad, the number of vehicles is much less, and the infrastructure is limited to serve one or a few vehicles at the same time. The access to a specific part of the infrastructure - a block at a special point in time - is called a slot. The operators have a different willingness to pay for different slots, varying with the underlying demand function of the passengers and the characteristics of the operators. For traffic running according to a timetable, real time pricing is impossible (as explained above). The slot pricing must be done in advance during the setting of the timetable.

Supply is therefore closely related to provision of blocks. The supply can be therefore increased either by making the blocks shorter e.g. by building new meeting stations or by making more blocks by building additional tracks, or by improved control and signalling installations.

Demand is derived from the underlying demand for passenger and freight transport. Generally, demand is strongly varying over the day, and this will make the value of different slots very different. There might be a peak at 1600 in the afternoon, but at 1545 and 1615 the passengers' total willingness to pay (WTP) might be lower. For freight the cost of expediting or postpone a departure will be regularly much lower.

Auction methods

In a market for multiple operators, the timetabling procedure needs to be done by an independent body. The separation of infrastructure and operators in EU-directive 91/440 is a way to arrange for such a timetabling body. Such a body may be a suitable procedure to allocate track in a market with very few competitors. Arranging for a meeting with the operators and the public authorities that specifies requests for certain routes at certain periods, might be sufficient to reach an agreement ending up in a timetable accepted by all parties. There is a risk that the timetable in such a procedure is sub-optimal and that the decision –making is biased. This could be in favour of the major company, or the company with the best negotiator, or the company that is most pleased by a few changes in the timetable, since such agreements tends to be quite conservative.

As mentioned before, in a multi-operator market a well-functioning market for slots seems to be appropriated, while tendering is already widely used for other modes of transport.

There are many forms of contracts that can be tendered. Some contracts are fixed, but other can be adjusted in many different variables. So there is no clear distinction between tendering and auctioning.

However, negative experiences with auctions should not be ignored, namely looking at the mobile phone market, where the licenses for 3rd generation network led to prices far over what (now) seems to be reasonable.

The most important differences of auctioning procedures are

- *Number of auctioning rounds (single round, two rounds, .., multiple rounds)*
- *In what order the objects are auctioned. (sequentially or simultaneously)*

Auctions with one round are often referred to as "closed bid auctions". Tendering procedures are often in this form. Multi-round auctions open up for raising bids over the highest bid from the previous round. One method has been referred to as "English auction". This is a form where the bids are stated orally in an auction premises, and where the bidder is free to raise his/ her bid upwards. Another method is often referred to as "Dutch auction". In this procedure the seller of the object (e.g. slot) announces a price and the price is lowered until some buyer accepts the price.

These methods are of the form where the winner pays the winning bet. Vickrey-auctions are another form of auction where the one that has stated the highest bid wins, but actually needs to pay the second-highest bid.

For allocation of slots in the railway sector Brewer and Plott (1996) introduced an auctioning mechanism called BICAP. In a BICAP auction any potential operator can bid on one or more licenses in a continuous time auction. The highest bid cancels out the lower, and the allocation of slots that maximises the auction revenue at any point in time is prevailing slots. The auction is over when a predetermined period has elapsed with no new bids. In the evaluation process of such bids the concept of "**auction efficiency**" can be helpful Auction efficiency can be assessed by the function below

In the following general equation there are n objects $y_1,..., y_n$ that are allocated between 'i agents. Agent j's valuation of the objects is given by the value function $V^j\left(y_1^j,.., y_n^j\right)$. Here $y_k^i = 1$ if and only if operator i wins the auction for object k. The denominator is the maximum value that can be retrieved by any allocation. $\hat{y}_1,...,\hat{y}_n$ is the real allocation from the auction.

$$\frac{\sum_{i=1}^{I} V^i\left(\hat{y}^i\right)}{\max \sum_{i=1}^{I} V^i\left(y_1^i,...,y_n^i\right)}$$

Time needed to undertake the auction might be causing the bidders great costs. There can be a trade-off between time-consuming auction procedures and auction efficiency.

Proposing a Model for Railway Slot Allocation

In a liberalised railway market, there is a need to allocate the scarce infrastructure between the operators. One solution is to let some committee of qualified personnel do the allocation. This has some advantages, in the way that knowledge of experienced persons can be used actively. Unfortunately, this might also reveal also human factor influence, as this system may end up too conservative in changing the existing system. Possible connections to the old companies may result in biased decision making.

Another way is to create a market for the infrastructure where the operators are invited to compete in a fair market. Different ways of doing this suggested by (Grether & al, 1989) are secret bids where the lowest accepted bid wins, or to distribute slots randomly and then let the slots be traded in a second hand market. It can be questioned if this might be too demanding for the operators. Another problem is that the operators cannot trade for the parameters set in the slots (e.g. risk premium by buying a "broader" slot),

However, this may be included in another auctioning system suggested by Nilsson (1998). Nilsson's method can be roughly explained as follows:

- First, reveal operators' true WTP for all slots. The bids will need to be some kind of distribution for WTP for departures near the requested points in time. A typical freight train may be illustrated by a quite broad value function, while a passenger train probably will have a higher sensitivity to time variations.
- Second, find the optimal composition of slots, i.e. the combination that maximises the social benefit.

The solution of the first problem is some kind of auction. The solution of the second problem is some kind of software that uses a mathematical optimisation technique. This ensures a non-discriminatory and correct optimisation. Finally, the following table summarises the major flaws and strengths looking of slot allocation procedures:

Table 8: Strengths and weaknesses of slot allocation

STRENGTHS	WEAKNESSES
• Best utilisation of available infrastructure	• Vulnerability to delays
• Good representation of true demand for capacity	• Inflexibility
• Effective management tool	• Mismatches at national borders
• Procedural transparency	• Uncertainty among operators concerning investments
	• Responsibilities in case of delays not obvious
	• Potential unfairness towards newcomers

6.6 Conclusions and Recommendations

The concept of ***train paths*** related to capacity allocation is a critical factor in the provision of track access service. This is, on most corridors, a scarce commodity in regard to departure times, arrival times and transit times. Existing timetables favour the established rail operators with multiple train paths at times that suit their business and with preferential transits that minimise the number of crossing delays. New operators are left with train paths that do not meet commercial or operational needs, but still costing the same, sometimes even more than those of the major operators.

This places new entrants in disadvantageous positions in relation to existing rail operators, in particular if we think about one of the most promising market segments for rail represented by freight. Hence there is a clear and real need to rationalise train paths allocation along with suitable charging mechanisms, in order to provide a level playing field between the railway undertakers while promoting the railway as a true alternative to road concerning freight.

The ***quality of the infrastructure*** is also critical in valuation of the service being provided. The track condition is a key factor, as there are large sections of track that cannot accept the top speed of high-speed trains. These substandard track sections reduce the ability of the traffic planner to maximize the efficiency of train paths. This causes sub optimal transits and increases the operational costs of the railway undertaker.

Also the ***information systems*** *must* be developed coherently on a cross-border perspective, in order to provide real time information concerning trains running and must be accessible to the rail operators. Currently, a number of different systems are used in different states. There would be benefits from deciding on a single system and ensuring that the system provides the operational and commercial requirements for both the track authority/company and operators.

Charges should be set for each corridor to encourage fair **competition with road and aviation**. Rates should be published and held for a minimum 12-month period. The current practice in some states, of negotiating with individual operators on the annual fee and/ or the usage fee, provides an area of uncertainty for rail operators regarding the equity of the result. Large annual fees on some track sections create **barriers to entry** for new operators. **The rates and fees must be uniform, transparent and reflect the quality of train path provided.**

The network authority/ company IM should be required to provide a range of services at a level consistent with rates, transit times and quality of ride competitive with road. Documentation of agreements should be standardised to incorporate uniform elements for all rail operators.

The **agreements** will need to address the levels of performance of both parties. The issues of termination, insurance and cost retrieval need to be reviewed and brought up to commercial grounds. Requests for train paths and negotiations for agreements should be given time frames and standard procedures and documentation introduced to facilitate this process.

All in all, charging procedures should give the right incentives for total railway production, competition between operators and between railway transport and road and aviation transport. The following chapter shows how this can be achieved.

Finally, **International traffic** which is heavily dependent on national charging schemes, priority rules and bureaucracy should be supported by common principles and clear charging systems ensuring transparency, predictability and non-discrimination. SRMC-pricing in all countries is a relatively easy methodology that will meet these demands.

Financial **mark-ups** to cover parts of investment costs to the infrastructure charges create a sub-optimal situation at a national level. In international traffic, the disadvantages of such systems are even more visible. Each national IM will have few incentives and will often miss the ability to see the impact of reducing international operators' surplus.

Below are presented key topics regarding network charging methods and slot allocation procedures supported by improved data sets at the light of the current EU relevant regulatory framework. These issues have been covered in Workpackage 7, which dedicates to Charging Methodologies and Data Requirements for Railway Infrastructure Access. For a complete overview of the context underlying these topics, please refer to the Deliverable 9 of IMPROVERAIL.

6.6.1 Data Requirements for Charging

In order to apply charging methodologies based on the effective knowledge of the costs associated to Infrastructure Management, it is necessary to have available and reliable data, which in turn will depend upon the existence of suitable information systems.

Some may be standard accounting systems, others simulation systems and some based on more or less regular studies carried out by accountants and consultants. In any case the data requirements supporting fair charging, e.g. by means of Short Run Marginal Cost pricing (SRMC), will necessarily have to account for the following main elements:

- **Wear and tear –** Induced need for maintenance caused by a specific train using the infrastructure
- **Marginal costs related to signalling surveillance etc** – Extra costs of railway system administration should be included if these are truly marginal.
- **Accident costs –** One more train on track increases the accident risk for passengers, employees and third parties. These costs should be included
- **Environmental costs** – Emissions and noise pollution are the main elements in this cost category
- **Congestion costs** – Each train added to a given network will rise, to an increasing extent, the expected delays in the railway system. This is an externality posed by the operator to the others and should be internalised by a correct internalisation scheme.

Most IMs are currently either using or in the process of implementing integrated information systems. Notably among these, it is SAP R/3 (and follow-ups) for internal data management, which could enable to build a common platform for effective data exchanges.

This new generation of information systems under implementation is expected to allow keeping track on costs and the accurate identification of the relevance of each categories, including its allocation to activity levels in order to produce historic series in support of, e.g. maintenance and renewal decisions.

To this respect, the allocation of the significant overhead costs currently summing up significant shares of the overall costs is an obstacle for a true assignment of costs. Such 'holes of information" should be reduce to the minimum aggregation level possible in order to keep tight control over the costs driven by the actual level of activity, enabling to reflect fairly related variations in charging.

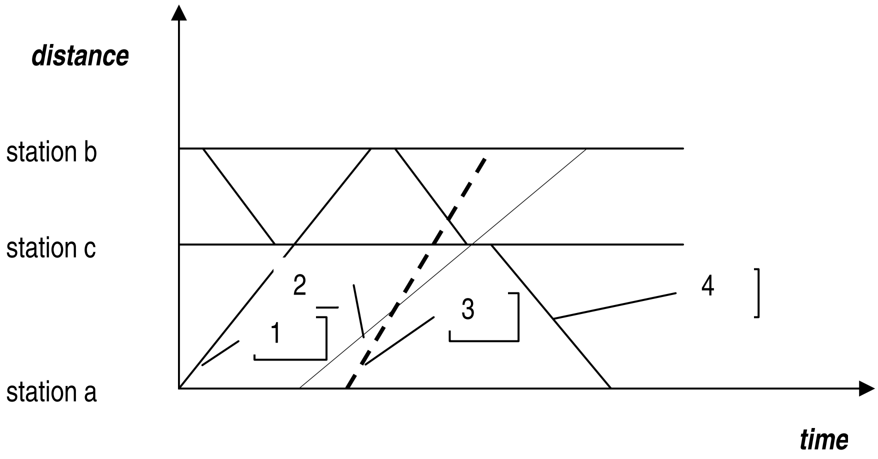
Moreover, the very different definitions of cost categories used in practise, that has been also identified in the approach to Lifecycle Costs within IMPROVERAIL, make it rather difficult to get a harmonised input.

6.6.2 The Role of Slot Allocation in Railway Charging Systems

Allocation of track access is not new, and was already an important matter when the national railways were the sole train operator. The national railways needed to allocate the track between different trains. This allocation procedure is a quite demanding task involving many objectives and considerations.

The figure below illustrates a railway consisting of three stations and two blocks. One block between station A and station C and another block between station C and station B. Time is on the horizontal axis and distance on the vertical axis. The inclining lines indicate different trains, and the slope represents the speed.

Figure 20: An example of conflicting train departures on single-track section with two-way traffic



Five trains are shown in the figure above. Three leaving station "A" and two trains arriving at station "C". There is just one conflict between these five departures. The train illustrated with the dashed line "3" will catch up with a slower train "2", and is therefore not fitted into a feasible timetable. Besides, the fast-going train will meet an opposing train "4" between station c and station b. We see that train 4 stops at station c, whereas train 1, 2 and 3 are non-stop departures between station A and station B.

Old fashioned track allocation can be described as trying to find the best way of allocating certain train departures, given considerations of speed, frequency and priority. The latter is a disadvantage of the old engineering system, since there is no objective way to ensure fair and efficient distribution of slots between operators with conflicting requests.

The main objective of putting together rail infrastructure charges and slot allocation charges is to promote the efficient use of the rail network. This is related to both the level of infrastructure use (so that there are neither too few nor too many trains using the network) and the pattern of infrastructure use (so that scarce capacity is allocated efficiently between different train operators).

The charges are set as to reflect the costs one additional train running on the tracks puts on society. If charges are correctly set from the point of view of social efficiency, theoretically, available infrastructure capacity will be efficiently allocated between train operators.

A second objective is promoting efficient investments in rail infrastructure. Possible ways to do this is by rewarding infrastructure managers for improving cost efficiency, for reducing delays to train services, and by giving the infrastructure managers motivation and insight to expand the network where the potential demand is biggest.

A third objective for railway infrastructure charging is to decrease the need for public funding by introducing charging rules that assure cost coverage of infrastructure investments.

In practice there will be a conflict between efficient provision of train services and the objective of financing the infrastructure investments, and therefore it is necessary for the policy maker to consider what the most important goals to achieve are.

When are slot allocation charges needed?

There are ways to allocate track in time and space without slot allocation charges. Before the liberalisation of the railway market, the timetabling procedure was a task of the railway company, and the timetabling procedure did not involve any conflict with other operators. As more operators enter the market, the body that designs the timetable has a increasingly demanding job, trying to make a timetable that doesn't discriminate operators and at the same time takes the public demands into account. It should be clear that all these goals become impossible to fulfil as the number of operators grows. In this situation a market for slots may be a good solution.

Implementation Issues for Slot Auctioning

System costs as **congestion costs and scarcity costs** are difficult to assess and to charge for. Therefore, a way to calculate these costs is to implement **auctioning systems**. Whereas the worst way of measuring these costs is by means of a dysfunctional auctioning system, careful attention should be paid when implementing such mechanisms. Hence, recommendations for methodology to calculate these costs can only be done for a given railway system, assessing the level of competition, the ability to control cooperation etc. and the level of these costs.

Some networks do not have very much congestion, while others are severely congested. Complexity of calculation methodology should also be able to reflect the potential benefits of these calculations.

In regimes where well functioning auctioning system is unlikely, the congestion costs can be partly taken care of by either one or more mark-ups for congested areas in time and space, or cost-benefit analysis of different alternative timetabling solutions. The latter may be sufficient in very small networks only.

In any case, this calls the attention to the concept of "train paths" or "slot allocation" related to capacity allocation should be seen as a crucial factor in the provision of track access service, together with charging principles. In fact, capacity tends, to become a scarce commodity in most corridors, with regard to departure times, arrival times and transit times. Existing timetables favour the established rail operators with multiple train paths at times that suit best their business and with preferential transits that minimise the number of crossing delays. New operators risk being left with train paths that do not meet commercial or operational needs, but still costing the same, possibly even more than those of the major operators.

This places new entrants in disadvantageous positions in relation to existing rail operators, in particular if we think about one of the most promising market segments for rail represented by freight. Hence there is a clear and real need to rationalise train paths allocation along with suitable charging mechanisms, in order to provide a level playing field between the railway undertakers while promoting the railway as a true alternative to road, in particular concerning freight transport.

In practical terms, *Slot allocation* mean everything from a round table designing the timetable to an advanced auctioning system for slots, bundles of slots etc. IMPROVERAIL has explored the relevance that lies in auctioning procedures, describing many of the problems and pitfalls that such methodologies induce. A hasty introduction of such systems is therefore not recommended, because the efficiency of the timetabling procedures might end up reduced, instead of increased.

To this respect it has been seen that Auctioning systems for residual slots may be a first step towards an auctioning system for the majority of slots in the future. Such advanced system is likely to function only in situations with mature competitive railway markets.

Such a market should have multiple operators that are able to deliver the same type of services. In addition public transfers to railway units should be clearly visible. For example public transfers to bidders may destroy the competition altogether: Such contestants should stand on equal terms, so that the bids reflect their underlying and potential productivity and not their access to public money.

The quality of the infrastructure is also critical in valuation of the service being provided. The track condition is a key factor, as there are large sections of track that cannot accept the top speed of high-speed trains. These substandard track sections reduce the ability of the traffic planner to maximize the efficiency of train paths. This causes sub optimal transits and increases the operational costs of the railway undertaker.

Slots sold to competing operators, should be sold in some way that reflects the Willingness To Pay (**WTP)** of the operators. Furthermore, slots may include **quality variables**, where WTP should reveal the market preferences and valuation. **RailNet Europe** is a promising tool in order to provide help to international traffic, representing a forerunner example in providing more transparency to the railway slot allocation.

Finally, infrastructure charging and slot allocation procedures can be performed within all present regulatory regimes. However, the way that the IM is functioning will strongly affect how the market will perform. But auctioning systems based on market mechanisms will not necessarily lead to better performance of the railway system. These methodologies do demand transparent public transfers to railways as well as a real competitive market for railway services, without which most of the advantages of efficient slot allocation will not fulfilled.

6.6.3 Building Contractual Relationships with Railway Undertakers

Agreements between Infrastructure Managers and Railway Undertakers need to address the levels of performance of both parties. The issues of termination, insurance and cost retrieval need to be reviewed and brought up to commercial grounds. Requests for train paths and negotiations for agreements should be given time frames and standard procedures and documentation introduced to facilitate this process.

With regard to the legitimate expectations from the railway demand side (Railway Undertakers), some crucial aspects should deserve special attention in the application of slot allocation, such as the preferred duration of the contracts between infrastructure managers and train operating companies, which differ considerably between parties.

In order to make an investment in rolling stock worthwhile for a train operator, the operator will want to have a long contract in order to guarantee stability of fees; the infrastructure manager on the other hand will want to maximise flexibility by having contracts as short as possible. *Grandfathering* partly solves this problem, but will also act as a barrier against new operators entering the market.

Slot allocation presumes a free market with competing parties. In the case of railways, the market might simply not be big enough for genuine competition, as in the case of scarcely populated countries. To reach the full economic and operational potential of slot allocation in these cases might be hard, if not impossible.

Penalty systems could be applied, but determining how much damage is caused by a delay is very difficult; the time of the delay is a factor but also the number of trains affected by the delay. Finally it is not always clear who is responsible for delays. However practical systems can be developed, accepted by both parties and put into practice, as the example of the private concession of Fertagus in Portugal clearly shows. RUs will also require flexibility from the IM side in allocating alternative paths, allowing operators to meet sudden changes in demand; and flexibility with re-routing in case of sudden obstructions or other unexpected problems. This means clear and up-to-date information from the IM side, providing the operators with transparent conditions, options and possibilities through high-quality Business-to-Business (B2B) information systems.

A well-functioning and flexible system must be offered to the various operators, rules that are imposed should be considered fair, operators must perceive to be using a good product. New systems are only accepted if they work well.

6.6.4 Charging In Cross-Border Corridors

Opening up for, and experiencing more cross-border traffic, passenger traffic as well as freight, will give us more information for what obstacles and problems related to the different regulatory environments. The market will therefore reveal costs and preferences, so that in near future we will have more information for choosing among different regimes. However it is already possible to anticipate that fair and non-discriminatory charging is an absolute demand in order to develop cross border traffic and competition in the years to come, supported by harmonized national jurisdictions and regulatory environments.

As there is a risk of inefficient rerouting of trains caused by different national charging practices, charging should be based on real internal and external costs in all countries, a requirement for the market to function close to optimal.

Furthermore, the key word is not harmonisation alone, but transparency: All prices must be visible as well as money-flows. Through a more developed international railway market with transparent regulation, financial flows and charging principles, the way that charging principles should be harmonised will be more visible.

However, there is a risk for welfare redistributions between countries, where countries near the hubs in central-Europe may pay for wear and tear of traffic that are to the benefits for countries positioned further out of the centre. This is an argument against lump-sum pricing and in favour of kilometre-dependent charging.

In an international environment the non-discrimination of IMs must therefore be secured. If one IM charges above SRMC, other IMs will suffer a relative disadvantage. On a specific route, an operator may be able to pay high transfers to one IM if the rest of the route is run on tracks where only SRMC is charged. In a system where all operators charge the same contribution margin above SRMC, this relative disadvantage would disappear. Harmonization of charges should be secured by introducing the same charging methodology in all states. If costs are varying between states, charges should also vary between states.

Overall, cross border railway traffic, heavily dependent on each national charging scheme, priority rules and bureaucracy issues should enjoy common and wide understanding from IM related to charging principles, further ensuring transparency, predictability and non-discrimination. To this end, SRMC-pricing seen as a common denominator should be able to meet partially such requirement, in addition to complementary fees as extolled in the recent charging Directive laying down charging principles.

By way of exception the Directive allows infrastructure managers to levy mark-ups, if the market can bear this, on the basis of efficient, transparent and non-discriminatory principles, while guaranteeing optimum competitiveness, with regard to international rail freight.

In addition, charges of each line at all times of the day should be available for all parties upon request. Websites are a good alternative for letting international train operators gain immediate access in order to plan, register and price a specific train route.

This further calls for international surveillance, in order to secure that market power is not abused, to this end being more important to ensure that common charging principles are shared among European Infrastructure Managers than pursuing the harmonisation of the charges themselves

7 BENCHMARKING AS A TOOL TOWARDS CHANGING EUROPEAN RAILWAY SYSTEMS

7.1 Introduction

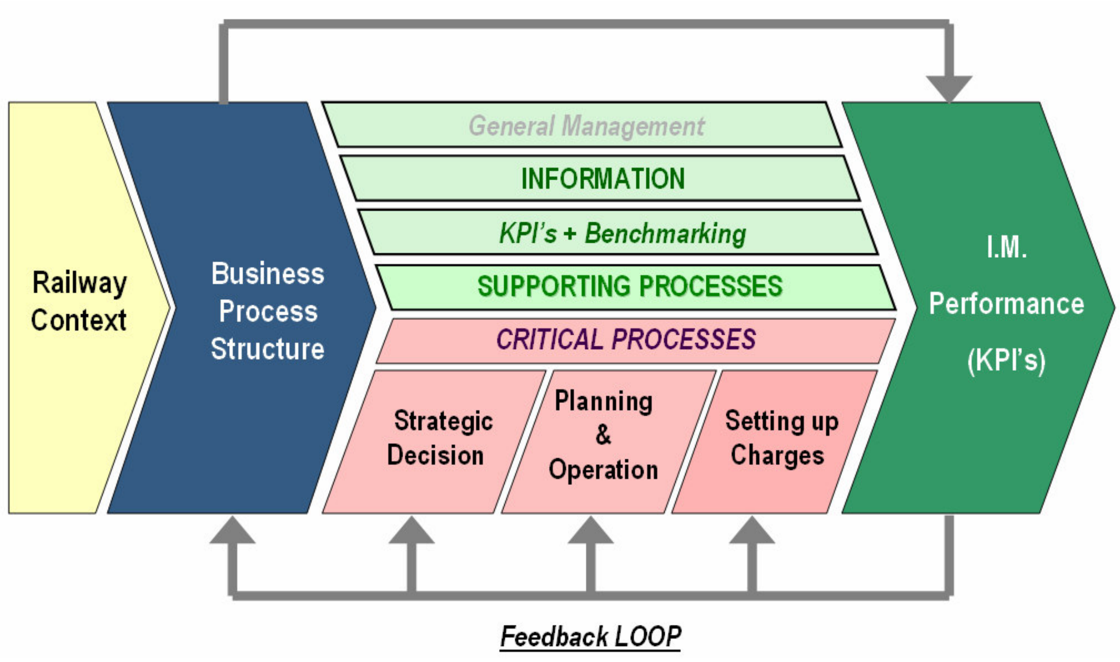
The aim of the Benchmarking part of IMPROVERAIL has been the development of methodologies for comparative analysis within railway infrastructure firms. The approach adopted covered from definitions and harmonization of concepts for benchmarking methodologies to final assessment of the operational, commercial and managerial performance of the railway infrastructure managers, using a integrated approach. This process has included the definition of proper and specific indicators for the industry.

The final goals of this benchmarking exercise have been to stimulate the exchange of information between stakeholders, promote standardization processes in the industry and contribute to better management of information within the industry. As such, IMPROVERAIL Benchmarking has dedicated to the development of benchmarking methodologies, frameworks and indicators for future benchmarking.

This conceptual exercise has kept a link to the core vectors analysed along the whole project, which are reflected in the scheme in the figure below. Bench,marking appears as the last of those vectors, understood as the assessment of IM's performance in view of the application of best practices.

Benchmarking will now be presented as a key part of the activity of the IM, driving continuous improvement in all areas and processes required to carry out the IM activity, such as **Strategic Decision Making** linked e.g. to Long Term capacity management, **Planning and Operation** linked e.g. to Short Term Capacity Management and Maintenance & Renewal and **Setting Up Charges.**

Figure 21 – Structured IM Business Overview



In result of the continuous flow of structured information that Benchmarking should enable, the feedback from critical processes are considered in a self assessment exercise that should be occur periodically in order to keep tight control on the IMs activity and business environment.

The key characteristics of the benchmarking methodology developed and proposed in IMPROVERAIL is that it should cover all the dimensions of the IM, and not only the traditional dimensions related to e.g. costs or reliability . Infrastructure Managers should therefore adopt both performance and process benchmarking in a process that must be supported by the Infrastructure Managers themselves. To this end, a commitment to continuous improvement and search for best practices is required.

7.2 Defining Benchmarking - The implication of choosing the right definition

Numerous definitions of benchmarking have been developed. The most successful exponents emphasize action, processes and the implementation of change, not accuracy in data comparisons:

For *Main*[8], "benchmarking is the art of finding out, in a perfectly legal and aboveboard way, how others do something better than you do - ***so that you can imitate - and improve upon - their techniques***".

Camp[9] called it "**the search for industry best practices that will lead to superior performance**." He was director of bench-marking at Xerox in the early 1980s as they pioneered it"[10, 11, 12] He quotes Kearns: "Benchmarking is the continuous process of measuring **products, services and practices** against the toughest competitors or those companies recognised as industry leaders."

This defines benchmarking as primarily external. "Major competitors should be the primary concern of any company, [but] you can also benchmark against other companies that set the standard in a functional activity."[13] In 1989 Xerox increased the number of performance elements from 14 to 237, and started collecting data on world-class benchmarks, the best performance in any industry[14].

In other words, benchmarking is the process of identifying the best practices and approaches by comparing performance in specific areas within one's own company with the performance of other organisations both within and outside the industry[15]. However, "**the aim should not be to bring back targets from benchmarking programmes, but to integrate ideas for improvement**.[16]"

Karlöf and Östblom[17] widen the definition to "the making of measurements with reference to a fixed data point," thus including internal benchmarking. However, there is a severe danger in using such a definition: when benchmarking is not oriented towards improving performance, it can become no more than an excuse for inaction – and often a highly expensive one. **If top managers do not want to implement change, they should not waste their money and efforts on benchmarking.**

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[8] *How to steal the best ideas around.* J. Main. Fortune, 126, (8), p.p. 102-106. 1992

[9] *Benchmarking: the search for industry best practices that lead to superior performance.* R. C. Camp. Milwaukee, WI:ASQC Quality Press. 1989.

[10] *Benchmarking as a mixed metaphor: disentangling assumptions of competition and collaboration.* J.R.W. Cox, L. Mann, D. Samson. J. Mgmt Stud. 1997.

[11] *Using competitive benchmarking to set goals.* H. K. Vaziri. Quality Progress. 10/1992.

[12] *Co-operative benchmarking: a tool for partnering excellence in construction.* H. Li, et al.. International Journal of Project Management. 2001.

[13] *Benchmarking: What it is and What it can do for you,* Xerox Corporation, Rochester, NY

[14] Xerox *Malcolm Baldridge National Quality Award Application Abstract*, , Xerox Corporation, Rochester, NY 1989 Subsequent Xerox details from original 1979-89 studies.

[15] *Dare to Compare for Better Productivity.* Jonathan D. Weatherly. HR Magazine. pp.42-46. 9/1992.

[16] *Case Study: Benchmarking linked with corporate strategy at Xerox, L.* Moseley, FM Focus Vol 2/4, Eclipse Group, London, Nov 1998

[17] Op.cit.

The following is a traditional viewpoint for the definition of benchmarking, as defined by the EC –BEST Programme:

"Benchmarking is a practical tool for improving performance by learning from best practices and understanding the processes by which they are achieved."

It is this philosophy which has driven the IMPROVERAIL methodological framework with regard to benchmarking. However, IMs may wish to use benchmarking for other purposes, such as achieving a better understanding of costs for forecasting and better project predictability, or for the monitoring contractual performance (e.g. train operating companies, maintenance suppliers, etc.).

7.3 Categories of Benchmarking

Most reviews distinguish up to 7 categories of benchmarking, the first three concerned with what is being benchmarked and how, and the next four with the benchmarking participants. All benchmarking will fall into both sets of categories, but many projects may overlap over different categories:

Table 9 Categories of benchmarking[18]

Types	Definitions
Performance benchmarking	The comparison of performance measures to determine how good our company or unit is as compared to others and identifying possible improvement.
Process benchmarking	Methods and processes are compared to improve the processes in our own company or unit and identify and implement best practice.
Strategic benchmarking	Radical differences in practice and performance in other industries or markets may suggest that such levels of change are possible that the company may be able to introduce a new competitive paradigm for a company or industry. Organisational structures, management practices and business strategies may be compared[19].
Internal	Comparisons made between departments/divisions of the same company or organisation.
"Competitive"	Performed against companies manufacturing the same product or delivering the same service to compare performance, processes, organisation and results. Often used to gain market share over competitors, but also used by both direct competitors and similar, non-competing companies to improve practice, reduce cost and grow the size of the total market.
Functional	A benchmarking study to compare the technology / process in one's own industry or technological area but using a collaborative approach. The purpose of this type of benchmarking is that all should learn from the best in each process and adopt the best appropriate technologies and practices.
Generic (world class)	Comparison of processes against world class best process operators in any relevant industry. The purpose is similar to that in functional / industry benchmarking, but may also address issues such as organisation and strategy.

[18] Adapted from: Moseley, 1998, *op.cit,* quoted by Bhuttan and Huq, 1999, and with material from Bogan and English, 1994

[19] *Benchmarking for Best Practices.* C.E. Bogan, M.J. English. McGraw Hill. New York, 1994

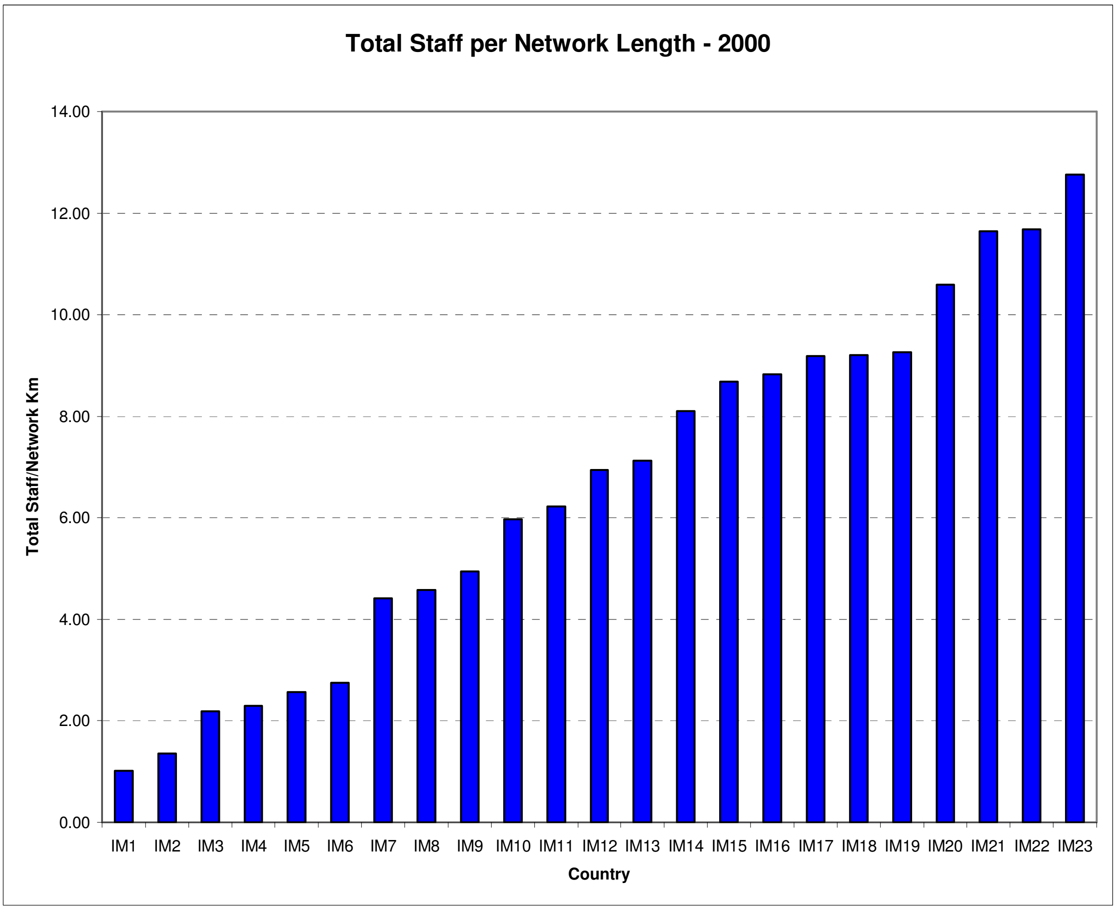
Railway benchmarking has concentrated mainly on performance and process benchmarking to reduce cost and improve customer service and safety. Strategic benchmarking is less common, because of the huge investments involved in building new railways according to a different strategic paradigm. Yet arguably, some of the biggest changes in the railway industry have come from precisely these new paradigms – the high speed passenger services TGV, ICE, AVE etc. on the one hand, and a few highly market-focused railways like the Heathrow Express, Hong Kong Airport Line and other premium-priced airport expresses on the other. However, most IMs will be primarily concerned with benchmarking those parts of their network which constitute the bulk of their investment, revenue and cost base.

7.4 Expected Benefits from railway benchmarking

Railways and metros have achieved some substantial results from benchmarking over the past few years. However, It is the adoption of best practice which generates the clearest immediate benefits. More or less all of an IM's functional areas can benefit from benchmarking to improve performance. Some examples of ways in which integrated railways or IMs have already benefited from benchmarking projects in the past, and functions which have benefited, include the following:

- Ideas for revenue generation, through telecommunications, property developments and other "lifestyle services" as JRE (Japan) describe them, have been adopted by FS (Italy)
- Better maintenance methods and ways of setting targets for performance have been two of the benefits available from various studies: INFRACOST I-IV, Railbench and the IMPROVERAIL delay attribution and asset monitoring pilot case study.
- British Rail were able to get more focus and better value from their R&D expenditure as a result of looking at how SNCF, DB and other industries carried out their programmes
- Increase in line capacity – London Underground achieved 4%-19% more capacity, New York City Transport 4.5%-17 %, in both cases with almost no capital investment.
- Adopting world best practice in maintenance methods led to significant reliability improvements for London Underground (+137%), MTRC (Hong Kong) (+61%) and RENFE (+99%).
- Station Management rationalisation by MTRC (HK) resulted in a 8% reduction in station staff. This came from comparing their functional profile and degree of supervision with other metros.
- MTRC (HK) asset replacement programme was expected to achieve savings of US$150 million by experimenting with life extension methods used in other railways, notably in London.
- Several metros have used benchmarking to achieve better government regulation.
- A comparison of national railways' telecommunications activities identified potential savings of 34% for one railway, while comparisons of maintenance methods have already resulted in higher availability and a lower need for rolling stock.

The most common reason for starting benchmarking is to reduce cost. There is huge scope for this amongst European railways. This next chart shows that the highest labour cost railway on the basis of train.km pays four times as much than the lowest cost operator (undisclosed IM's), even after adjustment for purchasing power parity in the different countries. The figure shows that in numbers of staff per network km, the difference is over 600%, using a larger sample.



The figures need adjustment for the degree of subcontracting, which might lower the total railway wage bill by perhaps 20-30%. However, 20-30% is immaterial compared with a difference in payroll cost of 400%. The figures demonstrate what benefit higher cost railways might be able to gain from learning from railways such as IM3 (in this case Norway), who have low cost in terms of train km and high efficiency per network km.

If their good performance were only per network or track km, one might ascribe it to geography or to a high proportion of single track routes, but low cost per train km is generally associated with high density operation – the opposite geographical characteristic. By looking at both together, we conclude that a significant part of their good performance is likely to be from good practice.

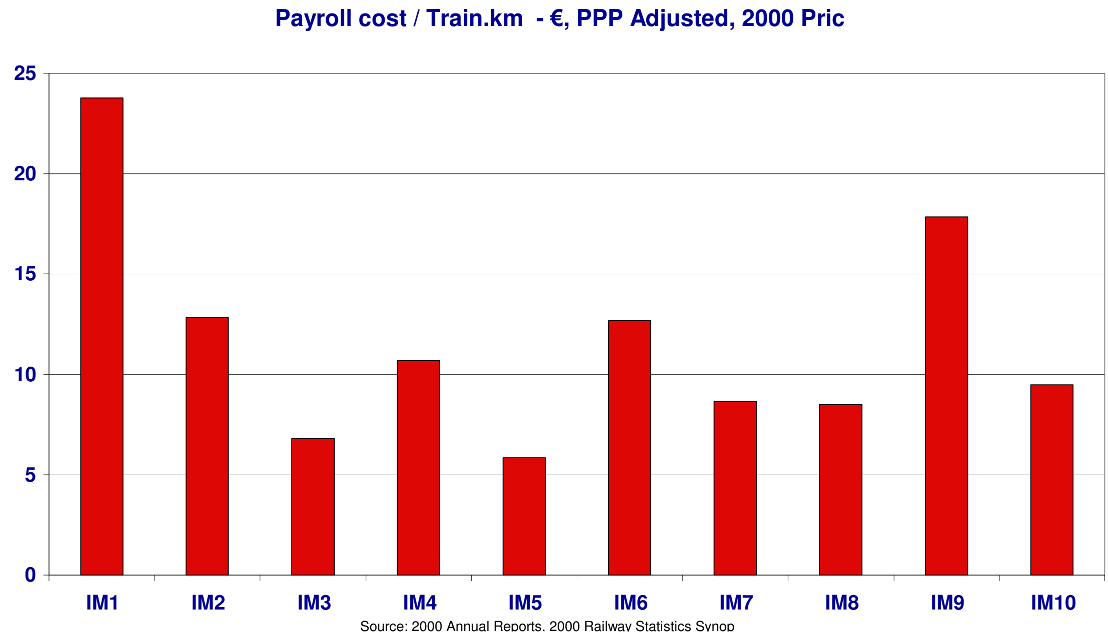


Figure 22: Staff costs compared with traffic volumes

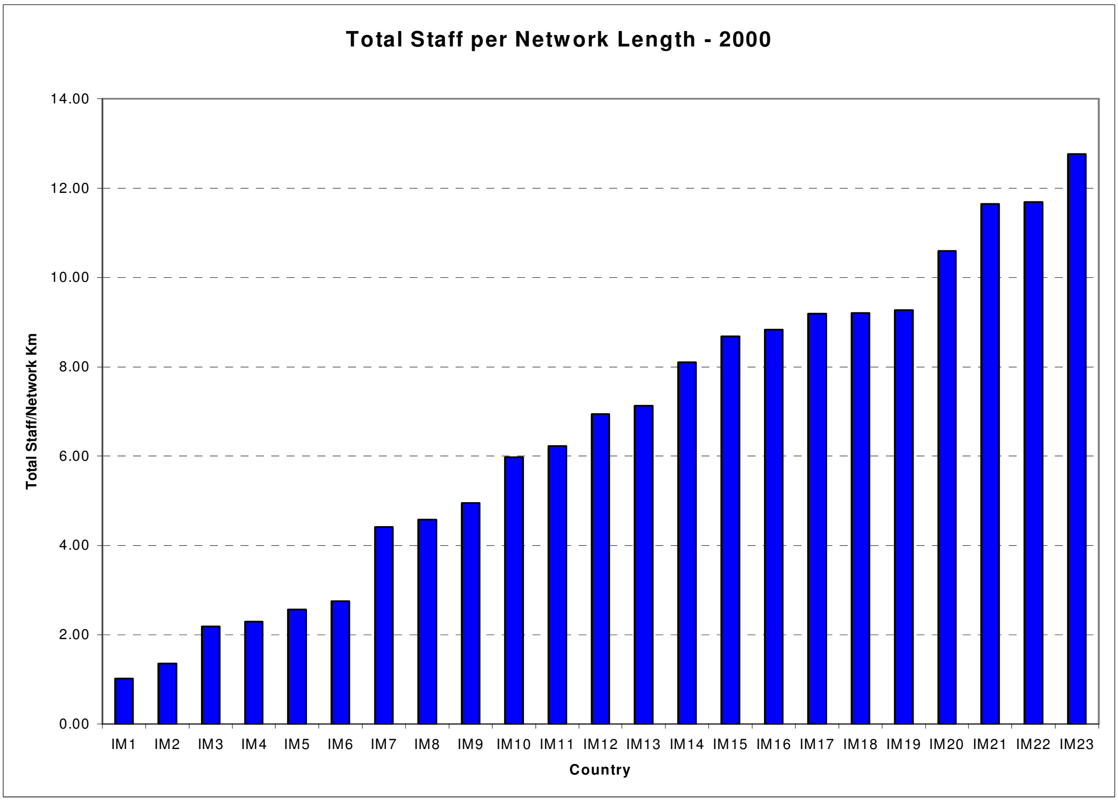


Figure 23: Staff levels without consideration of network utilisation

Of course, these figures in both the above charts are on an integrated railway basis, because no European-wide figures are yet publicly available to compare IMs – even if IMs carried out the same remit as one another, which is not the case.

The essential point is that the above comparison demonstrates that there is enough difference between cost levels to justify further study. Indeed, INFRACOST I-III has already investigated the cost of new line investment and line maintenance cost: but a study of other functional areas such as infrastructure operation and the efficiency of the relationship between IM and train operating companies in reducing overall manpower requirements might well bring substantial benefits.

A study of cost is not generally where the "quick wins" come from. Some of the greatest benefits of benchmarking come from adopting practices which enhance quality and reliability, in which Japanese and Hong Kong railways are far ahead of Europe. As we discussed above, RENFE have used best practice benchmarking for some time and have adopted some Japanese quality management techniques, as the Railbench and IMPROVERAIL pilot studies found. They use internal benchmarking between individual services, routes and even stations, and have compared themselves with other railways such as DB and FS. Like Xerox, they place more emphasis on improving quality and reliability than on reducing cost, though they are in fact cost leaders in certain respects as well. The result is that they have become one of the best performers in Europe in terms of punctuality. Their profitability has improved substantially, partly in consequence.

The extensive use of benchmarking by SBB, RENFE and the Netherlands railway is in line with a study of 500 companies by Ernst & Young, who found that it is the relatively good performers, not the low and medium performers who get the most benefits out of benchmarking. The CoMET and Nova programs also bear this out. Leading companies are less afraid of identifying areas in which they perform poorly, recognising and addressing the issue with concrete action. In general, they are the most open to outside ideas and practices.

As Boxwell said, understanding and changing processes is more important than merely comparing data[20], which is only the first part of the benchmarking process. Poor or medium performers find fault with the data and use lack of comparability as an excuse for lack of action. However, railways such as the Mass Transit Railway Corporation of Hong Kong testify that they have been able to obtain benefits from benchmarking running into hundreds of millions of US dollars, even in cases where the data contained demonstrable differences in measurement. **All that is really required of the data is to identify the best performers** so that other partners can find out what they do differently and learn from them.

Railways have achieved substantial results through benchmarking, both in terms of profit and cash flow improvements and in customer service and satisfaction. Some examples include:

- Increase in line capacity – London Underground achieved 4%-19% more capacity, New York City Transport 4.5%-17 %, in both cases with almost no capital investment. They selectively adapted dwell time control and passenger management methods used by Far East railways. These were mainly process changes, though an infrastructure manager might be responsible for some equipment, e.g. departure clocks. This shows the importance of integrated planning: the train operator can resolve capacity problems which would otherwise require far greater investments in upgrading or replacing signalling systems.
- Adopting world best practice in maintenance methods led to significant reliability improvements for London Underground (+137%), MTRC (Hong Kong) (+61%) and RENFE (+99%). CoMET and Nova have carried out these studies for both rolling stock and infrastructure reliability and maintenance.
- Station Management rationalisation by MTRC (HK) resulted in a 8% reduction in station staff. This came from comparing their functional profile and degree of supervision with other metros.
- MTRC (HK) asset replacement programme was expected to achieve savings of US$150 million by experimenting with life extension methods used in other railways, notably in London.
- Several metros have used benchmarking to achieve better government regulation.

[20] Boxwell, 1994

- A comparison of national railways' telecommunications activities identified potential savings of 34% for one railway, while comparisons of maintenance methods have already resulted in higher availability and a lower need for rolling stock.

A key factor in achieving these benefits is an open attitude to other railways and to change, leading to a readiness to experiment with other railways' methods observed during the project or documented as good or best practice in the report. Successful participants recognise their responsibility for making use of such insights and not waiting for complete comparability of data before running pilot projects.

7.5 Learning from previous Railway Benchmarking Initiatives

Comparing e.g. the CoMET/Nova, INFRACOST and IMPROVERAIL approaches, the main differences have been in the objectives of the participants, the level of detail of each study, and the choice of topics covered. The first four stages of INFRACOST were mainly concerned with lowering the life cycle cost of infrastructure, while CoMET/Nova have been more concerned with optimising processes and investment to deliver higher quality services (though also at lower cost where possible).

Three process benchmarking case studies were undertaken in IMPROVERAIL. Of these, one was concerned with safety improvement, another with improving service reliability and the third with optimising procurement processes. Like the CoMET/Nova studies, these have all been relatively short, low-input studies to identify those railways with best practice management approaches and indicate what those are, not to provide detailed cost targets and cost driver analysis, which only a major high-input study such as INFRACOST can provide.

However, the basic methodology of CoMET/Nova, INFRACOST I-III and IMPROVERAIL is very similar: in each case, the project starts out from an analysis of relative performance, which identifies high and low performers. It then passes to an analysis of the reasons for variances in performance, which inevitably leads to an investigation of the differences in process methods or uses of different technologies.

The differences in the methodology are mainly that

- INFRACOST I-III falls into the "competitive" or functional categories as described in the table, together with internal comparisons where multiple projects are considered. It also goes to some length to calculate target or "harmonised" cost for a standardised reference case.

- Most CoMET/Nova studies also include an element of world class benchmarking from other industries, and some contain internal comparisons as well, but concentrate more on identifying best practice than on calculating "harmonised" cost. The participants of those studies felt that once the best practice was identified, it could be left to the individual participant to invest the amount of resources that each felt was required in order to obtain the benefit. Once they had found better ideas, they preferred to base their targets on the leverage of anticipated benefits of the new processes on their existing cost base. This was also the approach in Railbench.

- IMPROVERAIL's top level KPI analysis is more akin to a "competitive" comparison, while all three IMPROVERAIL pilot case studies were functional studies,. It was hoped to analyse specific corridors compared with the corporate approaches as well, but not enough data was obtained.

From the above examples, it will be clear that the categories often overlap, and it is a mistake to get too concerned with categorisation.

Since IMs are very rarely in direct competition with one another, unlike bus or train operating companies, there should logically be no confidentiality problems in exchanging data with other IMs, provided assurances are given that the data is not then passed outside the peer group of railways. This is the practice in CoMET/Nova and was proved in practice during the IMPROVERAIL practical benchmarking exercise, since only one of the IMs who participated in were concerned to keep their data confidential. "Competitive" benchmarking can then be conducted on a collaborative basis, more like functional benchmarking.

A much greater problem is often experienced in finding the right person in the organisation who knows what data is available, and how to obtain it. A second problem is that key performance data which is readily available in and heavily used by the leading railways is simply not collected yet in many other railways. However, these problems do not need to determine which benchmarking method is used.

7.6 Conclusions and Recommendations

To attain improvement in the long term based on Benchmarking can only be successful if top management is committed to opening up to outside ideas and implementing best practice. Otherwise little benefit will be achieved.

The most common drawback of usual benchmarking approaches is that they require far greater resources than the classic benchmarking for best practice. To set target costs, for example, requires much more harmonisation of the figures than the identification of practices which can improve cost levels. The IMPROVERAIL benchmarking framework, as detailed in this document, is therefore mainly dedicated to the identification and implementation of best practices. We propose this benchmarking philosophy in IMPROVERAIL precisely because of the historically resourceful difficulties in achieving absolute comparability in performance measurements.

About the concept itself, numerous definitions of benchmarking have been developed. The most successful exponents emphasize action, processes and the implementation of change, and not accuracy in data comparisons. About the advantages of Benchmarking best practices, Hirsch[21] described e.g. how internal benchmarking exercises revealed that better market segmentation in units within the same company could improve branch profitability by 600%, and in another case, how differences in operating practice between divisions led to error rates of 33% in one and 12.5% in another.

Similarly, the CoMET benchmarking programme[22] found that differences in practice and performance between units in the same company were sometimes as great as between companies across different continents. Internal benchmarking is the easiest to implement, because differences between units are smaller and reasons for performance differences more understandable. In companies that are open to change, however, Leibfried & Mcnair were right in agreeing with Camp that competitive and world class benchmarking is the most valuable. Radical breakthroughs normally occur only when ideas from other industries or continents are introduced[23].

In general , the most common reason for undertaking benchmarking has been to bring cost levels down and efficiency levels up to those in other countries – especially European and American companies finding themselves well behind Japan on these measures. The higher performance of their Japanese competitors was the driving reason why e.g Xerox, General Motors, Ford, Renault and other large companies participated in benchmarking. The same applies to railways.

On a cost per passenger km basis, east Asian railways have a great deal to teach most European railways. However, it is particularly in the field of reliability and service quality that they now excel on a worldwide basis. CoMET and Nova metros and railways such as NS Reizigers and RENFE have applied lessons from the Far East with great benefit, as the IMPROVERAIL research and previous studies undertaken by Imperial College have revealed.

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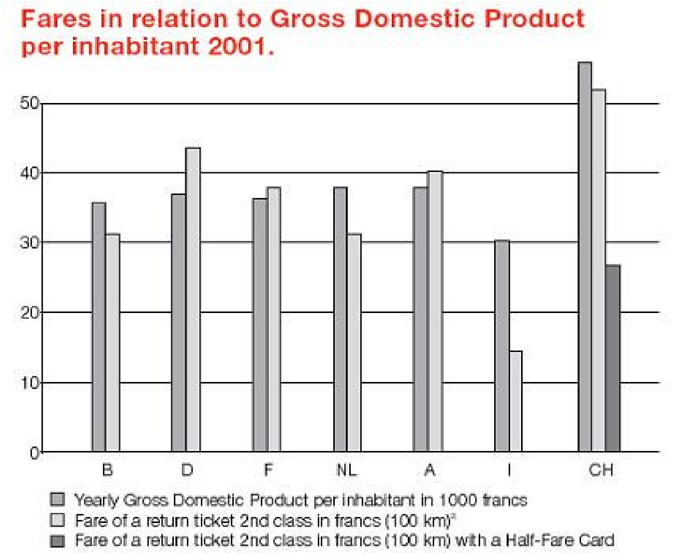
[21] *Getting the Ratios Right,* R Hirsch, Management Today, April 1990.

[15] *Making a real difference to performance: global benchmarking in railways,* R. Hirsch and W. Adeney, 2nd Conference on Performance Measurement, Cambridge, July 2000, pub. Centre for Business Performance, Cranfield, UK.

[23] Weatherly, op.cit.

It is not just Asian railways that one can learn from. SBB put comparisons of European railways into their annual report, revealing e.g. that the number of staff per network km for Belgium is over 4 times as many as for Spain. This alone has huge implications for cost, though of course the figures are only directly comparable after adjustment for train km per network km. The same table shows that the Swiss railway is the most electrified in Europe, with 99% of the network electrified compared with 31% for Denmark. By implication, SBB are comparing the degree of innovation previously undertaken. We also see that the Swiss take 40 railway journeys a year compared with 8 for Italy, 14 for France and 19 for the Netherlands – in spite of fares considerably above the Italian, French and Dutch levels, as their next graph shows:

Figure 24: Fare level comparison in SBB's 2001 Annual Report supplement



This is an example of benchmarking being used to formulate corporate strategy and sell it to customers and the state. It applies to the integrated railway, but a similar approach could be taken by an IM.

SBB are effectively using the data to show that their high performance approach is at an acceptable cost to Swiss passengers, who generally earn more than the inhabitants of the other countries mentioned. Netherlands railways also use benchmarking. They have recently described how they have used comparisons including Japanese and European railways to formulate their strategy for a high frequency, low cost railway with good reliability, and to set targets. Irish Rail used benchmarking to change their priorities from cost reduction to improving their service offering, with implications for investment in infrastructure and rolling stock, as well as investigating and adopting best practices in other European railways.

It is the adoption of best practice which generates the clearest immediate benefits. More or less all of an IM's functional areas can benefit from benchmarking to improve performance. Some examples of ways in which integrated railways or IMs have already benefited from benchmarking projects in the past, and functions which have benefited, include the following:

- Ideas for revenue generation, through telecommunications, property developments and other "lifestyle services" as JRE describe them, have been adopted by FS
- Better maintenance methods and ways of setting targets for performance have been two of the benefits available from various studies: INFRACOST I-IV, Railbench and the IMPROVERAIL delay attribution and asset monitoring pilot case study.
- British Rail were able to get more focus and better value from their R&D expenditure as a result of looking at how SNCF, DB and other industries carried out their programmes

There may be reasons for benchmarking other than to improve performance. These include:

- Explaining the situation to stakeholders (e.g. regulator, financiers, government)
- Justifying an appropriate level of financing from government,

- Justifying an appropriate level of track charges from the regulator
- Better understanding and forecasting of costs and revenues, leading to better project predictability
- Setting target cost levels
- Monitoring contractual performance (e.g. train operating companies, maintenance suppliers, etc.)

Benchmarking may of course be used for these purposes too. Setting target cost levels may also imply performance improvement. However, if benchmarking does not lead to improvement in the long term, it is a waste of resources. Moreover, if improvement is not the main objective, if top management is not committed to opening up to outside ideas and implementing best practice, little benefit will be achieved.

The other drawback of these last five reasons for benchmarking is that they will require far greater resources than the classic benchmarking for best practice as originally developed by Xerox. To set target costs, for example, requires much more harmonisation of the figures than the identification of practices which can improve cost levels. The IMPROVERAIL benchmarking framework is therefore mainly dedicated to the identification and implementation of best practices.

7.6.1 The Importance of Key Performance Indicators (KPI's)

Key Performance Indicators are "key" because they measure what is critical to the success of the company. In many cases managers are not even clear what constitutes success. This applies throughout industry and commerce, but it is particularly common amongst companies which have been for many years dependent on government subsidy, such as railway infrastructure management companies (IMs).

Success consisted merely in satisfying government and doing whatever they wanted the company to do – which might change with a change of government. It is difficult even to have a vision or strategy, when it is so dependent upon factors outside management control. In leading commercial companies on the other hand, top management ensures that the vision drives the company, and that as many employees as possible understand exactly what the vision is and what constitutes success. Amongst railways, the question "what proportion of your employees are aware of the vision and strategy of the company?" meets with derision in all but a small minority. However, those are the leading ones, such as RENFE and SBB – and most East Asian railways, where quality is of the highest importance and the railways are profitable and autonomous, if not privatised.

They have a vision and a strategy, and are aware what the different measures of success are – most of them use the Balanced Scorecard, in company with 50% of leading global companies – and what is critical to creating that success. For them, it is easy then to select key indicators.

7.6.2 The need to define benchmarking entities

General benchmarking methodology is relevant to IMs, but such companies are different in certain important ways from the majority of commercial manufacturing, trading and service companies for whom benchmarking was developed. They are more complex, with less standardisation of business units. It is relatively straightforward to see a factory or a trading unit (for example a branch) – or one of its functions such as invoicing or logistics – as a standard benchmarking entity. The same cannot apply to a railway region, because of the much greater differences between them. Much more adjustment is needed to make a standard comparable entity. This has been therefore a separate step in IMPROVERAIL.

Amongst railway infrastructure companies, functions and outputs are less standardised and definitions differ more from country to country. Partly due to their nature as government-supported or nationalised industries, their accounting principles and practices are also more diverse than companies which operate on a global basis. Railway benchmarking should be considered in the context of these special characteristics. Their figures are less comparable than most companies in the commercial sector.

There are certainly benefits from comparing whole railways, whatever the limitations. We need the big picture, particularly where the results flow directly from corporate top management decisions or from their relationship with the government. For example, in 2001, Amtrak was unpopular with the US government and one reason for its poor state of repair was the lack of government funding to rectify matters. After the appointment of David Gunn, the 2003 state contribution to Amtrak rose from original plans of $523m to $1.1bn as a direct result of his higher credibility with the Administration.

However lacking in comparability national railways are, it is therefore still worth comparing them in total as a starting point. Moreover, as the IMPROVERAIL top level and pilot benchmarking case studies have shown, much of the data is only available at total company level – and at this stage, this means total railway level, since many European national railways do not distinguish the train operation and infrastructure management functions, and even when they do, it is not always on the same basis. This may change, but probably more slowly than currently planned. Our first benchmarking entity is therefore the total railway, and the second will be the total infrastructure management company. However, a direct comparison of operational issues such as cost, reliability, capacity or maintenance strategy cannot be made without taking into account the differences due to the proportion of high speed lines, electrification or the number of tracks, for example. To make valid comparisons, wherever data is available, for operational benchmarking it therefore makes sense to attempt to benchmark comparable parts of railways, rather than the whole company. The entities to be benchmarked can be defined as one or more of the following, usually in combination:

- A product or service – such as High speed, Inter-city, Regional, Local or Freight lines
- A process or set of processes – such as operation, maintenance, administration, monitoring
- An asset or set of assets – such as ticket machines, signals, stations or track
- A relationship or set of relationships – e.g. with authorities, regulators, customers or suppliers.

For operational benchmarking it is better to select an entity with at least two out of the three primary dimensions. Initially, it is better to select a very small number of entities, each with a minimum number of Performance Indicators to cover the main success dimensions.

7.6.3 Selecting Benchmarking Entities – products, processes and assets

During the IMPROVERAIL process it was not possible to obtain data entity by entity, due to the current state of information in most IMs. However, we continue to be convinced that this is the right direction to proceed, and find three confirmations for this:

- ✔ When developing IMPROVERAIL pilot case studies, it was obvious that one cannot compare without adjustment such items as the list of the top 10 causes of delay between two railways with highly different degrees of electrification, since – for example – power failure will only be a significant issue for electrified railways. Similarly, a railway or corridor with a large number of level crossings will have a different safety profile from a corridor with none. Very high utilisation railways cannot be compared with low utilisation ones, but even a low utilisation railway will have certain high utilisation corridors. These can profitably be compared and conclusions drawn.
- ✔ We note that INFRACOST I-III also used a segmented method, comparing cost data for projects with similar characteristics. Some of their distinctions are necessarily more detailed, dividing lines into three categories: plain, open country; urban environments; and those going through hills and mountains, and between high speed lines (over 250 km/h) and other lines. They also suggest that it is necessary to take into account switch density, which makes eminent sense.
- ✔ Leading companies such as SBB, RENFE and RIB or NS Reizigers are already comparing performance line by line, service by service, region by region, station by station. RENFE can demonstrate substantial performance improvements when services are measured in this way.

The KPIs, defined (see Deliverable 3, Appendix A), have been developed to be usable at many levels: the total railway, total IM or segmented by entity. Nonetheless such an approach does not automatically guarantee an adequate level of comparability. If data is available, more sophisticated techniques such as econometrics should be employed if needed.

Table 10- Suggested segmentation of dimensions for entities to be benchmarked.

Top Level	Product / Service	Process	Asset
Top Level	Total company – all services including property etc. All passenger services All freight services	Network planning (new lines &/or stations) Capacity planning Safety system management Calculation of TOC charges Train path allocation	Primary long distance routes/ corridors
Product / service level	Commuter services into a city A specific commuter line Dedicated high speed passenger service High Intensity Mixed Freight And Passenger Intercity Routes	Train path allocation (Sub-) system operation Maintenance Asset condition monitoring Track possession planning New technology introduction	Signalling & train control Track Power Stations Ticketing

We therefore strongly recommend that all European railways should use this segmented approach, for benchmarking both internally and on a European basis.

7.6.4 Reaching Comparability among Railway Infrastructure Managers

A successful benchmarking exercise is not overly theoretical. For example, it is highly desirable to develop simple, powerful Key Performance Indicators (KPIs) with which managers can identify. The use of econometrics and sophisticated statistical techniques can certainly add value to the process, but they should only be used where necessary. To address these issues, the following methodology for the harmonisation of KPIs to use them and to identify and implement best practice has been developed as schematically represented in the next figure

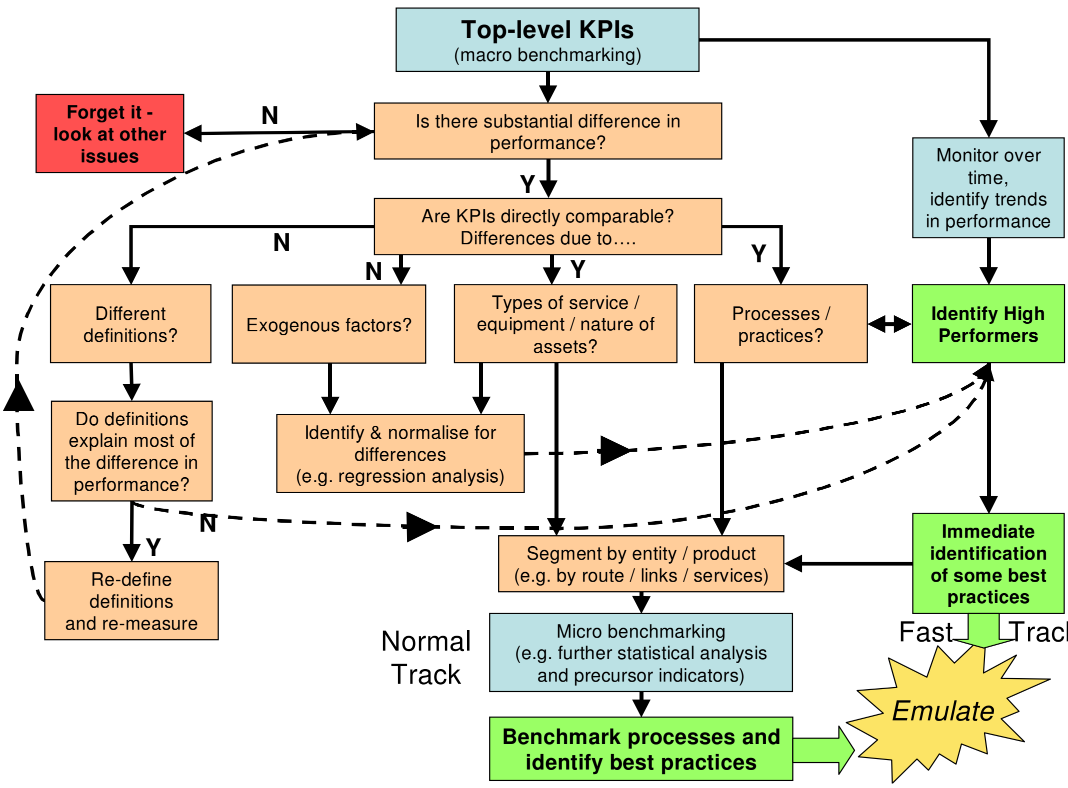


Figure 25 - Harmonising KPIs and using them to identify & implement Best Practice

The figure shows that on occasions it is possible to identify high performers directly from a review of top-level KPIs and to see very quickly what those participants are doing differently. Thus, the benchmarking approach recommended by IMPROVERAIL does not rely on the achievement of 100% comparability in order to identify and emulate best practices. Nonetheless, it is sometimes imperative to segment each IM into different entities (such as specific sections of line or routes). Statistical methods can be employed to achieve comparability, but the results are often difficult to interpret by top-level managers, and they rely on significant levels of resources and data which are frequently not available. Thus, IMPROVERAIL offers a framework for IM benchmarking which is focussed towards finding and emulating best practices and achieves comparability in a manner which does not necessarily rely on detailed, resourceful analysis.

In more complex situations, however, the use for regression analysis in normalising performance statistics from one IM to another can be helpful. Further uses include the completion of incomplete data sets based on statistical patterns, and most importantly, the weighting and disaggregation of different causes for performance levels. Data envelopment analysis (DEA) can also be useful. This is a linear programming technique allowing the combination of various performance indicators into a single measure of overall performance (Odeck, 2001)[24]. The inputs and outputs can be continuous, ordinal of categorical variables, and can be measures in different units. Thus the technique can be applied in a wide range of situations for a wide range of variables. The analysis also allows for the inclusion of correction factors for conditions that one would like to not influence the outcome such as scale economies and variables beyond the control of producers (e.g. geographical conditions). Since the measure of overall performance may be difficult to interpret for some, it may be difficult to convince those involved of the benefits of the technique. Whilst adequate for some comparisons, it has many weaknesses when looking at railways existing in different contexts and environments.

The use of both cross-sectional and time-series data is valuable, as is the analysis of disaggregate data where necessary. Data disaggregated (and re-grouped) by line, service-type, stations and rolling stock will enhance comparability.

7.6.5 Tackling the Barriers to Benchmarking

The definition and measurement of performance between IMs in Europe is currently very different. And for some KPIs, it will take many years to reach a satisfactory level of comparability. However, some benefits from benchmarking can be achieved immediately with incompletely comparable data.

Another issue in the scope of the Information systems are the asset registers, which are not currently adequate for successful benchmarking within most IMs. In fact also accounting systems are different between IMs and furthermore, due to the complex nature and vast scale of IMs, exogenous influences on performance, beyond the control of the IM, can mask the degree to which high or low performance is due to best practices or processes.

The existence of the INFRACOST I-III benchmarking studies, and the amount of resource put into it over the years, suggests that there are already at least twelve European railways that have been committed to exchanging cost data and information about their practices in order to improve their cost performance. This almost certainly implies that they would also be ready to benchmark for best practices in other fields such as quality and safety management systems, where great benefits might be gained from this sort of information exchange.

IMPROVERAIL has shown that not all projects need be as time-consuming and resource-intensive as INFRACOST I-III, and that IMs who have not been involved in benchmarking before would certainly be able to start doing so. It has documented a range of different projects that have taken place, and set out

[24] Odeck, J. (2001), Managing data: using data envelopment analysis in benchmarking, paper presented at BEST Conference 4, October 2001

an approach to benchmarking, and a proposed set of KPIs for the consideration of IMs. The main barriers to effective and mutually profitable benchmarking will be:

- The lack of incentive amongst some IMs to improve performance unless they are given strong encouragement in this direction by the authorities to whom they report.
- A culture of inertia and a concentration on cost cutting to the exclusion of all other success dimensions, which was previously expected of many IMs and is still deeply imbedded in the way of thinking in some countries.
- Inadequate data collection procedures for a variety of functional areas – IMPROVERAIL has identified weaknesses amongst the majority of IMs in all three areas in which pilot studies took place, the monitoring and control of delays and failures, safety management systems (where only a minority of IMs measure precursors or distinguish between major and minor casualties) and procurement (where most have no programmes for moving to a restricted number of approved suppliers as the automotive industry have done, and therefore little or no systematic performance data).
- Inadequate information systems, especially asset management systems

And although different definitions might not a problem in benchmarking, it is certainly true that small differences can only be ignored if the differences in performance are great enough. However, during the IMPROVERAIL pilot case studies, e.g. when the UIC figures were compared with internal figures in many of the IMs, there were often significant differences between

- The figures supplied by the IM to the UIC
- The figures in the railway's published annual report
- The figures published by research and political institutions in the country
- Internal figures from a variety of sources
- The basis on which different IMs or railways have prepared any of the above figures

These differences apply most of all to financial figures, but also to safety and to punctuality and other service quality measurements. For example, in safety figures, some IMs only count collisions that lead to injuries, others include all collisions, however minor; some include level crossing accidents and others exclude them. Hence , the lack of harmonised definitions may also become a significant barrier to IM international benchmarking. IMPROVERAIL believes that these barriers can be overcome but it will take time, focussed, sustained effort and co-operation between IMs. If the KPIs can be agreed and IMs can start to use them, and they can improve their data collection and information systems to the standard of the better railways such as SBB, RENFE or Netherlands railways, the potential for best practice benchmarking will be substantial. However, the change of culture and systems will not be an easy task.

7.6.6 Recommended Benchmarking Approach

IMPROVERAIL strongly recommends that IMs adopt both performance and process benchmarking.

First, performance benchmarking uses Key Performance Indicators (KPI's) to provide direction and objectivity for identifying which areas show the greatest variability and share of the total value chain. In this way it can indicate which areas have the greatest potential for profit and service quality improvement, and are thus the primary business processes to be analysed in process benchmarking. Then it can help to determine best practice leaders, which *process benchmarking* can confirm. Finally, performance benchmarking may also be used to formulate corporate strategy.

It is possible to initiate process benchmarking on its own, but the danger is that the processes being benchmarked may ignore the constraints and requirements of other parts of the railway system.

Performance benchmarking using a balanced scorecard such as that proposed below has the advantage that it engenders a holistic approach, but without process benchmarking it does not provide the analysis to improve performance.

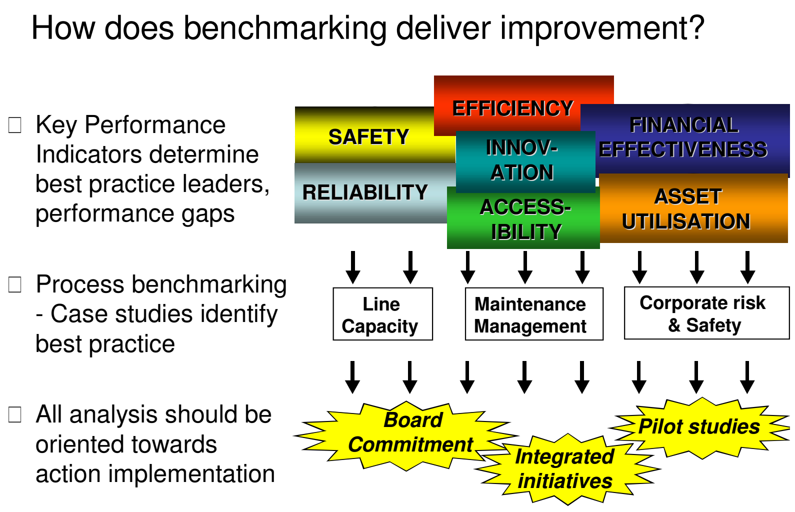
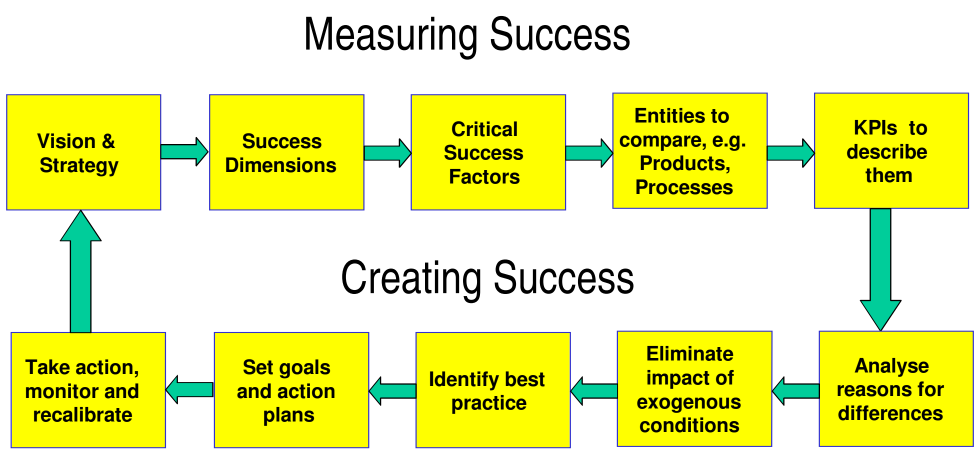


Figure 26: Performance and process benchmarking working together

The figure introduces the concept of "Success Dimensions" such as Asset Utilisation, or Safety. IMPROVERAIL proposes a holistic approach to define KPIs which are useful to the IMs and which cover all aspects of the business. The figure below presents a suitable Benchmarking model for adoption by IMs:



General benchmarking methodology is relevant to IMs, but such companies are different in certain important ways from the majority of commercial manufacturing, trading and service companies for whom benchmarking was developed. They are more complex, with less standardisation of business units. Much more adjustment is needed to make a standard comparable entity. This is therefore a separate step in IMPROVERAIL.

To make valid comparisons, wherever data is available, for operational benchmarking it therefore makes sense to attempt to benchmark comparable parts of railways, rather than the whole company.

The entities to be benchmarked can be defined as one or more of the following, usually in combination:

- A **product or service** – such as High speed, Inter-city, Regional, Local or Freight lines
- A **process or set of processes** – such as operation, maintenance, administration, monitoring
- An **asset or set of assets** – such as ticket machines, signals, stations or track
- A **relationship or set of relationships** – e.g. with authorities, regulators, customers or suppliers.

For example, much higher levels of comparability can be achieved by benchmarking the performance of similar sections of track or corridors, with similar service characteristics. Due to a low level of availability of data within IMs, it was not possible to perform such analyses within IMPROVERAIL.

The development of a set of Key Performance Indicators (KPIs) for IM benchmarking in the future is a key output of the IMPROVERAIL research, which is detailed in Appendix A of Deliverable 3 of IMPROVERAIL. A full glossary of definitions is also included, in response to the feedback from IMs engaged in IMPROVERAIL

The purposes of KPIs include the following:

- To identify priority areas for improvement within each IM
- To identify the best performing IMs in the different success dimensions: These will be the ones to emulate.
- To help determine how much improvement is possible
- To monitor progress over time: if performance has improved, what practices have led to the improvement ?
- To monitor an IM's own progress over time, in order to determine if it is progressing towards its vision and objectives.
- To estimate the effect of differences in processes and practices on actual outcomes
- To set targets for improvement

The KPIs should then be divided into four hierarchal categories:

- **Core KPIs:** For use by top level management (a small sub-set of 20 KPIs which have the most bearing on the success of the IM)
- **Second Order KPIs**: KPIs which support, or provide a deeper understanding of the performance described by the core KPIs, or whose impact on the performance of the IM is of a second order magnitude.
- **Contributory PIs:** Performance indicators which break down the components of a Core or Second Order KPI
- **Pre-cursor PIs:** Detailed (often process-level) performance indicators which describe incidences of events or conditions which may have a significant influence on the core or second order KPIs

IMPROVERAIL has shown that any benchmarking study can take many years to achieve a reasonable level of comparability. KPIs must be developed with full involvement and active participation from IMs.

This was not fully achievable within the scope of IMPROVERAIL, so the set of KPIs presented in this benchmarking framework report are at their second level of iteration. The definitions and the set of KPIs must be finalised by the stakeholders themselves, namely the Infrastructure Managers. These KPIs have been developed from the accumulation of research, experience with a series of previous benchmarking projects, together with practical exercises or pilot studies in benchmarking undertaken throughout

7.6.7 Which performance indicators to Choose

Relatively few Core KPIs should be chosen when devising a benchmarking exercise, as the more KPIs, the less focus on the top priorities. Rather more second order PIs should be chosen, because not all managers need to look at all of the KPIs – in fact they will normally only be concerned directly with those for their own area of responsibility. They will need to have enough PIs to explain the overall performance in that area. The following are the suggested key areas in which the adoption o KPI's is crucial:

Asset Utilisation

Two Core KPIs are chosen for service density: the total number of train km was divided both by track km and by route km. These were both considered critical because

- They satisfy the primary criterion for a successful infrastructure – that it can run frequent enough trains to cope with all possible demand. This is a medium to long term success measure, measuring the degree to which the IM has equipped its line with adequate signalling and removed bottlenecks, as well as how well it operates the timetable and conversely, ensures that the network is adequately utilised. Inevitably, it describes the status quo which may have been determined by investment by previous generations of IM managers. It is also more relevant to capacity-limited networks than to those which are running far less trains than they could.
- When divided by track km it measures the average headway, which measures how much pressure there is on the IM to limit its possession of the track for maintenance, and in a supply-limited situation is a measure of how efficient the IM is at managing capacity.
- When divided by route km, this measures the frequency of service, an important priority for both passengers and freight. This has effectively been transferred from the service quality success dimension, since it is key to success in either dimension. It is of course determined not only by the IM's management, but also by the TOCs operating on that network. It may also be dependent on adequate passenger demand, so the figure in rural countries will inevitably be lower than in those countries with high density populations.

The third Core KPI was the total number of gross hauled tonne km divided by the total number of main track km. This is not dissimilar to the Transport Units / main track km used by INFRACOST.

- The expression "main track km" was chosen because it was the main denominator used in the INFRACOST studies I-III. Although we are not party to all the arguments in favour of this denominator, it seems intuitively attractive. Moreover, a great deal more resources were invested in that study than in IMPROVERAIL, and 20 railways supplied data on this basis. We therefore felt that it was probably worth adopting, subject to a further discussion with INFRACOST members as to the advantages of that over track km.
- On the other hand, we rejected the numerator used by INFRACOST because a tonne of freight weighs more than a passenger, so that the TU for a primarily passenger-oriented railway does not have the same consequences for maintenance that a TU for a freight-oriented railway.

- The weight of the rolling stock is also of critical importance in creating the need for maintenance – thus the pressures on the Shinkansen and TGV for lighter vehicles, and the higher network cost associated with DB's ICE compared with the TGV.

The second order PIs break down the train km into passenger and freight, and introduce two more:

- The % utilisation of technically possible train paths by Train Operating Companies (TOCS), so as to measure the short to medium term operation of the infrastructure as well as how well it is equipped to run frequent trains. If this figure were low, a fully commercial IM would act like an airport, seeking out operators who could fill the unutilised train paths at a price nearer to marginal cost rather than to fully absorbed cost.
- The average % of time a main track km is possessed for maintenance is the other new PI. It measures the efficiency and effectiveness of the maintenance regime, and the degree to which the potential capacity of the existing assets is maximised.

Safety

Only two Core KPIs were chosen for safety, but they should be seen as the top level indicators in a cascade, with the lower levels explaining them and breaking them into their constituent parts:

- Total number of train accidents due to infrastructure divided by the total number of train km – this counts accidents resulting in death, injury or extensive damage or disruptions to service, and normalises the number by the amount of train traffic, not (the other possibility considered) by track or route km.
- It will be obvious that if there are more trains, the probability of an accident will be increased. The number of accidents may be greater on larger networks, but on a network with only infrequent trains, the likelihood of a collision, for example, will be very much lower than on a highly congested route. Such networks are usually in low population environments. This means that they are less likely to create an accident because of the lower level of road traffic which might be encountered at a defective level crossing.
- The other KPI is accidental equivalent fatalities per train km. The use of equivalent fatalities is increasing fast amongst railways, as the statistical basis of underlying safety becomes better understood. Out of 6 railways surveyed in 2002, almost all counted 10 major injuries as equivalent to one death, with 3 counting 100 minor injuries and 2 counting 200 minor injuries as equivalent to a death. Clearly, the precise number as well as the definition of a major and minor injury will need international agreement, and this IMPROVERAIL recommendation could be the spur to reach this agreement. However, virtually all involved with probabilistic risk management are convinced that this is the right direction to proceed.

The second order PIs are mainly breakdowns of the equivalent fatalities figure into its constituent components, in some cases normalised by more outcome-specific references – passenger deaths or serious injuries, for example, divided by passenger journeys rather than train km. Similarly, deaths and injuries to staff and contractors are normalised by comparing them by work hours. The average severity of injuries is also measured by comparing work hours lost due to work related accidents divided by the staff and contractors' total working hours.

A further second order PI measures the total safety output in terms of the avoidance of accidents: the number of train accidents divided by train km brings in the issue of how well the IM manages the interface with TOCs – because in many cases the IM has a responsibility to ensure that the TOCs rolling stock and procedures are adequately safe.

Contributory PIs break down these metrics further into categories where cause and effect can be more clearly identified and the impact of good practice can be seen. We also recommend the use of precursor indicators which evaluate the underlying level of safety. These were selected from the indicators currently being monitored by IMs such as IRI and Network Rail, and generally considered by other railways to be the most valuable guides to the probability of accidents in total.

While these PIs all measure the performance of the railways, the performance levels will of course depend also on the TOCs' performance to some extent, the design of the network (for example, how many level crossings are there? How well protected is the railway from the incursion of trespassers?) and the prevailing social culture (in UK, children are known to throw objects in front of trains; by and large, this is not the case in East Asia).

Service Quality and Reliability

Once adequate frequency has been reached, the primary factor of value to customers is the punctuality of trains or their freedom from delay. Different IMs and railways use different thresholds for measuring if a train is late. However, what came out very clearly was that better performers used more rigorous rules: the most reliable long distance trains in the world, the JR Shinkansen, are accounted late if they are 30 seconds behind time at any point; other high speed trains such as RENFE's AVE and commuter trains both have a higher performance against a tighter threshold than regional or other Inter-city trains.

Some case material from RENFE collected in the IMPROVERAIL pilot study suggests that introducing more rigorous measurement itself leads to better performance. For this reason, IMPROVERAIL recommends using a 3-minute threshold for all services at the top level, and 3 minutes for all passenger services at the second order and contributory levels. Only for freight trains is a longer threshold recommended, and then only at the second order level. The core KPI is at the total (aggregate) level, but this is then broken down into types of service and entities at the second order and contributory levels. The same applies to the severity of delay, or train hours delay, which is best normalised by train hours, so as to minimise the distortions caused by different network speeds.

What is of course most critical to customer satisfaction is not whether trains are delayed, but how often and for how long passengers are delayed. It is of importance for efficiency if an empty train outside peak hours is delayed, but the customers only care if they or their freight is held up, or there is no train when they expected it. Long delays cause a greater annoyance (and add to the generalised cost of travel more) than short ones. For these reasons, the total number of passengers delayed and the hours of passenger delay are both measured, but as the IMPROVERAIL pilot study reported in D3 Part 1 found, TOCs contribute a high percentage of failures leading to delay. As a result, it was felt better to concentrate on the IM's % share of these passenger delays rather than the absolute number. This normalises to some extent for the differences in past investment in the network and rolling stock.

While the second order PIs are mainly a breakdown of the top level indicator by type of train (passenger, freight), they also contain the absolute number of trains delayed divided by total trains, including all other causes – because even where the IM is not directly responsible, it may be able to influence delays due to non-infrastructure causes. In addition, at the second order level the issue of track possessions for maintenance is again addressed. In this success dimension is introduced a measure of the delays to trains caused by overruns on such possessions.

In some IMs, cancellations are included in the overall figure of delayed trains, but in others this is currently not the case. A separate second order measure is proposed to capture the total number of cancellations separately. In the quality and reliability success dimension, it is even clearer than in other dimensions that in order to understand what is important and deserves priority action, more contributory PIs are needed. These break down the causes of delay into the most common sources and precursors. The PIs listed in this category were chosen from the lists that the largest number of railways currently use, to ensure the maximum degree of commonality.

In this dimension IMPROVERAIL uses the precursor category to express second level contributory indicators – those that explain the behaviour of the indicators at the higher levels. For example, to explain why trains are delayed by over 3 minutes due to signal failures, an IM needs data both on the mean time between the main elements which fail (most usually signals and detection equipment, in particular track circuits and axle counters) and on the mean time to repair them. The more generic factor in explaining delays is the degree of sophistication of asset monitoring, for which the first step is the completion of an asset register. Most recent research by members of the IMPROVERAIL team found the % fill rate (or completion) of a complete asset register to be closely correlated with lower levels of failures causing delay

Efficiency

One would normally expect that the core efficiency indicators would be the total number of staff and contractor hours divided by either main track km and train km respectively. Contributory elements such as the frequency and length of track possessions for maintenance would normally be at the next level down. This would certainly be the case for an integrated railway. However, for an IM, it was felt that the latter were better core indicators because this lies at the heart of efficient action in terms of the ultimate output of the infrastructure – its availability for providing train paths. The reduction in manpower requirements and therefore cost is of lesser importance if the network is highly utilised. The highly utilised Japanese railways demonstrate that more resources, both labour and power, may be justified for greatest overall efficiency (including train operations and revenue generation) if the network utilisation is near capacity. It is relatively easy to cut resources per track km if utilisation is low, but this is not a strategy for the best use of the network.

In the second order indicators, the total labour hours (including contractors) are divided by three different denominators:

- Main track km, to compare the resources required at minimum production or utilisation levels
- Train km, a relatively customer-oriented measure to compare resources needed to fulfil the main output required from the infrastructure
- Gross hauled tonne km, a cost-driver-oriented measure which recognises the effect on the infrastructure of different rolling stocks as well as their payloads. Power consumption is also measured against this, the main variable on which consumption depends.

The final second order PI is the average relative age of assets. This is a measure of how old the assets are, compared with their expected economic life. The relative age is the current age in years of each rail infrastructure asset divided by the expected total lifetime of that rail infrastructure asset. It is then expressed as a percentage of the total expected life of that asset. By using an asset database that holds the current age and estimated life of each single asset, it is then possible to add together the total percentage figures and divide by the total number of assets. (The same result would be obtained by dividing the sum of current ages by the total estimated lives.) It would also be possible to analyse this by groups of assets, or to weight it by asset value or by the potential risk of failure of each asset. The PI proposed is a first step, using unweighted values. For the sake of efficiency, in a mature network it is best to have an average figure of approximately 50%, in order to minimise peaks and troughs of renewal. A growing network will have a lower figure, so for best comparability, for internal comparisons with mature networks such an IM should exclude new build sections from this PI. With very few exceptions, the percentage for mature networks in fact tends to be over 50%, due to the reluctance of the government to fund all of the renewals and replacements requested by the IMs, and the fact that almost all IMs are dependant on such government funding.

Almost as important as the average age is the level of deviation of the relative age. A high level of deviation may not be good for reliability, since some assets will be nearing the end of their useful life and (if subject to wear and tear), will pose a greater risk of failure. But from an efficiency point of view, a high deviation is preferable. If all assets, even in one class of asset, have to be renewed at the same time, excessive demands on staff and contractors will push up the price of renewal, while if there are periods with relatively little renewal required, there will not be enough work for the IM's employees or its regular contractors

It might be considered that the average relative age of assets can only be accurately calculated when the fill (completion) rate of the on-line asset register is close to 100%, but in fact a great deal can be learnt based only on a representative sample of assets. Obviously, the higher the fill rate, the higher the confidence that the figure will be correct.

Innovation and Growth

Just as the average relative age of assets should ideally be around 50% for purposes of efficiency, so a younger relative age of assets is a core KPI for innovation. As we have just seen, mature networks that are not growing tend to have assets aged more than 50% of their estimated or expected useful life. Dynamic networks with a high growth rate will be investing in new lines and stations, so these assets will have a long life ahead of them. Innovative networks such as Kowloon Canton Railway in Hong Kong are now planning to replace signalling systems in as little as 18 years, knowing that technology will advance and create higher functionality which will cost justify such early replacement. Such railways that are committed to high levels of reliability and quality will invest in new technology everywhere where it can be justified on the grounds of improving their basic service.

Other important measures of growth are the % change in route km, main track km or train km, but it was decided that these were so dependent on government and TOC decisions that they should not be considered core KPIs for the IM – especially as there is an overlap between these and the average relative age of assets. They are in fact contributory factors to that KPI.

Instead, the % change in train km per main track km was selected as a core KPI, showing as it does the success in increasing utilisation of the existing network – which recent research suggests[25] will have a strongly positive on the IM's profitability, whereas building new routes or adding track may have a neutral or negative effect.

The third core KPI is the % change in % trains delayed due to infrastructure causes – in other words, has the IM succeeded in reducing the infrastructure's share of total delays? This was felt to be preferable than the absolute rate of improvement, because it goes some way to removing the differences in the starting point. In some networks, the punctuality figures are so good that a further substantial improvement is very difficult, whereas in others they are so bad that huge improvements should be possible. By comparing the improvement achieved by the IM with that achieved by the TOCs on the same network, this initial handicap or benefit is minimised.

Second order PIs range from the use of modern management techniques, through the growth of an entrepreneurial spirit, to the modernisation of specific aspects of the network.

- The % of employees who know the vision, mission and strategy of the company is almost universally recognised among leading Fortune 2000 and other countries' top blue chip companies as of great importance. Interestingly, only RENFE and Netherlands railways knew their own employees' degree of recognition. In their case it was of course for the total railway, but the PI proposes measuring this for the IM employees separately.
- The % change in total non-transport revenue (which could be placed either in this category, or in capacity utilisation, or in financial effectiveness) is a key measure of entrepreneurship. The two keys to profitability of railway networks are high intensity (or density) utilisation and using the same assets to generate multiple income channels.
- The % of the network equipped with ERTMS is a good indication of the degree of innovation driven by the IM. A second indicator is the % of stations with real-time passenger information, though this may in some cases be installed by the TOCs or whoever else operates the stations on a line.

[25] Graham, Couto, Adeney & Glaister, *"Economies of scale and density in urban rail transport"* Transportation Research, 2003

Financial Effectiveness

This success dimension has a relatively large number of indicators, because of its fundamental importance to stakeholders, on a similar level to quality and reliability. The primary core KPI is the proportion of annual operating cost provided by commercial revenues – passenger and freight track access charges and any other private sector contracts plus non-transport revenues such as advertising, property income and fees for the use of infrastructure assets (for example leasing fees for telecommunications capacity).

The second is the converse side to the same question – what proportion of annual operating cost does the government (national or local) provide in subsidies or service contracts for providing a certain number of trains? In the second case it is important to isolate current operating costs from government subsidy for investment in new lines or extension to existing lines. To deal with this, the KPI specifies government subvention specifically for operating cost excluding such investment in expansion. Accounting methods in different countries vary greatly in many respects, but no more so than in the treatment of government subsidy or subvention. Much more work and a higher level of cooperation between IMs will be needed before an acceptable level of comparability is reached for this KPI.

Two more core KPIs are total annual cost of the existing network, including the cost of renewal and upgrading. This is normalised by dividing in the one case by main track km and in the other case by gross hauled train km. The differences in the accounting treatment between operating and total cost, and the many ways of handling depreciation, mean that a new approach is needed to enable benchmarking to be carried out. Moreover, depreciation costs often seem completely unrelated to the amount of investment in the railway. In many but not all cases, railways revalue their assets and most charge depreciation on a different basis, some on historical cost, others on replacement cost (how much would it cost to replace the asset now). For that reason, IMPROVERAIL recommends calculating total cost by adding to operating cost the average of investment (renewals and any upgrades) made in the existing system over 10 years. Unfortunately, this will not get over the problem that some railways count renewals as investment while others treat it as major maintenance. IMPROVERAIL defines major maintenance as maintenance rather than renewal, but it is almost certain that differences of interpretation will continue to persist. For this reason, a further core KPI compares harmonised life cycle cost (LCC) per gross hauled tonne, which includes both maintenance and renewal in the life cycle cost.

Second order PIs consider non transport revenue as a percentage of other total income (commercial plus government), and total commercial revenue divided by train km. Another PI looks at total transport commercial revenue over train km, thus calculating the average charge per train km. Others still break down the elements such as operating cost, maintenance cost and investment cost. These are divided by main track km and gross hauled tonne km, thus normalising both for network size and for intensity of use.

To clarify the labour situation, total contractor costs are divided by total cost, and average staff labour cost per hour (excluding employers' tax) is compared with national average industrial wage for that country. Below this level, contributory indicators break down the income sources by source, and analyses operating cost into its constituent parts, operations, maintenance and administration.

All the KPIs and PIs are only fully understandable in the light of the Glossary, included in the main deliverable (see D3)

Accessibility

No core KPIs have been selected for accessibility, in spite of the importance of this success dimension to the customers of the railway and the population and industry of the country where it is located. This is because in the 21st century, accessibility depends very largely on the network built in the 19th and 20th centuries. The PIs measure the contribution of that network to that country, but were considered of second order as far as measuring the performance of the management of the current IM is concerned. They really measure the effectiveness of previous generations of management to identify the needs correctly and to convince their government to invest the money to meet those needs.

The PIs start with the question, “what railways exist?” It is phrased in terms of coverage of population areas. IMPROVERAIL proposes measuring the percentage of population centres of 100,000 or more served by a passenger railway station. The parameters may or may not be correct: IMPROVERAIL would welcome the reactions of the IMs, but some measure of this availability of railway travel is an essential start.

The second question is “how open the railway network is to other transport modes and to trains from other countries?” The PIs here are the % of trains from or going to stations outside the country, and the number of stations with other public transport mode connections – bus, taxis, airports or seaports.

A further PI that was considered but rejected was the number of TOCs or the percentage of trains run by TOCs other than the main national operator. The reason for its rejection was that this is not necessarily the decision of the IM, but mainly of the government and local authorities. Moreover, the decision to close down Lovers Rail in the Netherlands and the latest policy statements in the UK show that it is not always considered the best thing to have as many TOCs as possible.

The next question is “how much operated capacity does the IM actually provide?” This question addresses both the question of how many train paths are available, and how well the IM can persuade the TOCs to run high frequency services. The primary output, passenger train km, is divided both by route km (to express frequency) and by population. Of course, passenger train km per route km is also dependent on the number of double and multiple-tracked routes built in the past by previous generations of IM managers and politicians, and both will depend partly on the demand being there for the trains. Density of population is highly important in this respect, as well as how that population is distributed. One would expect a dominant capital city like Vienna or Paris, which contain a very high percentage of the population, to lead to less passenger demand than smaller centres of relatively equal weight, such as in Germany or Switzerland.

Background indicators

A number of parameters are essential for understanding the background in the variability in performance between different railways, even though they are not themselves measures of performance. These describe the size, station density, maximum speed and degree of electrification of the network. It helps, too, to know how full the trains are (passenger km divided by capacity km) and the current capacity offered compared with main track km. This last figure is of course driven both by the frequency and length of trains and also by the train design, in particular whether they include double deck trains.

For further details please refer to Deliverable 3, Appendix A

7.6.8 Hints for Successful Implementation of Benchmarking

A benchmarking project is never finished until action plans have been set in place and implemented to start using best practices and processes. This should condition the entire project from the choice of success factors and KPIs through to the organisation of resources as better practices are identified during the project. All should be implementation-oriented. It is a waste of resources even to analyse differences in performance if there is nothing the IM management can influence or change about them. While one role of benchmarking is certainly to explain why an IM is in the position that it is (and especially in what respects it is favoured or handicapped by its environment), this should not excuse it from searching out and implementing better ways of doing things.

One of the keys to successful implementation is the choice of people on the benchmarking team. It is essential to have a dynamic person to run the programme and to include the process owners or their representatives from the outset, so that they can evaluate the relevance of the findings and the realism of the recommendations as the project proceeds. It is important to plan enough resources available both during the project and afterwards to support the implementation proposals.

Senior management should be visibly available and demonstrate their support for the project, and crucially, follow the example of the Chairman of Mass Transit Railway, Hong Kong who said "don't tell me where we did best: give me a list of measures where our company did not perform as well as other railways and a schedule of actions to bring it up to the level of the best performers."

In most cases, it is essential to set up a project manager to ensure that all actions for improvement are planned and implemented at the time that is scheduled. This is less so where process owners are highly committed to the programme, but in larger organisations, organisational change can often lead to good ideas from the benchmarking programme being forgotten because key managers have moved on to new responsibilities.

A further important success factor is to ensure that the benchmarking programme is well integrated with whatever else is going on in the organisation. Where Total Quality Management, Six Sigma or other quality programmes or Business Process Re-engineering, corporate restructuring or customer care programmes are in process, the benchmarking programme should be dovetailed with these other initiatives for mutual support. Benchmarking can then supply the objective measures which these other programmes require for good implementation and both programmes can support each other in terms of breaking down the barriers to change.

Some items are essential before benchmarking will deliver the results of which it is capable:

1. The initiators of the project must be the benchmarking participants, not consultants or outsiders such as political authorities. It is not possible to benchmark on behalf off other organisations and then expect them to pick up and implement best practice: they will not accept its findings and will expect the consultants to do it all for them without their active cooperation.
2. Top management support[26]. If top management do not want to adopt new ideas and feel that benchmarking is the way to get them, there is no point in starting such a project in the first place. If the participants do not own the project and are not committed to it, it will fail. Projects driven by middle managers are usually starved of resource and data, and incapable of getting other middle managers to implement any good ideas which come out of the project. It is essential that an Executive Board member should sponsor the project and attend the opening and final meetings of the project, and that the manager responsible for the project should report to that Board Director. Successful benchmarking relies on a culture that is supportive of change and openness[27]. It is essential that those undertaking the analysis have full access to data and people across the organisation. Top management support can help this, while conversely, benchmarking can act as a tool to implement culture changes that top management want to set in motion.
3. A senior manager should be responsible for the progress of the project, and put in enough time to make sure that the direction of the project is in line with the priorities of the company. This manager should attend all the project steering committee meetings at the beginning and end of each phase, and should have a data coordinator reporting to him or her. Ideally, this manager should be one of the younger and brighter managers in the organisation – benchmarking projects can lead to high profile exposure and the manager will have a good overview across the whole organisation. Ideally, this should be a person who can act as a powerful change agent, able to break the barriers of inertia and resistance to outside ideas in the company.
4. It is essential to ensure that the process owners are involved in the benchmarking programme from the outset, and come to understand the advantages that they might be able to draw from it for their own areas of responsibility.[28]

[26] As noted in the CoMET/Nova, BEST, INFRACOST and PROMAIN reports.
[27] As noted in BEST
[28] As Promain, CoMET/Nova and INFRACOST showed.

5. The data coordinator who carries out most of the work in getting together the data from the different managers and data sources around the organisation[29] must be reasonably knowledgeable about where such data is likely to be held, and supported by good information systems. The data coordinator this should normally be a young, reasonably well qualified professional with promise: drive, intelligence, flexibility, persistence and ambition. For the length of the project this person should be free to put at least half of their time into the project.
6. There should be enough meetings of the steering committee of the participants to create a community of interest[30] and a desire to form informal networks to exchange information on new ideas and best practice beyond what is being covered in the project itself. This will make all participants readier to be open about their data and their processes, and to be honest and self-critical when they do not have all of the right answers.
7. An external professional facilitator for the project is normally essential. This facilitator should be an expert in the process, not necessarily in the functional areas, but should be able to call on external expertise if appropriate.
8. There should be at least 5 actively participating members of the benchmarking project. Up to 10 is helpful, but more than that becomes unwieldy[31]. With less than 5, if one or two are unable to provide data, that part of the project will be of little or no value. What is needed is a critical mass of participants who are fully committed to making the project work, and adjusting its direction to get the greatest value for their own organisations.
9. The approach to analysis should be action and value-oriented[32]. Theoretical analyses are useful to academics, but not to practicing managers. This means that work should be focussed in areas where the largest improvements are possible and the greatest contributions can be made to profit, cash flow and customer service. It should concentrate on issues which form a large proportion of the value chain or which are critical to customers' top priorities as expressed in market research.
10. While concise questionnaires are important in collecting data, they should be followed up with face-to-face interviews with the relevant managers where appropriate, and with site visits to see other railways, particularly those that are suspected to be good performers[33]. More can often be achieved by visual observation than by detailed analysis.
11. For case studies, it helps to prepare a set of hypotheses at the outset, which are then tested in the course of the study. These hypotheses can be fine tuned as the study proceeds and greater understanding is acquired, but they should be precise and "hard" enough so that participants will be proven either right or wrong, but not normally left in doubt.[34]

A strong confidentiality agreement is essential to protect commercially sensitive information and is also vital to ensure trust and therefore cooperation in the supply of data and information[35]. Data does not always need to be kept secret within the benchmarking group, but uncontrolled leaks to potentially hostile media and political representatives can lead to misunderstandings and the use of partial or misleading data which can be embarrassing or compromising.

[29] Noted as necessary by both CoMET/Nova and INFRACOST.
[30] Noted in PRORATA, PROMAIN, CoMET/Nova and BEST.
[31] As noted in CoMET/Nova
[32] Noted in CoMET/Nova
[33] As noted in PROMAIN, INFRACOST, and in CoMET / Nova studies and confirmed in the IMPROVERAIL pilot studies.
[34] Experience from CoMET / Nova and Railbench studies applied and proven in the IMPROVERAIL pilot case studies. It also appears to have been used implicitly in INFRACOST and PRORATA.
[35] Noted in CoMET / Nova and an alternative, anonymous approach used in INFRACOST.

7.6.9 A Route map for IM Benchmarking

The existence of the INFRACOST I-III benchmarking studies, and the amount of resource put into it over the years, suggests that there are already at least twelve European railways who have been committed to exchanging cost data and information about their practices in order to improve their cost performance.

This almost certainly implies that they would also be ready to benchmark for best practices in other fields such as quality and safety management systems, where great benefits might be gained from this sort of information exchange.

IMPROVERAIL has shown that not all projects need be as time-consuming and resource-intensive as INFRACOST I-III, and that IMs who have not been involved in benchmarking before would certainly be able to start doing so. It has documented a range of different projects that have taken place, and set out an approach to benchmarking, and a proposed set of KPIs for the consideration of IMs. The main barriers to effective and mutually profitable benchmarking will be

- The lack of incentive amongst some IMs to improve performance unless they are given strong encouragement in this direction by the authorities to whom they report.
- A culture of inertia and a concentration on cost cutting to the exclusion of all other success dimensions, which was previously expected of many IMs and is still deeply imbedded in the way of thinking in some countries.
- Inadequate data collection procedures for a variety of functional areas – IMPROVERAIL has identified weaknesses amongst the majority of IMs in all three areas in which pilot studies took place, the monitoring and control of delays and failures, safety management systems (where only a minority of IMs measure precursors or distinguish between major and minor casualties) and procurement (where most have no programmes for moving to a restricted number of approved suppliers as the automotive industry have done, and therefore little or no systematic performance data).
- Inadequate information systems, especially asset management systems

IMPROVERAIL believes that these barriers can be overcome but it will take time, focussed, sustained effort and co-operation between IMs. If the KPIs can be agreed and IMs can start to use them, and they can improve their data collection and information systems to the standard of the better railways such as SBB, RENFE or Netherlands railways, the potential for best practice benchmarking will be substantial. However, the change of culture and systems seems not to be an easy task.

There are many more practical and process-led obstacles to successful benchmarking. In particular, the encouragement of full steerage from the stakeholders (the IMs) is essential for application of practical benchmarking. Importantly, there must be an incentive to improve performance amongst IMs, and data collection procedures and information systems must be improved before benchmarking can achieve its maximum potential

Next steps for a possible roll-out of IM Benchmarking across Europe are detailed in the figure below : (dates are merely indicative):

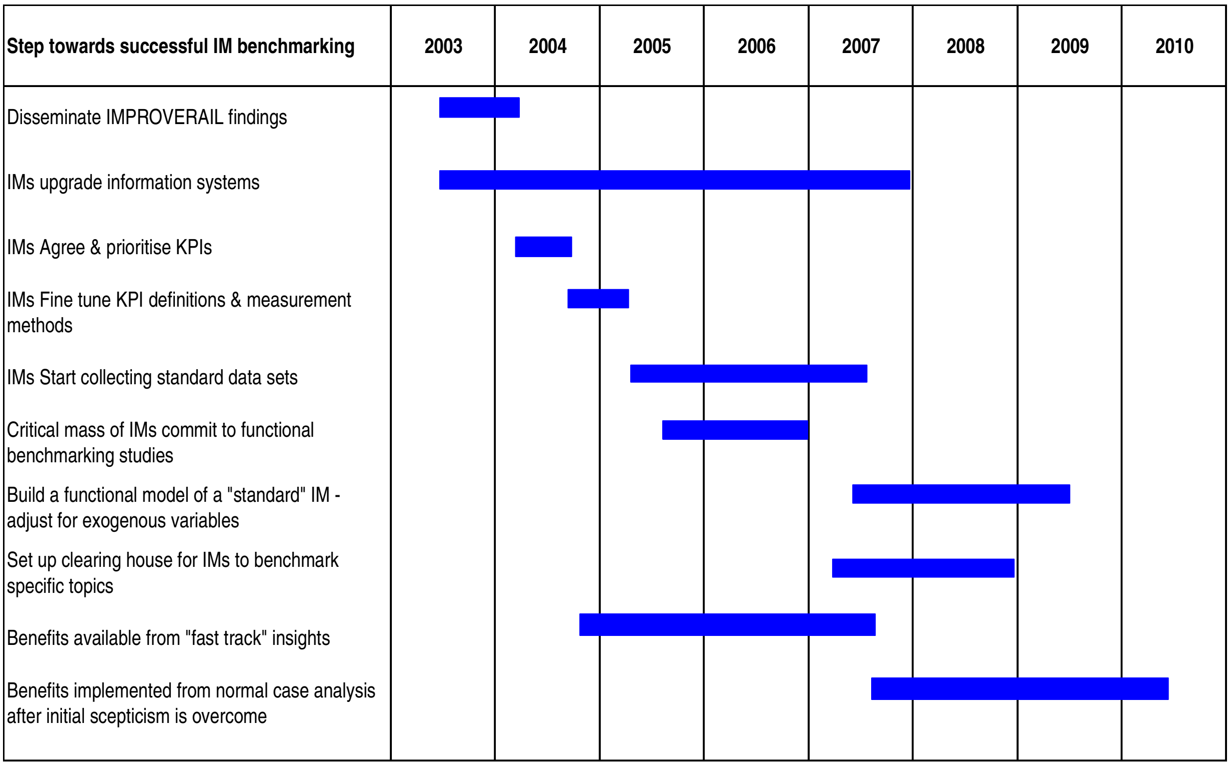


Figure 27 ***Possible roll-out of IM Benchmarking across Europe***

8 RAILWAY INFORMATION SYSTEMS

8.1 Introduction

As the railway market becomes more disaggregated and complex, the demand for reliable information systems becomes vital to keep up with the required integration of information flows that should help driving efficiency in the railway sector. This means everything from the well known information systems that are available to end users (B2C) to the management of the interactions between I.M. and other stakeholders (B2B).

But perhaps most importantly, it is today absolutely necessary to devise and implement information systems that allow knowing more about the inner activities of the network provider. Indeed not only Railway Infrastructure Managers but also regulatory organs, control organs and researchers need to have available such detailed information, currently scarce and often hampering detailed analysis. This was felt along the development of IMPROVERAIL, in particular regarding the approach to Benchmarking and to Lifecycle costs, appeared as a key issue for railway should the sector wishes to fulfil current expectations of improved market position.

The pressure of Directive 2001/14, by which IMs should consider developing and adopting a more disaggregated cost analysis, should allow relating those to the provision of services to Railway TOCs in support of fair and harmonised charging systems.

However, some interesting developments in the deployment of information systems start now being reported, as it is clear today that without grounded information support, it will not be possible to move towards the envisaged modernisation of railway.

Top areas for integration include financial and economic issues (Charging), technical aspects (M&R), Assets' management and commercial (market transparency), the latter looking in particular at the international freight traffic corridors. In addiction, such systems should provide compliance with the EU Directives, and are expected to foster competitiveness of the sector along with optimised operational and management processes, ultimately resulting in decreased operating expenses and increased income for the IM Company.

8.2 Data Requirements for Charging

In practice different charging systems make use of the relevant cost data to a different degree. It was seen that some IMs are running commercial accounting systems as Quo Vadis (NL) or SAP (NL, P, D). In these cases the quality of available data is assessed to be sufficient. Some IMs as in Norway or Germany are using own LCC models to assess the costs of wear and tear. Some have precautions to develop and establish new accounting models with external support (RO). Therefore the quality of existing data is presumably not sufficient. Development of cost methodologies is performed in many countries, and IMPROVERAIL has made a contribution to give the European railways a new tool for designing such cost schemes and for comparison of cost categories, structure and level between countries.

For the assessment of cost components different information systems are used. Some systems are standard accounting systems, some are simulation systems and some are based on more or less regular studies carried out by accountants and consultants. The data sources mainly allow the identification of cost categories and the allocation of specific costs. However, the allocation of overhead costs follows different principles that cannot be analysed from an outsiders´ point of view. Moreover, even the different definitions of cost categories used in practise make it uneasy to get a harmonised input into cost data sources.

What is still missing in the existing data sources is the linkage of cost to the benefits of certain infrastructure managing activities. For example, the use of specialised railway snowploughs imposes costs to the IM, but creates benefits to all TOCs in winter times. However, if the benefits of the TOCs are unknown IM will reduce investments in such equipments to the damage to the overall system quality. Therefore it is necessary to establish Service Level Agreements in order to internalise such benefits (or damages) in the non-cooperative system.

In order to apply charging methodologies based on the effective knowledge of the costs associated to Infrastructure Management, it is necessary to have information systems available. Some systems are standard accounting systems, some are simulation systems and some are based on more or less regular studies carried out by accountants and consultants.

In addition to that, IMs are obliged to publish the key data based on their infrastructure management systems. Currently, most IMs are either using or in the process of implementing integrated information systems. Notably among these, it is SAP R/3 (and follow-ups) for internal data management, which could enable to build a common platform for effective data exchanges. However, the very different definitions of cost categories used in practise make it uneasy to get a harmonised input into cost data sources.

Such information systems allow keeping track on costs and the identification of relevant categories, including its allocation to activity levels to develop historic information in support of, e.g. maintenance and renewal decisions. Also the allocation of overhead costs currently follows different principles, which is an obstacle for the true assignment of costs. Again, it is necessary to reduce these costs to the minimum aggregation level in order to keep tight control over the costs which are driven by level of activity in order to fairly reflect those variations in the pricing principle applied, in particular regarding SRMC.

8.3 Infrastructure Data in Support of M&R Strategies

For an infrastructure manager it is of high importance to have a clear view on the state of its infrastructure. To be able to manage the maintenance and renewal process efficiently and economically, an infrastructure manager has to set up databases describing the infrastructure and its current state. The databases should provide enough up-to-date information on the infrastructure in such a structured way that the infrastructure manager can efficiently use this information to develop the right policy for maintenance and renewal. In case the infrastructure manager outsources the M&R projects, the contractors will be responsible for the input of useful infrastructure data. The infrastructure manager's role concerning the data gathering process will become more steering, controlling and facilitating.

The following describes the infrastructure data that should be available in order to make good management possible and will elaborate on the data gathering and storage process, first in a situation where the infrastructure manager is gathering and storing infrastructure data himself and second in the situation that (a part of) the M&R activities are outsourced.

8.3.1 Key Topics for Infrastructure Data Management

The following aspects reflect the crucial questions to starting developing a comprehensive Infrastructure database by understanding what is currently available:

- What infrastructure data exists?
- How is it stored (where is it available)?
- How is it obtained?
- How can I use this data to efficiently manage the maintenance and renewal process?

Most interesting will be then to ask the question: What information should be available and how should it be stored and analysed? To this respect, the following types of databases have been identified:

- The general composition of the infrastructure (**system database**)
- The history of monitoring operations and the result of these inspections (**monitoring database**)
- The history of work carried out (**action taken database**)

- The history of incidents and faults (**incidents and accidents database**)
- The inventory of resources and costs (**resource and costs database**)

The UIC report mentions a list of infrastructure data that minimally should be available in each of the specific databases. The system database should contain a description and decomposition that should be followed in all other databases.

System database:

General characteristics of infrastructure components, for example:

- Curves, connections, cants gradients, transitions
- Structures and earthwork, barriers
- Tunnels, anti-noise walls, cut-and-cover sections
- Singular points (building and various installations, etc)
- Service and emergency access points
- Drainage systems
- Position of overhead lines
- Switches and crossings locations
- Position of signalling installations

Superstructure inventory (this list refers to the decomposition in the previous chapter):

- Rails
- Ballast
- Fasteners
- Sleepers
- Switches
- Level crossings

This database has been grouped according to the decomposition of infrastructure proposed in the previous chapter (not to the UIC report decomposition). To be able to plan maintenance activities for the long-term the information in this database about each infrastructure component should at least include:

- Identification number
- Location (number)
- Building year
- Deterioration models
- Expected lifetime

The identification number should be a unique key ID to be able to store and retrieve information about this specific infrastructure component. This number can be linked to the proposed decomposition of infrastructure (previous chapter) and split up according to a certain hierarchy within a component.

The geographical location (as a number) should be included in the unique identification number of the component. This location number can be an important key to link different databases, for example with the use of a GIS interface. In many cases it is necessary to retrieve information on infrastructure components within a certain area, rather than only on a certain type of infrastructure. The location number within the identification number of a component allows for the purpose of linking databases.

For the long-term aspect it is sufficient to know when the infrastructure components have been built and placed (building year, production year) and what the expected lifetime of the infrastructure component is, according to experiences (deterioration models) and expected use.

Monitoring database

The monitoring database is important to be able to check, for the long-term, whether the expected remaining lifetime of the infrastructure component is still feasible. If not, the system should produce a warning to the infrastructure manager that the infrastructure component should be repaired or replaced.

The monitoring database should contain up-to-date information on at least the following subjects:

- Recordings relating to track geometry and ultrasonic inspection
- Work records for switches and crossings
- Evaluation files of the condition of components (sleepers, rails, fastenings, etc.)
- Recordings of corrugation, testing etc.

Two types of data gathering methods feed this database:

- ✔ **Data of measurement cars:** Various track condition and geometric parameters are recorded by computerised measurement equipment on board a special measurement car. Modern measurement cars often include also an ultrasonic inspection of the rails, giving evidence of rail cracks. Other examples are the catenary measurement cars. The measurement cars pass typically every section in the rail network once or twice a year, thus updating the monitoring database.

- ✔ **Visual inspections:** Visual inspections also provide input for the monitoring database. Employees of the IM walk along the inspection to do visual inspections on the state of the track. If the IM outsources the M&R activities, these visual inspections are often used to check the work done by the contractors.

"Action taken" database:

The action taken database should provide information that enables the infrastructure manager to obtain a more realistic view on the remaining lifetime of a component. From the information in this database the IM should be able to predict how many years the component should function correctly as a result of the M&R actions performed.

This database should contain information on the following M&R actions:

- Work done on the geometry of the track and switches (levelling, tamping, aligning, local repairs, lifting, etc.)
- Work carried out on track components (grinding, replacements of sleepers, replacements of rails and switch components, welding of rails, work done on damaged rails, etc).
- Infrastructure renewals

Incidents and accidents database:

This database contains an exhausting inventory of incidents, accidents and disturbances as well as their causes and possibly, their remedies.

Resources and costs database:

This database contains information on all possible resources. Information should be stored on staff (and contractors when the M&R work is contracted out), the equipment, track components, tools, rail and vehicle fleet, and cost management. The latter is often stored within an ERP system, for example SAP.

In the long-term M&R perspective, the main concern is the replacement of a component and its planning. With respect to the planning process for M&R on the medium and short term, more information is needed. For this purpose it is recommended to establish database links in a way that information concerning inspection reports, current state information (monitoring database), maintenance history (incidents and accidents database, action taken database), quality indices etc. can be combined and analysed. This information, in combination with the resources and costs database, represents the structured and efficient information basis needed to derive a realistic medium and short term M&R planning.

A general remark on infrastructure databases should be made here. It is obvious, that the data collection, maintenance and update of such a comprehensive database is an extremely tedious and time-consuming task for the infrastructure manager. Another aspect that causes problems is the connection of the different existing databases. Different databases are often set up by different people at different times, making the linkages a difficult problem since there is no common format.

8.3.2 Databases of fixed Assets (DfA)

Another type of database should be added here: an asset management system (AMS) combined with a Geographical Information System (GIS). Such a database contains dynamic maps of the infrastructure and at the same time it gives accurate information about the exact geographical location of the infrastructure object. If this database could be linked to the other databases, it becomes a very useful management and decision support system for an IM.

The Database of Fixed Assets (DfA) solution of SBB is an asset management system that records and manages all data on its fixed assets. The DfA represents the core system of the SBB infrastructure manager.

This extremely complex railway network continually requires maintenance of all fixed assets, as well as their replacement if and when needed, and requires management planning for expansion to meet future requirements. To enable the various maintenance management requirements, the complex construction work, and optimisation of the track business, it is essential that all information on network condition, individual assets and their relationships are available at all times through the DfA. Because railway network assets are highly complex, the DfA supports the SBB infrastructure manager in the extremely demanding task of documentation and management.

The DfA solution centrally records all data relating to the rail infrastructure and makes it available at all times to the SBB managers, services, project leaders and staff as well as to third parties. The DfA delivers a comprehensive range of possibilities for recording, managing and analysing the rail infrastructure data. The user access is provided by the use of many of the technical solutions and platforms available today, including Internet, Intranet, mobile computing and GSM mobile communication. For instance an employee of the IM may demand information on a specific object through his mobile phone and receives the answer on the phone display in the form of a text message.

The DfA solution adopted by SBB reflects the way ahead for efficient maintenance and management of an entire railway network. All information and data are also available to third parties for projects and planning. Despite its rather good structure, the DfA of SBB still requires further adaptation of its "taken actions" database.

The DfA includes a rather exhaustive table, storing all maintenance or renewal actions that have been undertaken in the past. However, the DfA does not log the evolution of the infrastructure. In other words, the system allows knowing what kind of work has been executed in year 1990, but does not provide information on materials (type of rail, sleepers, ballast) that composed the infrastructure at that time. So, if the considered track has been renewed between 1990 and today, it is impossible to get the type of components that were in place in 1990.

Many infrastructure managers face the problem of forecasting their infrastructure need in M&R actions, in the long term. Statistical analysis is a good way of answering that question, but one should be able to rely on a wide sample of data. In the case of the DfA, most of the "taken actions" table can't be adequately used as stored data can't be systematically put into relation with types of components.

8.4 Data Availability for International Railway Traffic

With regard to international traffic, centralized Information systems must be developed coherently, in order to provide real time information concerning trains running to be accessible to the rail operators and stakeholders in general. Currently, a number of different systems are used in different states and pioneering websites aiming at such objectives are already implemented. However, there would be benefits from deciding on a single system ensuring that it can provides the operational and commercial requirements for both the track authority/company and operators

In turn, data requirements in terms of the costs related to network provision are most relevant. However other data elements should not be disregarded, such as the ones related to the assets utilization, e.g. actual capacity utilisation, slot availability, etc, which are very relevant in the scope of the relation between the IM's and the international traffic market (TOC's). Overall it has been seen that the Implementation of a comprehensive railway management information system supported by harmonised costing principles is required to bring clearness to charging across Europe.

8.5 Conclusions

It has been seen that there is currently an information gap that prevents practical application of theoretical infrastructure charging principles. Moreover the quality, reliability and consistency of definitions of existing data are generally bad, preventing e.g. better transparency and efficiency of infrastructure charging rules.

To this respect, the link of costs to related benefits is often missing. Therefore if the benefits from certain IM activities are unknown, the IM might be tempted to reduce related investments, which may be restrained by the adoption of Service Level Agreements (SLA).

All in all the comparability of the existing data is bad and cannot be improved without significant changes. On the other hand, the low level of data comparability is also based on different cost allocation principles. For that problem, a better transparency of infrastructure charging components would increase the performance of all infrastructure charging systems and the performance of planning cross border-train services. In this sense, data reliability as well as data validity seem to be currently a problem. Different ways to calculate cost elements may also cause great differences. Therefore further R&D in combination with new software is needed to help IMs and operators assess the marginal cost elements.

An instrument to support the theoretical pricing mechanisms with grounded data is therefore the harmonisation of data quality. This instrument allows a better benchmarking of individual cost allocation policies and different pricing policies across Europe.

Whereas policymakers and regulators are not able to fully overcome such information asymmetry, regulatory economists have developed a set of light-handed instruments for regulation. Those instruments set incentives to behave as efficient as possible without pulling the regulator into the procession of huge amount of detailed data.

The consortium recommends national detailed models able to assess system costs for the use of calculating system costs as well as allocate track efficiently. Gradually, as the technology evolves, such systems can be made mandatory for all countries. To this respect a visible gap has been shown between data requirements for harmonised infrastructure charging in theory and practice even if we take into consideration that the need for such harmonisation can be limited to the principle of transparency.

As a general recommendation, it should be further considered some specificities of data management in case of outsourcing of M&R activities. In such situations it is recommended to Infrastructure managers that these should not outsource core decision processes associated to their assets. As the long-term M&R planning belongs to this process category, related actions should be done by the infrastructure management company.

This raises the question of data management when outsourcing certain important activities. If an infrastructure manager has contracted out the maintenance and renewal work to one or more contractors, the task of the infrastructure manager concerning the collection of infrastructure data will change. Apart from some visual spot checks of the track from time to time, the IM does not itself collect the infrastructure data needed. It has to rely on the data collected and presented by the contractors. The role of the IM turns into one of managing the data collection, instead of performing it itself.

Therefore in the case that M&R is outsourced, the infrastructure manager should ask, apart from the above-mentioned aspects, the following additional questions:

- Who is obtaining the data?
- By which methods?
- Who is storing the data?
- Is the stored data centralised or decentralised?
- Who is analysing the data?
- What is the quality of the data?
- Who is checking the quality of the data?
- How often will the information be updated? (How often should it be updated?)
- Are there mixed interests with the contractors concerning the availability (and the place of storage) of infrastructure data?

9 CONCLUSIONS AND RECOMMENDATIONS

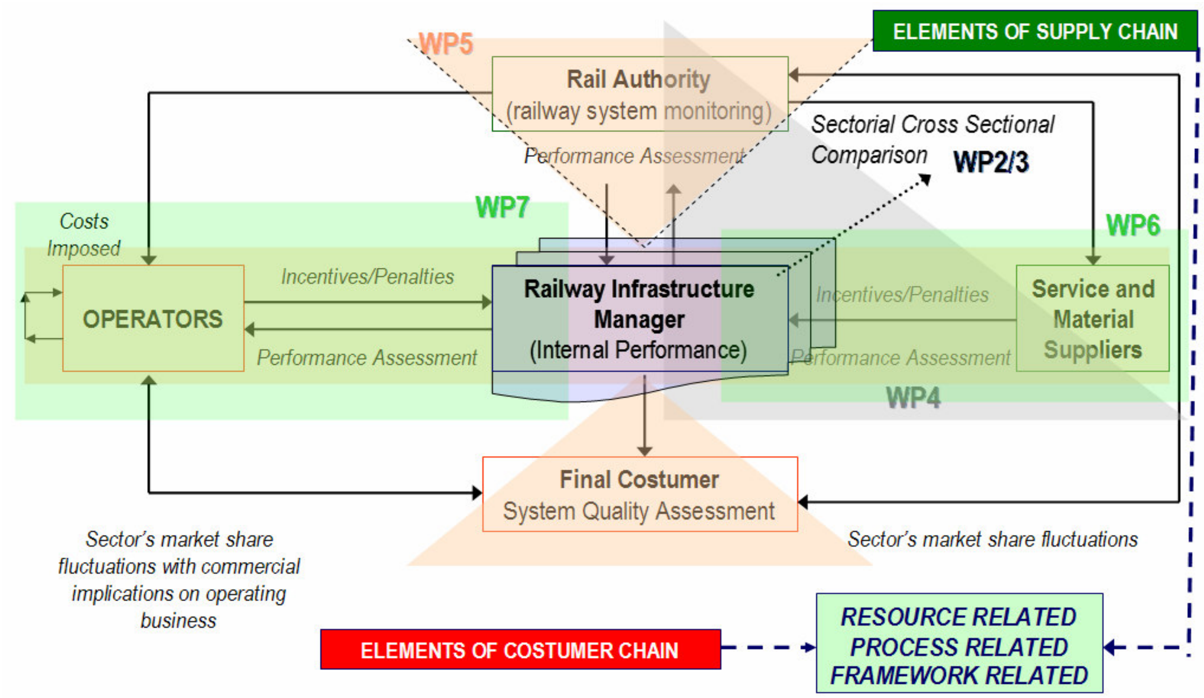
9.1 Integrating the Strands of Research Developed

This Final Report for the EC Research Project IMPROVERAIL reflects what has been a wide scoped study on Railway Business, namely at the level of the Infrastructure Management, an emerging business sector on its own, upon the separation between railway infrastructure ownership and railway operation, in result of the implementation of the EU Directive 91/440.

The integrated approach undertaken in IMPROVERAIL has proved particularly challenging, as only specific parts of the whole picture for railway business and Infrastructure Management had been analysed before, making IMPROVERAIL the first comprehensive study that considers a wider set of key vectors. These vectors are broadly related to the need to reflect on the Railway Infrastructure Managers (hereinafter referred as "IMs") the consequences accrued from the implementation of EC Directives and the fundamental restructuring of the relationships between the new entity "Infrastructure Manager" and the other railway stakeholders, such as **Train Operators**, **Service and Material Suppliers**, **Rail Authority** and **Final Costumers**.

The next figure highlights those vectors, further relating them with the supply and the demand sides of the IM Business, and with the specific strands of work carried out in IMPROVERAIL designated as WP (Workpackages), which correspond to the shadowed coloured areas. Some overlaps can be acknowledged, which reflect the close interdependence that the consortium has explored between the varied subjects dealt in each WP.

Figure 28 – IMPROVERAIL Framework



The workpackages mentioned, which have driven the IMPROVERAIL research, are identified below:

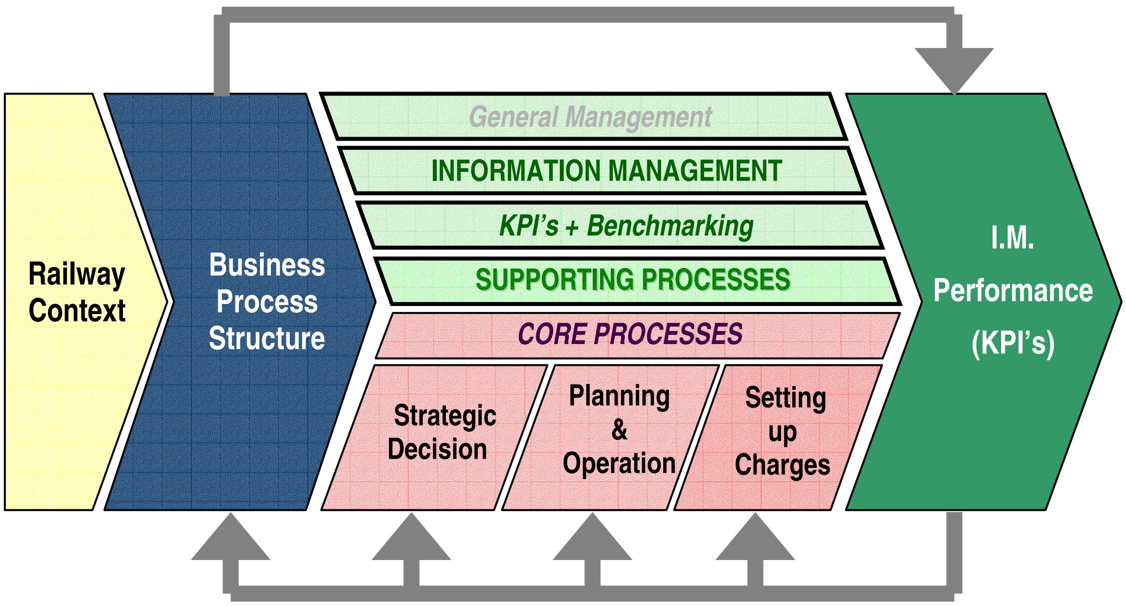
- **Workpackage 2**: Benchmarking business processes and performances
- **Workpackage 4**: Business process re-engineering
- **Workpackage 5**: Methods for capacity and resource management
- **Workpackage 6**: Railway Life Cycle Costs
- **Workpackage 7**: Data requirements for harmonisation of charges

The project has approached some of the key areas related to the Infrastructure Management business, namely those which remain in the scope of the Production Function (provision of service), leaving out the General Management aspects, such as financial and administrative issues. The key areas addressed were the following:

- **Railway Context and Business Relationships**
- **IM Business Processes & Structure**
- **Supporting Processes**: Information Management, Development of Key Performance Indicators
- **Core Processes**: Strategic Decision Making, Planning & Operation, Charging
- **Self Assessment of Performance** (Benchmarking based on KPI's developed)

The following figure illustrates how each of these areas fit within a suggested framework reflecting the chain of activities undertaken by the Infrastructure Managers, the arrows representing the feedback loop that should be promoted and made dynamic allowing the IM to keep a tight control over its activity.

Figure 29 – Structure of Railway IM Business



9.2 BPR in Railway

The vast majority of BPR projects have been carried out in the private sector, with only a few situations in public organisations, with several such BPR projects having met very limited success. However, even in private companies with strong market orientation and profit motive as well as clearly defined customers, between half and three quarters of all BPR exercises fail! Thus any attempts in Railway BPR should be treated with caution. A review of the BPR that has been carried out in the European railway industry revealed that very little has taken place. Whilst there has been extensive restructuring, mainly as a result of the EC Directives 91/440 and 95/19, this has been almost exclusively organisational, with little or no focus on processes.

Nevertheless, following BPR principles may at least help supporting the assessment of infrastructure managers' performance, with the ultimate aim of improving the organisation's productivity. Indeed, a number of infrastructure managerial decisions and processes can be source of inefficiencies and/or failure to meet objectives, which result to the ineffectiveness of actions or decisions taken by other key players such as railway undertakers.

In this context, a methodological framework along with a self-assessment management tool was developed in IMPROVERAIL, aiming at supporting BPR way of thinking among Railway Infrastructure Manager, according to the generally accepted principles of Business Process Reengineering (BPR), but in attention to the specificities of BPR in Railway Infrastructure Management.

This generic but innovative BPR methodology is supported by inputs accrued from the cross sectional work carried out in IMPROVERAIL. The main concern driving its development has been the easiness in use and applicability in most IM structures. It should help the infrastructure managers to evaluate performances and structuring BPR initiatives. Its frame of reference is the full range of IM structures.

The fact that the Infrastructure Management has been consistently separated from operation does create a privileged ground for innovative approaches towards the improved performance of the infrastructure management activity, possibly where the need for such approach turns out to be more sensible. In any case, the objectives of BPR methodologies, applied to companies that have been traditionally dominated by the public sector (as is the case of railways), is to provide a road map rather than specific solutions for business process re-engineering.

BPR should therefore be understood as an opportunity to streamline the key business processes.

As the adequacy of BPR as a tool will depend to a large extent on the nature of the organisation in which it is applied, the IMPROVERAIL has attempted to segment railway companies as production, commercial and market oriented organisations, which is required in order to compare the appropriateness of the technique in different circumstances. Representative processes were therefore chosen in each of the three identified areas of the organisation: **operational**, **commercial** and **managerial.** .

It should be noted that the decision to re-engineer is made with reference to the IM structure and considering the actual national policy environments and stakeholder interests. There is no single formula for IM re-engineering but rather a number of these. The selection of the best formula is a responsibility of the IM stakeholders.

The BPR methodological framework consisted of five phases that are interrelated and they are somewhat the required logical steps that follow the pattern:

Understand the environment → Set the Objectives → Use tools to accomplish them → Produce outputs → Recommend activities / implementation

At the first phase of the methodology the roles and functions of IMs are set out and the forces shaping railway dynamics in today's competitive world are identified. This is done in view to the forthcoming changes in regulatory frameworks (transport deregulation, privatisation, specific EU Directives for railways, etc.), which are expected to redefine the attitudes of the IMs. It includes two steps: the reconnaissance and the assessment of IM position within the railway industry.

The second phase describes the objectives that re-engineering is designed to achieve. It also defines the IM's strategies for the future, enhancing the sources of its competitive advantage and redirecting its competencies. It consists of three steps: an environmental scan, a benchmarking process and a guideline to set the Objectives and Strategies.

The third phase provides a description of different structures and organizational models (possible in the identified regulatory frameworks). It also suggests different change paths to shift from one structure to the other and highlights their strengths and weaknesses. It includes the sectoral and the organisational steps.

The fourth phase provides a description and classification of some key processes that can be re-engineered. These include: Procurement, Track possession management and Slot allocation. This phase also describes specific mechanisms and options from two case studies, involving a core and a non-core activity. It includes three steps; the core processes, re-engineering options and the BPR assessment.

The fifth phase describes how to get from concept to effective implementation. It also provides a methodology to assess the performance of the IM after re-engineering. It is structured in two steps: the strategic and the transaction preparation.

This methodological framework is provided in IMPROVERAIL also as a software Toolbox, featuring an interactive electronic book, complemented by a user's manual. This should facilitate the understanding and simulation of steps to develop specific re-engineering measures based on the IM's goals and the needs of train operators and other recipients of IM provided services. It also provides an insight of the interplay between competition and regulation and understand how the risks and rewards vary from one re-engineering option to another.

9.3 Prospective Network Capacity Management

Due to political trends as well as to a general growth of transport market, the traffic on main European railways corridor has been constantly increasing, looking bound to maintain this trend. As a consequence, many rail infrastructure owners face today, or will face in the future, capacity bottlenecks in their networks.

But saturated railways sections raise two contradictory issues: the maintainability and the availability of the infrastructure. Several railways companies put a very high importance to the availability of their network and tend to reduce traffic interruptions for infrastructure maintenance activities, inducing either lacks of maintenance or a drift of maintenance costs. On the other hand, some infrastructure owners mainly consider the maintainability of their infrastructure and allow extended traffic interruptions, neglecting the quality of the service provided to operators and end-customers. Usually, both of the behaviour are the consequences of a lack of efficient strategy evaluation methods or are inheritance from the history.

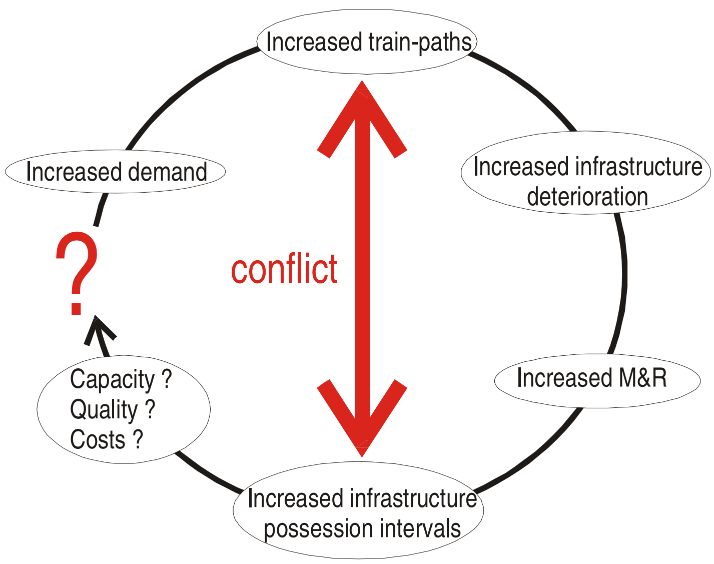


Figure 30 – Conflict between M&R and Network Availability

This calls the attention to the fact that to carry out a lean railway business requires adopting careful long term (**strategic**) planning of both network capacity investments and infrastructure M&R, as railways investments often require several years between planning activities and deployment of the hardware. The challenge of strategic management level refers to adjusting network's capacity as close as possible to demand, taking into account M&R needs.

At the medium/short term level (**tactical and operational**) infrastructure managers also face challenges. Here the concern is the optimisation of the use of resources, keeping up with the strategic objectives set for infrastructure M&R, while securing the network availability contracted with operators without incurring in contractual compensations at the cost of both financial and image loss.

Hereafter the word infrastructure refers to the physical system constituting the railway's network. The word capacity refers to the maximal number of marketable train-paths that can be operated during a given time span, on a network, on a line, or a node, under given conditions and quality of service.

Long Term Planning

When devising to undertake demand forecasts to anticipate the long term evolution of the network, the top management will have to choose a development strategy for the infrastructure, questioning whether the network dimension will be able to cope with the most likely scenarios in a horizon of a decade or two. This is crucial in result of the time gap between decision making and actual implementation of the solutions, which in turn will have a global effect on M&R strategies. In that sense, the following recommendations come in support of those involved in the long term planning of the infrastructure development, by providing guidance throughout the planning path.

- When planning Market orientated Investments in long term it is necessary to consider designing and providing adequate services, accounting for market segmentation, each segment (of final clients) having different weights for the various service attributes.
- It is necessary to develop infrastructure so that various market segments can be served efficiently, even if weight of those segments may vary over time. All this should be accomplished while avoiding excessive investment.
- Flexibility rather than "perfect fit" to each client type should be envisaged.

- Systematic review of market evolution, in dimension and requirement of the various segments. In turn the correct judgement on investments relies on adequate charging systems that are also discussed within IMPROVERAIL.
- Close monitoring of operation, identifying bottlenecks and other sources (physical & organizational) of loss of efficiency.
- Good linkage between processes of planning and operations (forward and backward implications) are key in this context, which aspects cannot be detached from the implementation of effective information systems and comprehensive asset registers for network management

Short Term Planning

To implement efficient decision support tools to find the best tactic balancing M&R and capacity needs requires dealing with the permanent conflict between the maintenance and the marketing departments. This means that the realm of short and medium term planning is perceived to be much closer to day-to-day actions and therefore often deserve more focus from people responsible. To that end, we provide hereunder a number of conclusions on key issues related to the topic. These come in support of those involved in the short / medium term planning of the infrastructure M&R, by providing guidance throughout the planning path. For further details on technical aspects we provide a reading guide for related matters in Deliverable 6.

Overall, and from the research undertaken, it may be concluded that there is quite some variety between the companies, both in sophistication and in the concepts they apply. The answers in this report should be considered in the perspective that the authors had much access to particular infrastructure companies, like the Dutch RIB and the Swiss one.

Some key conclusions are that:

- There is no overall embracing database system containing information on the state of all the elements of the railway system. Instead information is scattered over many systems. The main information system seems to be SAP, but that has mainly an accounting role and is not linked to quality information systems. Several attempts are being made and it is an essential, yet difficult, task if maintenance planning is to be done in a thorough way.
- There is no possibility to link the present state of the infrastructure with deterioration models, except for Ecotrack and IRIS cases. A proper maintenance planning systems requires such a link.
- There are no good overall quality indicators, giving insight into the average state of the infrastructure and which can be used in budget determination. To day, budgets seem to be based on ad-hoc processes rather than on a thorough analysis on what is needed in the long-run.
- The possession planning seems to be in many countries a manual based process which can be improved using concepts developed with RIB in the Netherlands.

9.4 LCC in Infrastructure Management

To the extent that Railway is characterised by the need for large initial investments and large annual budgets for maintenance/renewal activity, a very long life cycle and significant correlation between quality of investments and need for maintenance, Life Cycle Cost assessment (LCC) became a crucial issue for the economic sustainability of the railway business. The increasingly competitive business environment, declining resources and an ever-increasing need to obtain value for money will inevitably lead to the wide adoption of LCC in railway, contributing to ensure that available resources are rationally used.

However, and despite the clear advantages in following the LCC rationale, it was seen that unlike with railways rolling stock for which several LCC calculation models exist for the assessment of costs, infrastructure side of the railway industry does not have, to a large extent, such tools available. Although during the he past 20 years, most European Infrastructure Managers made efforts to develop and implement tools that are required for professional life cycle design and maintenance management, these tools are still in an early phase of development and examples of successful implementation in the decision-making processes are almost absent. In an effort to summarise all the progress done in Life Cycle Costing in Railways Infrastructure Management, a review of European Railways Procedures took place. Out of all, only RIB showed significant attempts to introduce and eventually establish LCC techniques in the infrastructure management.

From the LCC combination of the investment and the maintenance/renewal a number of potential areas for cost-reduction may be identified. To such extent it was seen from previous research that a lean and appropriately specified infrastructure, may offer a two digit reduction potential for investment and maintenance/renewal. From previous studies it was also seen that Life-Cycle related choices, like timing of renewal, quality and maintainability of assets have an important effect on cost-competitiveness. Circumstances of construction as well as maintenance and renewal (traffic interruptions, local accessibility and track access time) are of vital importance for LCC considerations. It was further revealed that technical and operational knowledge which was traditionally in the hands of practitioners tends to get lost. Therefore LCC analysis should see whether possible raising costs of subcontracting dependence may have an impact on long term cost estimations.

Moreover, the commercial assessment of technical and operational issues is often neglected, sometimes constituting even a “blind spot”. Few practical decisions are really taken on well-informed commercial grounds. The lack of knowledge at the technical-economic interface is widespread and sometimes astonishing. Relevant areas for knowledge acquisition and decision-support should be, among others:

- the effect of standards and quality-levels on cost
- planning and optimisation of asset-replacement strategies, extensions of useful life for “cyclic components” like rail, etc.
- asset condition monitoring and prediction for tailor-made maintenance processes
- technical solution and innovations, driven by clear-cut commercial objectives
- the understanding of mechanisms and quality-aspects of various maintenance processes and inspection tools and
- the commercial assessment of the impact of rolling-stock quality on infrastructure LCC

The application of a LCC DSS to the design of new high-speed line shows that many factors influence the actual costs and performance. Uncertainties related to, for instance, the train operations and innovative technologies complicate the analysis. These uncertainties are worsened due to the poor availability of historic maintenance data. A univocal expectation of infrastructure costs and performance is therefore missing for inclusion on LCC models

The possibilities for planning infrastructure costs and performance are somehow limited, especially in the design phase, due to the above-mentioned reasons. This is one of the acknowledged reasons why Railway companies do recognise that the introduction of LCC is a long-term process that is costly and requires changes within company structures and also cultures to become effective,

Overall, we have seen that the development of a harmonized methodology for assessing rail infrastructure Life Cycle Costs (LCC) related to investment (infrastructure related), maintenance and renewal costs, vehicle-infrastructure interaction, delay and scarcity costs and accident/environmental costs, requires that reliable data is available and that common criteria is adopted.

Furthermore, LCC techniques applied to railway should not only include time dimension and costs attributable to the project analyzed, but also account for cost variation patterns. Also the possible changes in cost structures due to the implementation of the EU Directives should be considered. In fact the implementation of the EU Directives had the consequence of driving changes in railway cost structures, primarily due to the separation of roles between operation and maintenance. However, this does not mean a straightforward and simple split, since much of this process has implied a refinement of the quality of the data along with cost allocation criteria. In fact this separation has brought along also charging issues for access to the infrastructure by the operators and therefore well identified "IM related" cost arguments are required for the IM to support billing schemes that are fair and reflect signals of the real cost of the provision of railway infrastructure.

But such change is not yet fully put to place, as the implementation process mentioned is in most cases still underway or least still in its maturity phase. Therefore it is expectable that the fine tuning required in railways regarding cost accounting structures in result of the new regulatory environment may also foster LCC implementation, since analytical accounting and cost knowledge concerns are broadly shared by both LCC requirements and charging schemes' requirements.[36]

In any case, we recommend that all new projects undertaken in railway nowadays should at least be framed by life long cost concerns, which although possibly based only on raw data and statistical studies will nevertheless represent second best approaches to LCC that are worthing to be explored.

9.5 Allocation of Network Capacity and Charging Issues

The separation between provision of train services and the infrastructure management has provided the basics for a new railway business concept, calling for a new approach regarding the relationship between network managers and new coming competing operators. Such cleft raises the need for feedback relations among railway stakeholders, fostering the rational production of the railway transport service. This means that it becomes necessary to implement a market structure based on financial flows, promoting the system's optimisation. Hence, infrastructure charging emerges as a crucial "part of the picture" required to fulfil the expectations that remain in railway transport.

In direct relation to the charging issue comes the fair allocation of capacity, adopting the concept of ***train paths*** related to capacity allocation. Indeed, this became a crucial issue in the context of the provision of track access service. This is actually a scarce commodity in most corridors across Europe, regarding departure times, arrival times and transit times.

Existing timetables favour the established rail operators with multiple train paths at times that suit their business and with preferential transits that minimise the number of crossing delays. New operators are left with train paths that do not meet commercial or operational needs, but still costing the same, sometimes even more than those of the major operators. This places new entrants in disadvantageous positions in relation to existing rail operators, in particular if we think about one of the most promising market segments for rail represented by freight. In a railway liberalised market, operators (R.U.) would have a different willingness to pay for different slots, varying with the underlying demand function of the demand and the characteristics of the operators

Hence there is a clear and real need to rationalise train paths allocation along with suitable charging mechanisms, in order to provide a level playing field between the railway undertakers while promoting the railway as a true alternative to road concerning freight.

According to the Directive 2001/14/EC, charges must be paid to the infrastructure managers and used to fund their business; in principle, the charge for the use of railway infrastructure equals the cost directly incurred as a result of operation of the trains; the infrastructure charge may include a sum reflecting the

[36] See Workpackage 7 - Deliverable 9 , dedicated to Data Harmonization for Charging

scarcity of capacity; and the infrastructure charge may be modified to take account of the cost of the environmental impact of operation of the trains.

Referring to the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification the EC Directive 2001/14 of the European Parliament and of the Council of 26 February 2001, says explicitly, "*the charging and capacity allocation schemes should permit equal and non-discriminating access for all undertakings and attempt as far as possible to meet the needs of all users and traffic types in a fair and non-discriminating manner*".

The directive 2001/14/EEC defends that the infrastructure charging schemes have to encourage the infrastructure manager to minimise disruption and improve the performance of the railway network. While respecting the management independence, the specific charging rules are established by the state member or the infrastructure manager. As already considered in the previous directive 91/440/EEC, the infrastructure manager determines and collects the charge for the use of infrastructure except if the infrastructure manager is not independent in its legal form, organization and decision-making from any railway undertaking.

In general, the charging systems that are analysed hereby allow clarifying the role of charging in promoting access to services facilities and supply of services, including the different capacity allocation strategies combined with the levying of the charges. A discussion on the adherence of Marginal Cost pricing principles to the recent EC Directives on this subject is also included, along with the importance of the charging systems in the relationships with the Railway Undertakers and in the promotion of cross border railway traffic.

A key aspect reviewed in IMPROVERAIL in relation to charging and capacity assignment is the ***quality of the infrastructure*** for the valuation of the service being provided. The track condition is a key factor, as there are large sections of track that cannot accept the top speed of high-speed trains. These substandard track sections reduce the ability of the traffic planner to maximize the efficiency of train paths. This causes sub optimal transits and increases the operational costs of the railway undertaker.

Also the ***information systems*** *must* be developed coherently on a cross-border perspective, in order to provide real time information concerning trains running and must be accessible to the rail operators. Currently, a number of different systems are used in different states. There would be benefits from deciding on a single system and ensuring that the system provides the operational and commercial requirements for both the track authority/company and operators.

Charges should be set for each corridor to encourage fair **competition with road and aviation**. Rates should be published and held for a minimum 12-month period. The current practice in some states, of negotiating with individual operators on the annual fee and/ or the usage fee, provides an area of uncertainty for rail operators regarding the equity of the result. Large annual fees on some track sections create **barriers to entry** for new operators. **The rates and fees must be uniform, transparent and reflect the quality of train path provided.**

The network authority/ company IM should be required to provide a range of services at a level consistent with rates, transit times and quality of ride competitive with road. Documentation of agreements should be standardised to incorporate uniform elements for all rail operators.

The **agreements** will need to address the levels of performance of both parties. The issues of termination, insurance and cost retrieval need to be reviewed and brought up to commercial grounds. Requests for train paths and negotiations for agreements should be given time frames and standard procedures and documentation introduced to facilitate this process. With regard to the legitimate expectations from the railway demand side (Railway Undertakers), some crucial aspects should deserve special attention in the application of slot allocation, such as the preferred duration of the contracts between infrastructure managers and train operating companies, which differ considerably between parties.

In order to make an investment in rolling stock worthwhile for a train operator, the operator will want to have a long contract in order to guarantee stability of fees; the infrastructure manager on the other hand will want to maximise flexibility by having contracts as short as possible. *Grandfathering* partly solves this problem, but will also act as a barrier against new operators entering the market.

Slot allocation presumes a free market with competing parties. In the case of railways, the market might simply not be big enough for genuine competition, as in the case of scarcely populated countries. To reach the full economic and operational potential of slot allocation in these cases might be hard, if not impossible.

Penalty systems could be applied, but determining how much damage is caused by a delay is very difficult; the time of the delay is a factor but also the number of trains affected by the delay. Finally it is not always clear who is responsible for delays. However practical systems can be developed, accepted by both parties and put into practice, as the example of the private concession of Fertagus in Portugal clearly shows. RUs will also require flexibility from the IM side in allocating alternative paths, allowing operators to meet sudden changes in demand; and flexibility with re-routing in case of sudden obstructions or other unexpected problems. This means clear and up-to-date information from the IM side, providing the operators with transparent conditions, options and possibilities through high-quality Business-to-Business (B2B) information systems.

A well-functioning and flexible system must be offered to the various operators, rules that are imposed should be considered fair, operators must perceive to be using a good product. New systems are only accepted if they work well. All in all, charging procedures should give the right incentives for total railway production, competition between operators and between railway transport and road and aviation transport. The following chapter shows how this can be achieved.

Finally, **International traffic** which is heavily dependent on national charging schemes; priority rules and bureaucracy should be supported by common principles and clear charging systems ensuring transparency, predictability and non-discrimination. Financial **mark-ups** to cover parts of investment costs to the infrastructure charges, despite extolled in the recent EC Directive 2001/14, may create a sub-optimal situation at a national level. In international traffic, the disadvantages of such systems are even more visible, as each national IM will have few incentives and will often miss the ability to see the impact of reducing international operators' surplus. It is therefore recommended to analyse carefully the definition of a cross border charging system

9.6 Railway Infrastructure Benchmarking

In IMPROVERAIL we have seen that attaining improvement in the long term based on Benchmarking can only be successful if top management is committed to opening up to outside ideas and implementing best practice. Otherwise little benefit will be achieved.

The most common drawback of usual benchmarking approaches is that they require far greater resources than the classic benchmarking for best practice. To set target costs, for example, requires much more harmonisation of the figures than the identification of practices which can improve cost levels. The IMPROVERAIL benchmarking framework, dedicated to the identification and implementation of best practices. We propose this benchmarking philosophy in IMPROVERAIL precisely because of the historically resourceful difficulties in achieving absolute comparability in performance measurements.

About the concept itself, numerous definitions of benchmarking have been developed. The most successful exponents emphasize action, processes and the implementation of change, and not accuracy in data comparisons.

What we have seen in IMP*ROVERAIL is that the definition and measurement of performance between IMs in Europe is currently very different. And for some KPIs, it will take many years to reach a satisfactory level of comparability. However, some benefits from benchmarking can be achieved immediately with incompletely comparable data.

Another issue in the scope of the Information systems are the asset registers, which are not currently adequate for successful benchmarking within most IMs. In fact also accounting systems are different between IMs and furthermore, due to the complex nature and vast scale of IMs, exogenous influences on performance, beyond the control of the IM, can mask the degree to which high or low performance is due to best practices or processes.

The existence of the INFRACOST I-III benchmarking studies, and the amount of resource put into it over the years, suggests that there are already at least twelve European railways that have been committed to exchanging cost data and information about their practices in order to improve their cost performance. This almost certainly implies that they would also be ready to benchmark for best practices in other fields such as quality and safety management systems, where great benefits might be gained from this sort of information exchange.

IMPROVERAIL has shown that not all projects need be as time-consuming and resource-intensive as INFRACOST I-III, and that IMs who have not been involved in benchmarking before would certainly be able to start doing so. It has documented a range of different projects that have taken place, and set out an approach to benchmarking, and a proposed set of KPIs for the consideration of IMs. The main barriers to effective and mutually profitable benchmarking will be:

- The lack of incentive amongst some IMs to improve performance unless they are given strong encouragement in this direction by the authorities to whom they report.
- A culture of inertia and a concentration on cost cutting to the exclusion of all other success dimensions, which was previously expected of many IMs and is still deeply imbedded in the way of thinking in some countries.
- Inadequate data collection procedures for a variety of functional areas – IMPROVERAIL has identified weaknesses amongst the majority of IMs in all three areas in which pilot studies took place, the monitoring and control of delays and failures, safety management systems (where only a minority of IMs measure precursors or distinguish between major and minor casualties) and procurement (where most have no programmes for moving to a restricted number of approved suppliers as the automotive industry have done, and therefore little or no systematic performance data).
- Inadequate information systems, especially asset management systems

And although different definitions might not a problem in benchmarking, it is certainly true that small differences can only be ignored if the differences in performance are great enough. However, during the IMPROVERAIL pilot case studies, e.g. when the UIC figures were compared with internal figures in many of the IMs, there were often significant differences between

- The figures supplied by the IM to the UIC
- The figures in the railway's published annual report
- The figures published by research and political institutions in the country
- Internal figures from a variety of sources
- The basis on which different IMs or railways have prepared any of the above figures

These differences apply most of all to financial figures, but also to safety and to punctuality and other service quality measurements. For example, in safety figures, some IMs only count collisions that lead to injuries, others include all collisions, however minor; some include level crossing accidents and others exclude them. Hence, the lack of harmonised definitions may also become a significant barrier to IM international benchmarking. IMPROVERAIL believes that these barriers can be overcome but it will take time, focussed, and sustained effort and co-operation between IMs. If the KPIs can be agreed and IMs can start to use them, and they can improve their data collection and information systems to the standard of the better railways such as SBB, RENFE or Netherlands railways, the potential for best practice benchmarking will be substantial. However, the change of culture and systems will not be an easy task.

9.7 Information Systems

It has been seen that there is currently a gap in what concerns information systems in railways, in particular regarding the support to LCC and Changing under the new regulatory framework. This prevents practical application of theoretical infrastructure charging principles and optimisation of lonf term investment decisions. Moreover the quality, reliability and consistency of definitions of existing data are generally bad, preventing e.g. better transparency and efficiency with regard to infrastructure charging.

To this respect, the link of costs to related benefits is often missing. Therefore if the benefits from certain IM activities are unknown, the IM might be tempted to reduce related investments, which may be restrained by the adoption of Service Level Agreements (SLA).

All in all the comparability of the existing data is bad and cannot be improved without significant changes. On the other hand, the low level of data comparability is also based on different cost allocation principles. For that problem, a better transparency of infrastructure charging components would increase the performance of all infrastructure charging systems and the performance of planning cross border-train services. In this sense, data reliability as well as data validity seems to be currently a problem. Different ways to calculate cost elements may also cause great differences. Therefore further R&D in combination with new software is needed to help IMs and operators assess the marginal cost elements.

An instrument to support the theoretical pricing mechanisms with grounded data is therefore the harmonisation of data quality. This instrument is expected to allow a better benchmarking of individual cost allocation policies and different pricing policies across Europe.

The consortium recommends national detailed models able to assess system costs for the use of calculating system costs as well as allocate track efficiently. Gradually, as the technology evolves, such systems can be made mandatory for all countries. To this respect a visible gap has been shown between data requirements for harmonised infrastructure charging in theory and practice even if we take into consideration that the need for such harmonisation can be limited to the principle of transparency. Also as a general recommendation, it should be further considered some specificities of data management in case of outsourcing of M&R activities. In such situations it is recommended to Infrastructure managers that these should not outsource core decision processes associated to their assets. As the long-term M&R planning belongs to this process category, related actions should be done by the infrastructure management company.

This raises the question of data management when outsourcing certain important activities. If an infrastructure manager has contracted out the maintenance and renewal work to one or more contractors, the task of the infrastructure manager concerning the collection of infrastructure data will change. Apart from some visual spot checks of the track from time to time, the IM does not itself collect the infrastructure data needed. It has to rely on the data collected and presented by the contractors. The role of the IM turns into one of managing the data collection, instead of performing it itself.

Therefore in the case that M&R is outsourced, the infrastructure manager should ask, apart from the above-mentioned aspects, the following additional questions:

- Who is obtaining the data?
- By which methods?
- Who is storing the data?
- Is the stored data centralised or decentralised?
- Who is analysing the data?
- What is the quality of the data?
- Who is checking the quality of the data?
- How often will the information be updated? (How often should it be updated?)
- Are there mixed interests with the contractors concerning the availability (and the place of storage) of infrastructure data?

10 REFERENCES

This document builds on the following project outputs developed in the course of the IMPROVERAIL, synthesising their contents and further providing an integrated overview of each separate project results.

- **Deliverable 0** (WP0) - Inception Report
- **Deliverable 1** (WP1) - Report on the 'State of the Art in Railway Infrastructure Capacity and Access Management'
- **Deliverable 2** (WP2) - Report on 'Benchmarking Methodologies and Harmonisation of Concepts in the Railway Sector'
- **Deliverable 3** (WP 2/3) - Report on 'Benchmarking Exercise in Railway Infrastructure Management'
- **Deliverable 4** (WP4) - Report on a 'Framework for Business Process Re-Engineering for Railway Infrastructure Managers'
- **Deliverable 5** (WP5) - Intermediate report on 'Modelling Long Term Infrastructure Capacity Evolution and Policy Assessment Regarding Infrastructure Maintenance and Renewal'
- **Deliverable 6** (WP5) - Report on 'Methods for Capacity and Resource Management'
- **Deliverable 7** (WP6) - Intermediate report on 'Life Cycle Costs Concepts and Definitions for Infrastructure Provision and Use'
- **Deliverable 8** (WP6) - Final report on 'Life Cycle Costs for Infrastructure Provision and Use'
- **Deliverable 9** (WP7) - Report on' Improved Data Background to Support Current and Future Infrastructure Charging Systems'