Maintenance Improvement: an Opportunity for Railway Infrastructure Capacity Enhancement

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Abstract

The continually increasing demand on railway service in terms of the quantity and quality of both passenger and freight train operations is the core of the general railway capacity challenge. Moreover, this challenge has been the driver for some improvements in the technical system, traffic operation & management as well as maintenance process, although the room for improvement in the maintenance function is still large. An effective capacity management entails critical study of the three essential capacity parameters: infrastructure, traffic and operating parameters. To further explore the fundamentals of capacity management, this paper investigates some essential issues on railway infrastructure capacity. A review of the general railway infrastructure capacity challenge and management is presented, including some strategic measures to enhance capacity and quality of service of existing infrastructure. We have proposed maintenance improvement framework to explore the opportunity of improving the capacity situation on a network. This framework will facilitate the identification of both critical systems and activities with the largest impact on the capacity and also some root causes for critical system. The framework has suggested methodology to improve allocation and utilisation of track possession time, giving room for capacity expansion of existing railway infrastructure.

1.0 Introduction

The expansion of economic activities and the increasing mobility of people locally and globally is a major concern to the transport sector. The need to cater for both essential growths in a sustainable and economically efficient way is the core of the general capacity challenge in the railway industries. In effect, infrastructure managers (IM) are saddled with the ambitious targets of increasing the competitiveness of railway transport through capacity and service quality improvement.

Notable indications of capacity challenge for both freight and passenger traffic as identified in literature include: high seat & vehicle utilization, recurring unpunctuality, poor robustness & irregularity of time schedule, increasing demand for train path, difficulty in getting track possession for maintenance etc. [1-3]. Furthermore, in the EU15 countries there has been 15% and 28% increase in rail freight tonnage-kilometers and passenger-kilometers respectively over the period 1990-2007 [4]. In Sweden there has been a noticeable increase in the annual tonnage-kilometers and passenger-kilometer except in 2009 with large drop due to reduced global economic activities. There is an anticipated increase in traffic volume of the 473km long heavy haul line in Sweden from the present 28MGT to 45MGT in 2015. This will most likely necessitate an axle load increase from 30 to 32.5tonnes.

In recent years several research efforts within the railway industries has been centred on managing the capacity and service quality of the existing railway infrastructure network. The researches extend from improvement of rail services, rail management system and rail technology, all of which contribute towards a sustainable and more competitive railway transport [4]. Effective capacity management is a key stratagem to the success of railway sector. Primary solution to capacity challenge would be capital expansion of infrastructure but this is a cost intensive means and long term plan for increasing capacity [1]. This explains the need for a cost effective and feasible way of managing the capacity of existing railway infrastructure through effective utilization of infrastructure possession times.

Achieving the goal of improving the capacity of existing railway infrastructure entails optimization of maintenance decisions and actions which will influence infrastructure performance, reliability, degradation and availability. An overview of techniques used in planning infrastructure maintenance and determination of best practices has been done [5]. This includes an overview of degradation model and scheduling models. Optimization model for determining the allocation of maintenance activities and crew to minimized train disruption was developed by [6]. Among other track possession and planning models developed are those in [7-9].

However in this article we present a conceptual framework for the enhancement of capacity through reduced track maintenance possession time. The article is arranged as follows; description of capacity situation with various actors, review of capacity assessment process, capacity parameters and enhancement measures. Finally, the conceptual framework proposed is described.

2.0 Capacity Situation

Railway transport is a multi-stakeholder business and its capacity is a complex issue which can be viewed from different perspective of the market, infrastructure planning, traffic scheduling and operations [10]. Though capacity is said to depend on the way it is utilized, the operational capacity and quality of service largely depends on the views and practices of the stakeholders. The ability of a defined rail line to move specific amount of traffic within a given resources and service plan largely depends on its design capability, operating conditions and maintenance condition. Figure 1 shows the interaction between all the active parties in a typical railway business and the resulting quantity/quality of railway service. The figure consists of two scenarios: the present and ambitious scenario. The present scenario is the upper part of the figure and it reflects the present or operational capacity with the influencing parties. However the lower part shows the emerging ambitious targets inspired by political promise, recommendation of international bodies and demand from train operators. With this situation in view, there is need to improve the sector to enhance both the quality and volume of traffic.

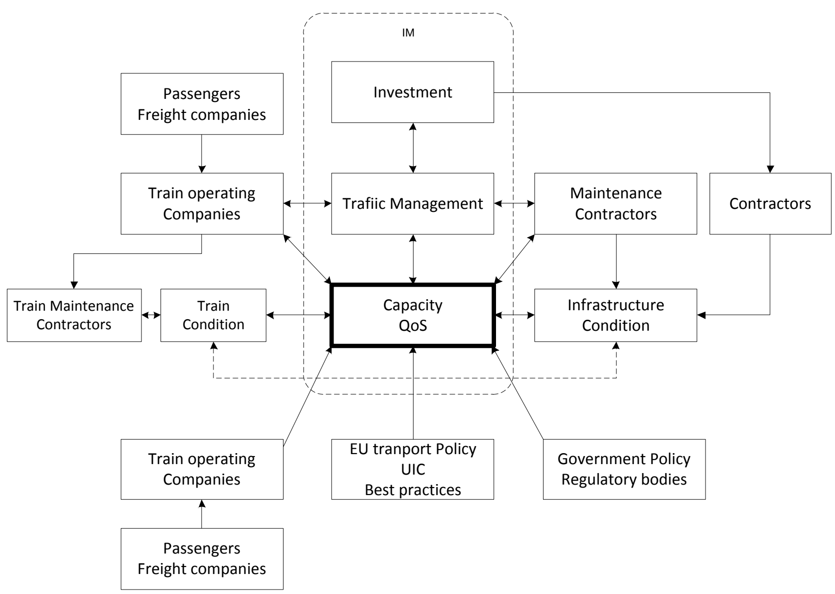

Figure 1: Capacity scenario and involved stakeholders (Qos-Quality of service)

3.0 Capacity Management

3.1 Capacity Assessment

Railway capacity measures the ability of a specific railway infrastructure to move a volume of traffic satisfying the requirements of the infrastructure manager and quality demand of the customers. This ability can be evaluated, factors affecting it can be identified and the influence of these factors can be analyzed. The several available tools and techniques for the evaluation of railway capacity are in three categories: analytical, optimization and simulation methods. Examples of the simulation tools are; Railsys, Multirail, Opentrack, CMS, VirtuOS, SIMONE, MOM, SIMON etc. For detailed information on capacity assessment and the different tools, we refer to the following references [1], [11], [12].

The general process flow in the calculation of railway capacity as recommended by international union of railways (2004) and further demonstrated by Landex [13] is shown in Figure 2. The first step is to understand the characteristics of the railway infrastructure; i.e. parameters describing the infrastructure in terms of the length of track subdivision, percentage double track, signal spacing, line spacing and so on. Furthermore the traffic parameters in form of timetable should also be known, this include the train paths, running time, train mix, average speed, priorities etc. The next step is to divide the railway network into line sections, thereafter compress the timetable so that the minimum headway time between the trains is obtained. The outcome of this assessment is the length of time which the facility is occupied in operation or the infrastructure occupation time; this is otherwise referred to as capacity utilization.

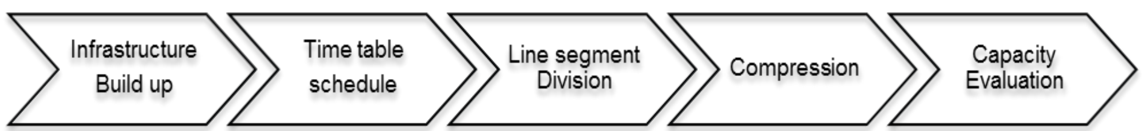

Figure 2: *General work flow for capacity evaluation*

The description of capacity situation on a line or network is often categorized into 3 based on the utilization of the inherent capacity and additional demand; Large problem (81-100%), averagely high problem (61-80%) and Low problem (<=60%) [13], [14]. The result of the capacity assessment of the Swedish network performed by [14] is used to illustrate the evolution of the capacity situation from 2009 to 2011 in Figure 3. The capacity situation is the outcome of increasing traffic and enhancement measures. This is indicating challenging situation in the future as some line segments including three line segments on the heavy haul are still in the large problem categories (81-100%) even in the presence of capacity enhancements plans. This requires both continuous improvement and new investments to achieve the business goal of the IM.

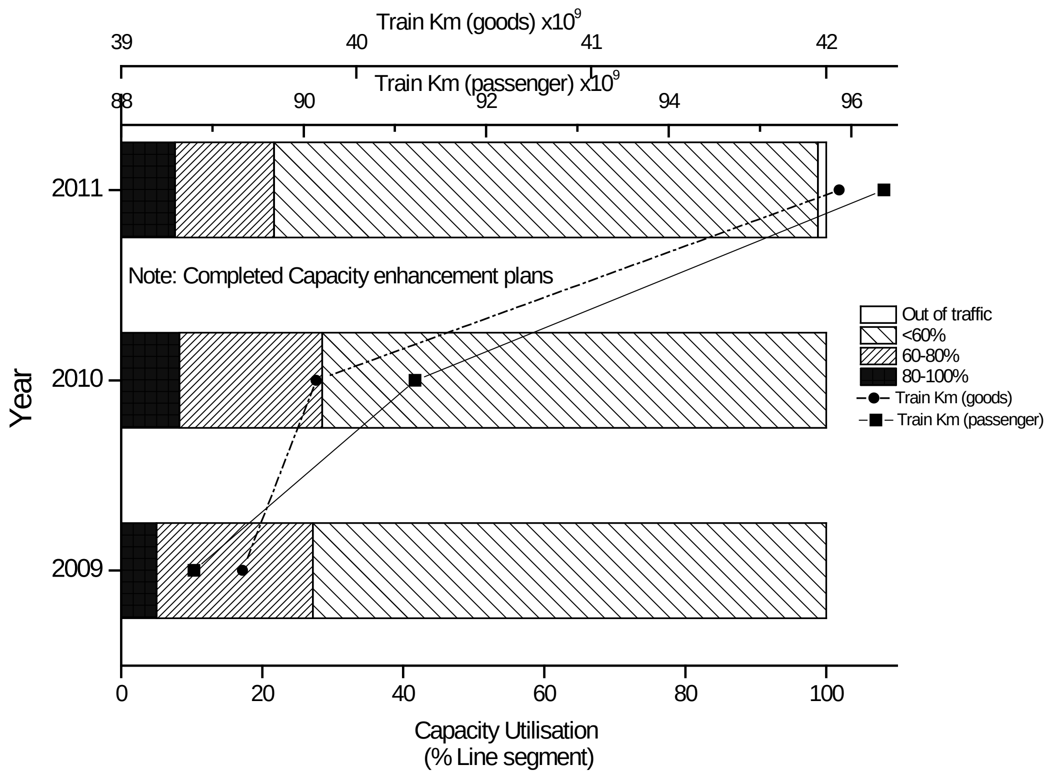

Figure 3: Capacity assessment of Swedish transport administration network

3.2 Railway capacity Parameters

Capacity analysis of the railway infrastructure is a vital but complex issue, it is not only determined by infrastructure build up, but there are other parameters which have either main or interacting effects on capacity. The characteristic capacity parameters are categorized into three: infrastructure in the system, traffic condition and the operational incidences [1], [11]. A particular combination of these three parameters will have a fixed capacity value, thus changes in any of these parameters will result in the dynamic response of capacity.

> Infrastructure: Length of subdivision, track geometry & layout, signaling system, double/single track, meet pass planning point spacing etc.
>
> Traffic: Traffic peaking factor, priority, average speed, heterogeneity etc.
>
> Operation: Track interruptions, speed reduction regime, train stop time, maximum trip time threshold and desired stability/quality.

The focus of the researchers is very much on maintenance and thus the operation parameters are of interest. Track interruptions and outages are indications of the RAMS characteristics of the infrastructure and their random nature makes it even more critical capacity parameter.

3.3 Capacity enhancement plans

There are several strategies and plans which have been deployed to enhance the capacity situation of infrastructure network, these ranges from short term straight forward measures to complex, expensive and long term measure. Some of the measures are listed below [1], [12]:

- Increase in the length of trains, platforms and sidings
- Closing down less busy stations to homogenize traffic
- Improving logistics of rolling stock - sharing maintenance facilities among operators, expanding the track yard and marshaling facilities.
- Adopting computer based system with enhanced facilities for planning, optimizing and simulating track possessions.
- Optimization of train schedule using the techniques of operations research for time table compaction & saturation.
- Upgrading tracks to accommodate higher axle loads
- Changing layouts of junctions & curves, building capacity enhancing structures such sidings, flyovers, tunnels etc.
- Implementation of traffic management strategies such as route utilization strategies,
- Installation of modern signaling system which is capable of reducing block length on track for train occupation. Thus improving traffic volume and massive flow.
- Other special measures e.g track repair patrol team in critical areas.

4.0 Conceptual Framework for maintenance improvement

A major concern in capacity management is the operation related parameter especially when existing infrastructure is under consideration. The management of outages or track possession time for maintenance is still an aspect with promising potential. The allocation and utilization of possession time for maintenance requires improvement if the track design capacity and reliable service is to be achieved. The required improvement is not only limited to planned maintenance but also extends to the strategy for handling unexpected interruptions. Such improvement programme should be holistic and it should address several issues which are considered essentials. This should be well presented in a supporting structure or framework for successful implementation like other improvement methods such as the Deming cycle.

Maintenance improvement being an integral part of maintenance process is inspired by the assessment of maintenance performance, benchmarking with best practices or request from stakeholders. A typical improvement programme designed for the enhancement of capacity and quality of service on existing infrastructure is shown in Figure 4. There are four distinct elements in the programme.

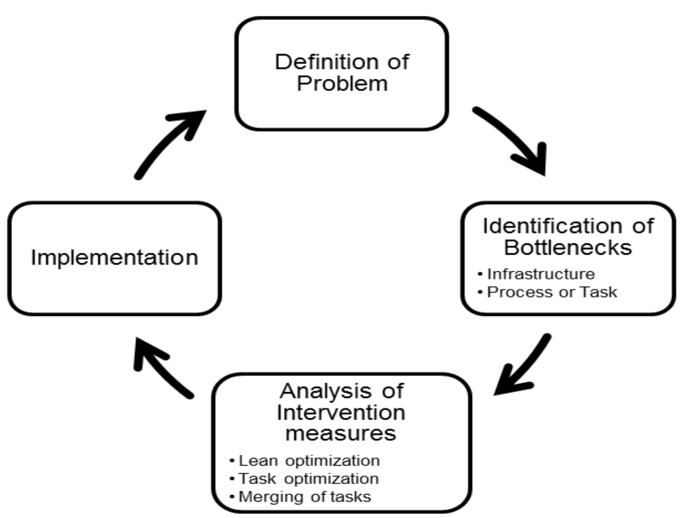

Figure 4: Maintenance improvement Framework

4.1 Definition of Problem

An essential pre-requisite to the definition of problem is a maintenance performance measurement system which helps to quantify the efficiency and effectiveness of past maintenance actions. The achieved outcome of past maintenance decisions and actions can be compared with set objectives or benchmark, and the ensuing gap is apparently the core issue in an improvement programme. In some cases the problem could be unsatisfied customer need, stakeholder request or an idea from technical development. A clear description of such gap is essential to drive the improvement process and also to validate any proposed solution measure. In this study, reduction of track possession time is the subject of the improvement programme.

4.2 Identification of Bottlenecks

Maintenance management of railway infrastructure is an elaborate process with large system and several activities. It is essential to identify the critical activities and systems which have the largest contribution to the observed gap or deficiency in maintenance function. This phenomenon or incident is referred to as bottlenecks. Bottlenecks could denote processes, activities or even subsystems that limit the capacity of an entire system or cause delay. In this case it restrains the flow of traffic through a line, or network. From maintenance point of view it could be hard measure or soft measure.

Hard Measures: These can be referred to as infrastructure bottleneck or critical point on a line or network. Traffic flow is limited at such point due to pronounced failure and consequential impact of the resulting interruptions. Bottlenecks can be identified at different system level depending on the purpose of the investigation. It can be a segment or line section in instances of high level system while for others it can be low level system such as turnouts, bridge, signaling boxes and catenary system. These critical points have impairing contribution to the RAMS characteristics of a line or network. This does not only affect the availability and safety of the network but also capacity and other quality measures. Since railway RAMS describes the confidence with which a network can guarantee the achievement of a defined quantity and quality of traffic, identifying negative contribution from any part of the entire system is an essential task for improvement. A typical cause and effect diagram showing the factors that could influence RAMS of a system, segment or sections are shown in Figure 5. In other words the diagram supports the process of identifying bottlenecks on a network and their root causes. Some relevant techniques and methodology which can be used to identify critical areas can be found in [15], [16].

Soft Measures: These are measures related to processes or tasks which have high impact on the operational capacity and quality of service. In some researches these are referred to as cost drivers or performance killers, but we have used the term bottleneck since we are concerned with track possession time or limitation to capacity utilization. Investigation in one of the EU projects [17] has shown that most important cost drivers are international. This indicates that maintenance tasks with high cost and most likely track occupation time could be similar for different Infrastructure Managers. The project has mapped most significant track problems into categories apparently representing corresponding maintenance interventions. A deduction from the project is that the following track maintenance tasks have the greatest impact on cost and perhaps on capacity: line tamping, grinding, inspection, re-sleepering, rail change, welding, vegetation control, joint renewal, turnout repair etc. However, it is recommended to conduct similar mapping into task categories using track possession time as performance measure.

It is noteworthy to mention that investigation and identification of critical assets or tasks require detailed study of historical data, failure data, maintenance data and operation data as well.

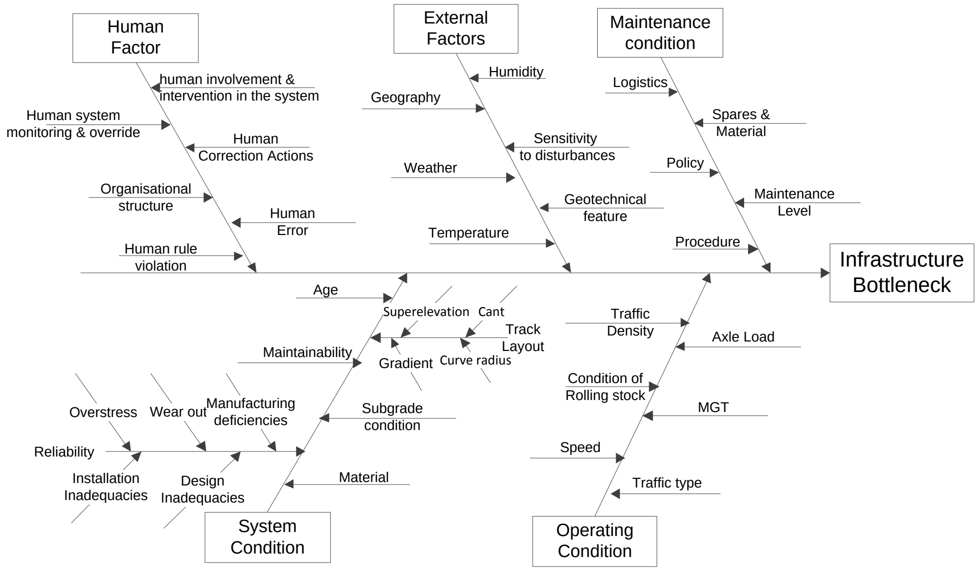

Figure 5: Root causes of infrastructure bottleneck

4.3 Analysis of intervention measures

This is another important element in the maintenance improvement programme. Having identified the gap between target and maintenance outcome, as well as pointing out critical asset and tasks, analysis of intervention measures is the next element in the framework. Typical intervention measures could be changes in maintenance concept, level of maintenance, maintenance procedures, skills and training of maintenance and operations personnel, spare parts and materials, operating procedures and conditions, safety and environmental procedures, equipment and system design. Moreover a detailed analysis of the intervention measures or suggested changes is necessary to accomplish an optimize maintenance principle and practice which supports optimum possession of the track for maintenance. There are three important perspectives of the optimization in this framework

- Lean Optimization of task with significant impact on capacity: This involves the deployment of TPM principles to identify non value adding activities in maintenance task which demands high track possession time. These are wastes and losses that can be eliminated and the process becomes efficient.
- Mathematical optimization of the possession frequency of the tasks: Operation research principles are to be used together with some existing physical degradation model of the system.
- Bundling or grouping strategy of the relevant tasks: Mathematical models can be used to analyze related maintenance tasks for possibilities of grouping them in the same white period. This will reduce the frequency of track possession for maintenance.

4.4 Implementation

The last stage in the framework for the improvement programme is the transformation of the changes into actions. This will include strategic arrangement for the deployment of these changes at the operational level. The implementation procedure gives the detail of what to do, when to do and some other guidelines needed to execute the solution at the appropriate level within the organization. It is essential to customize the implementation plan to fit the business environment of the infrastructure organization. Adequate strategy is needed if the maintenance function is outsourced to external contractors and subcontractors. Management support and effective communication will facilitate the implementation of suggested intervention measures. It is essential to mention that the improvement programme should be integrated with the overall maintenance process to ensure a holistic maintenance procedure.

5.0 Conclusion

This paper has given capacity scenario with the views and influence of different stakeholders. The three broad classification of capacity parameters are mentioned with emphasis on operation parameter. Some practical capacity enhancement plans that have been implemented by some IMs are presented. The key contribution in this paper is the proposal of maintenance improvement framework which is practically oriented to improve the RAMS of railway infrastructure. The outcome of this will be reduction in track outages due to planned or unplanned maintenance thereby improving the capacity situation of railway network. The authors are currently working on further development of the framework especially development of optimization model for improved allocation and utilisation of track possession time for high impact maintenance tasks.

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