Use determines a given maintenance strategy, but planning determines that strategy's cost effectiveness.

(A) Introduction:
This paper/presentation deals with the conventional railroad systems only. It covers the key points highlighting cost effective maintenance strategies of permanent way components. This paper does not include structure maintenance e.g. bridges, tunnels practices associated with conventional track structure etc. Track has been termed the permanent way. The permanent way components of ballasted tracks are rails, sleepers (ties), fasteners, ballast, sub ballast and soil formation (subgrade). Track is the system of materials from the subgrade to top of rail in ballasted track or from the bottom of a rail support device (fastener, block tie) to the top of rail in ballast-less track. In Australian rail freight operations, railway track maintenance makes up between 25% and 35% of total train operating costs and models have shown that track maintenance costs can be reduced by 5% to 10% through improved planning (Scott A. Simson, Luis Ferreira, Martin H. Murray; 2000). The conclusion for most advanced railways will be that traditional, manual track improvement measures are economically obsolete (Phil Anderson and J. S. Mundrey, 1995).

One of the cost-effective maintenance practices for conventional track structure is the use of modern methods of track maintenance. There are few modern methods of track maintenance like mechanized maintenance or mechanical tamping, measured shovel packing and directed track maintenance. The various factors that influence track maintenance cost are: track material costs-life cycle cost, use of new technology, track labor cost, track maintenance activities, work windows (work blocks), track inspection and maintenance policies, operating characteristics, budgeting and accounting practices, availability of capital and operating funds, recordkeeping procedures and miscellaneous (e.g. geographical, cultural etc.) factors. The effect of use of new technology as well as the use of concept of life cycle cost of track components are significant.

There are various conventional track structure maintenance activities, which control the track structure maintenance cost. They are rail maintenance, track geometry maintenance, tie and fastener maintenance, ballast maintenance, track inspection, emergency services (derailment repairs, storm repair, etc.), underperforming track system maintenance and track access influence on track maintenance.

General track maintenance approach is of two types. They are preventive track maintenance and curative/crisis track maintenance. The railroad companies should not wait to do emergency restoration work after an accident due to track maintenance failure. Railroad companies are advised to prepare and apply for preventive track maintenance plans. At the long-term, preventive track maintenance plans present lower overall costs than curative/crisis track maintenance.

There are various track maintenance strategies related to mechanization of track maintenance. They are complete & effective mechanization of track maintenance, procurement of latest state-of-the-art new generation high performance machines, implementation of mobile maintenance system, integrated implementation of all aspects of a track modernization project and complete track renewal (CTR) as one of the cost effective maintenance practice.

The author has proposed a low-cost maintenance strategy of existing turnouts. This strategy is based on the author’s 2011 AREMA conference paper on Higher Diverging Speed Turnout Design in the Same
Footprint. The various key steps have been proposed based on this cost effective maintenance strategy for increasing the diverging speed in the same interlocking footprint of the existing turnout. These steps are reduction of switch entry angle, provision of transition curve in diverging portion of track, higher cant deficiency for turnout diverging track structure, use of kinematic gauge optimization or thick web switches technique, provision of special type of heel & switch plates with braces, provision of a special type of frog, provision of check/guard rails level higher than stock rail or inner curve rail, provision of suitable flange way, use of heat-treated switch tips and provision of guarded turnout.

Railroad companies are advised to start with basic manual/mechanized maintenance practices and then go for more sophisticated cost effective maintenance practices to achieve better operational efficiency, less maintenance cost and aim for no accidents. The various cost effective maintenance practices can save dollars in providing credible service at cheap prices to railroad companies’ customers.

(B)Description:

a. General

The permanent way components of ballasted track are rails, sleepers (ties), fasteners, ballast, sub ballast, soil formation and in ballast-less track are rails, sleepers (ties), and rail support device (fastener, block tie).

- **Rail**: It transfers the loads from train onto sleepers (ties) and provides a continuous and level surface for train movement, provide lateral guidance to the train wheels. There are different types of rail. Its cross section detail varies depending upon type of traffic and other factors.
- **Sleepers(ties)**: They transfers the load from Rail onto ballast and hold rails in correct alignment and spacing, provide firm and even support to rails.
- **Fasteners**: They connect rails to sleepers. There are different types of fasteners e.g. Rigid fasteners for Yards and Elastic fasteners for bridges & their approaches etc.
- **Ballast**: It transfer, distribute loads from ties to the subgrade and facilitates drainage.
- **Sub-ballast**: It transfers and distributes loads from ballast to soil formation. Sub ballast stones are smaller compared to ballast stones.
- **Soil Formation/Subgrade**: It finally load is transferred to soil formation/subgrade.
- **Rail support device (fastener, block tie)**: Rail is attached to block tie through fastener in ballast-less track.

The maintenance of a conventional track structure should be such that, it should follow or tends to follow the requirements of an ideal permanent way⁴. There are various requirements that an ideal permanent way should possess, e.g. the gauge should be uniform and correct, both rails should be at the same level in straight track and at proper super elevation in a curved track; the permanent way should be properly designed so that the load of the train is uniformly distributed over the two rails, the fasteners and the ties; the track should have enough lateral strength; the curve radii and super elevation should be properly designed for the intended operating speed and prescribed uncompensated centrifugal acceleration; the track must have a certain amount of elasticity; all joints, points and crossings should be properly designed and offer a degree of robustness; the drainage system of the permanent way should be as perfect as possible. In summary, all the components of the permanent way should satisfy the design requirements and should have adequate provision for easy renewals and repairs.

Track needs regular maintenance to remain in good order, especially when high-speed train operations are involved. Improper maintenance will impose speed restriction along the affected track route to avoid accidents. In the past, track maintenance was purely performed using manual labor. At that, time trackmen used to fix irregularities in horizontal alignment (using lining bars) and vertical alignment (using tamping jacks) of the track structure. During the course of time, maintenance of track was facilitated by use of a variety of specialized machines such as the ballast-cleaning machine (BCM), Universal Tamping
Machine (UTM), etc. Nowadays, maintenance of track structure is more mechanized compared to earlier times. Mechanized maintenance has obvious advantages when compared to manual maintenance.

The comparison of life cycle costs of Slab Track Austria vs. Conventional Ballasted Track systems is performed (Exhibit-4). The following observations are made:

- After approximately about 20 years, the cost of construction and maintenance of the Conventional Ballasted Track is significantly higher than that of Slab Track Austria.
- Up to 20 years, the cost of construction and maintenance of the Conventional Ballasted Track is lower than that of Slab Track Austria.
- Estimated life time for Slab Track Austria is at least 60 years which is much longer than Ballasted Track System with 30-40 years.

The track structure can be ballasted or non-ballasted. There are various typical types of track structures e.g. ballasted track structure on embankment (Exhibit-1), track structure in tunnel (Exhibit-2) and ballast-less track structure with rail support device (Exhibit-3). Both types of track structures (ballasted or non-ballasted) have their own advantages and disadvantages (Exhibit-5).
Typical Ballasted Track Section

Exhibit-1
Typical Track Section through Tunnel

Exhibit-2
**Typical Ballast-less Track Section**

Exhibit-3
The comparison of life cycle costs of Slab Track Austria vs. Conventional Ballasted Track systems.

Exhibit-4
### Comparison between Ballasted and Ballast-less Track Systems

#### Exhibit-5

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Ballasted Track</th>
<th>Ballast less Track</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maintenance Input</td>
<td>Frequent maintenance and non-uniform degradation</td>
<td>Less maintenance for geometry</td>
</tr>
<tr>
<td>2</td>
<td>Cost Comparison</td>
<td>Relatively low construction cost but higher life cycle cost</td>
<td>Relatively high construction cost but lower life cycle cost</td>
</tr>
<tr>
<td>3</td>
<td>Life Expectation</td>
<td>Poor life expectation (15-20 yrs)</td>
<td>Good life expectation (50-60 Yrs)</td>
</tr>
<tr>
<td>4</td>
<td>Noise</td>
<td>Relatively High Noise</td>
<td>Relatively Low Noise</td>
</tr>
<tr>
<td>5</td>
<td>Availability of Material</td>
<td>Limited</td>
<td>No such Problem</td>
</tr>
<tr>
<td>6</td>
<td>Lateral Resistance</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

**b. Maintainability of a Typical Turnout:**

The maintenance of a turnout is quite complex compared to other portion of track. The maintainability of a typical turnout is controlled by its geometry. A turnout is defined as an arrangement of a switch and a frog connected by closure rails, by means of which rolling stock may be diverted among different tracks. A
turnout could produce high lateral forces and accelerations, which require slower operating speeds and can have adverse effects on ride quality and component life.

**There are seven factors control the maintainability of a typical turnout:**

A. Toe of Switch (TTS): Kink in Alignment  
B. Toe of Switch: Change in Curvature  
C. Heel of Switch: Change in Curvature  
D. Toe of Frog: Change in Curvature  
E. Gap at the “V” of Crossing  
F. Heel of Frog: Change in Curvature  
G. Lead Curve without Cant /Super-elevation

\(^3\)A Typical Turnout Configuration  
**Exhibit-6**
c. **Conventional Manual Track Maintenance**

The author would like to mention the most common manual maintenance practice followed in most of the Asian countries. The manual permanent way maintenance is largely done by *gangs* consisting of gangmen under the supervision of a *gang mate*. The most common system of routine manual (non-mechanized) track maintenance is known as through packing. This includes the following steps:

- Opening of ballast and loosening of rail fittings;
- Examination of track and squaring of sleepers (ties);
- Gauging, sleeper (ties) packing and re-packing of joint sleepers (ties);
- Boxing the ballast section and clean up.

In addition to basic maintenance, the local gang may undertake shallow and deep cleaning of ballast. Deep cleaning of ballast, by contrast, is usually done by gangs of 400-500 workers and involves removal of all ballast under the crossties, screening it to remove fines, replacing it along with new ballast as necessary, and manually lining and leveling the track. Since above steps are strenuous work, labor productivity is low.

Some developing country railways maintain track by traditional manual measures using hand tools, while other railways in developed countries rely on mechanized measures with on-track machines. North American railways justified mechanized measures for track improvement by their labor savings.

---

*Typical Light Maintenance of Track Structure*  
Exhibit-7
d. Main Modern Methods of Track Maintenance:
The railroad companies have moved from era of manual labor to partial mechanization and planning to move to fully mechanized track maintenance. The main modern methods of track maintenance are
1. Mechanized Maintenance or Mechanical Tamping
2. Directed Track Maintenance (D.T.M.)
3. Measured Shovel Packing (M.S.P.)

1. Mechanized Maintenance or Mechanical Tamping:
This is preferred and considered as the universal method of modern track maintenance compared to other two methods. It makes use of track machines (tamper) for day-to-day track maintenance. This method is relatively more effective, economical, and efficient to cater the needs of high speed and heavier axle loads.

There are two methods of Mechanical Tamping. They are Off and On Track Tamping.
- **Off-Track Tamping:** Off-track tampers which are portable and can be taken off the track within a short period and hence it requires no blocking of the traffic
- **On-Track Tamping:** On-track tampers, which are self-propelled vehicles, are used to tamp the sleepers automatically through various controls provided in the operator's cabin. Automatic aligning, lifting, cross and longitudinal levelling and packing are simultaneously possible.

2. Directed Track Maintenance (D.T.M): It is also called Track Maintenance System (TMS). This method ensures optimization of labor and material input in track. This is timely planning for replacement of track components. This is used to maintain the track to a high standard of maintenance as per the prescribed tolerances and to achieve economy in maintenance by avoiding unnecessary work involving men and materials.

3. Measured Shovel Packing (M.S.P.): In this method, the track defects like unevenness and voids are accurately measured, the track is lifted by means of jacks and measured quantities of ballast are placed under the ties/sleeper, to bring the track to the predetermined level. No traffic block is needed for carrying out maintenance job.

e. Track Maintenance Strategies (related to Mechanization of Track Maintenance):
1. Complete & Effective Mechanization of Track Maintenance: Complete & effective mechanization of track maintenance is the need of the hour. Modernize track maintenance by introducing cost effective on-track machines. The deployment of on track machines is to be judiciously planned for its optimum utilization. Time and money are valuable assets on railway worksites. Combining work functions into one-track maintenance machine brings a range of advantages. The range of services are expanded, the working output is increased and the overall efficiency is raised. The potential for cost effective track maintenance exists, when railroad companies use individual track maintenance machines to combination track maintenance machines.

2. Procurement of Latest State-of-the-Art New Generation High Performance Machines: Due to growing traffic and availability of less maintenance traffic blocks and or General Orders (tracks out of service), railroad companies have to go for procurement of latest state-of-the-art new generation high performance machines.

3. Implementation of Mobile Maintenance System: For implementation of mobile maintenance system, railroad companies have to establish the effective system of maintenance of small track machines. The mobility of mobile maintenance units is to be improved by providing rail and appropriate road vehicle.

4. Integrated Implementation of All Aspects of a Track Modernization Project: Integrated implementation of all aspects of a track modernization project is essential, including especially the provision of appropriate numbers of adequately trained personnel to operate and maintain the mechanized fleet as well as to manage the new type of maintenance programs. Also, sufficient annual funds must be made available to procure spare parts, maintain equipment and train qualified personnel.

5. Complete Track Renewal (CTR) as one of the Cost Effective Maintenance Practice: Whenever complete track renewal (CTR) is carried out to replace rail, crossties, and ballast, cost-effective track components and materials should be installed. The most important cost effective component will be
welded rails (SWR- Short Welded Rail or LWR- Long Welded Rail or CWR- Continuous Welded Rail) because they eliminate rail joints and can reduce maintenance costs by as much as 50%. During CTR the transfer to the site of welded rail and concrete crossties will be mechanized to some extent because of the difficulty of moving these heavy track components by manual labor alone and the risk of damage in handling them manually.

f. **Need and Working of a Typical Tamping Machine:**

f1. **Need of a Tamping Machine:**
Due to passage of a train over a track, it generates enormous vibrational forces. The entire track consisting of rails, sleepers and ballast is an elastic system that deforms and returns to its original position. Over the passage of time, this high stress results in deterioration of the track geometry leading to speed restrictions. The track structure loses its elasticity and does not return to its original position. To avoid such a situation, tracks should be maintained at regular intervals – this includes levelling, lifting, lining and tamping. This ensures that the ideal geometry of the track is restored.

f2. **Working of a Tamping Machine:**
In order to get the ideal geometry of the deteriorated track, the track should be maintained by levelling, lifting, lining and tamping. The proper tamping will provide a homogeneously compacted ballast bed. There are two factors which control tamping procedure. Firstly, all tamping tines work with the same pressure; and secondly, the tamping tines vibrate with the ideal frequency of 35 Hz. This directional, linear vibration combined with the non-synchronous tine movement produces a homogeneously compacted ballast bed. After this tamping work, the disturbed track consisting of rails, sleepers and ballast behave as an elastic system that deforms and returns to its original position under the dynamic loading.
Typical Working of a Tamping Machine

Exhibit-8
Automatic (On Track) Tamping Machine of Track and Turnouts Plasser & Theurer UNIMAT 08 – 475/4S (Mechanized Track Maintenance)

Exhibit-9
g. **Conventional Track Structure Maintenance Major Activities: (Which Control the Track Structure Maintenance Cost):**

1. **Rail Maintenance:** It consists of the maintenance of existing rail as well as replacement of existing rails by better and or new rails. This is significant as rail transfers the loads from train onto sleepers (ties) and provides a continuous and level surface for train movement; provide lateral guidance to the train wheels. There are different types of rail. Its cross section detail varies depending upon type of traffic and other factors.

2. **Track Geometry Maintenance:** It consists of the maintenance of track gauge, cross-level, horizontal and vertical curve parameters etc.

3. **Tie and Fastener Maintenance:** It consists of the maintenance of ties/sleepers and fasteners connecting rails to ties. Sleepers (ties). This is significant as sleepers (ties) transfer the load from Rail onto ballast and hold rails in correct alignment and spacing, provide firm and even support to rails. Fasteners connect rails to sleepers. There are different types of fasteners e.g. rigid fasteners for yards and elastic fasteners for bridges & their approaches etc.

4. **Ballast Maintenance:** It consists of the maintenance of ballast. Ballast transfer and distribute loads from ties to the subgrade. This is significant as it facilitates drainage. Sub ballast transfers and distributes loads from ballast to soil formation. Sub ballast stones are smaller compared to ballast stones.

5. **Track Inspection:** Maintenance should be followed by inspection of the permanent way. The various types of inspections used to inspect the conventional track structure (particularly in Indian Railway) are inspection by foot, push trolley inspection, motor trolley inspection, footplate (engine) inspection and rear vehicle inspection.

6. **Emergency Services (derailment repairs, storm repair, etc.):** It consists of the maintenance during emergency services, which includes damage caused during derailment, storm etc.

7. **Track Access Influence on Track Maintenance:** Track maintenance costs, practices, and policies are primarily influenced by track access and the track access cost adds to the direct cost of accomplishing a track maintenance task.

8. **Maintenance of Underperforming Track Systems:** Maintenance of underperforming track systems is substantial and eventual replacement is costly. Other than underperforming track designs, the primary maintenance cost is from normal wear and fatigue.

h. **Factors Affecting Track Maintenance Cost:**

1. **Track Material Costs-Life Cycle Cost:** Track maintenance cost depends on track material cost. Higher the track material cost, higher will be the track maintenance cost. Life cycle cost of track materials is also considered and will be described in detail in next section.

2. **Track Technology:** The improvements in maintenance costs are attributed to improvements in technology and practices. Track maintenance cost vary dramatically over time, usually beneficially. This will be described in detail in next section.

3. **Track Labor costs:** Track maintenance cost directly depends on the Track Labor costs. This cost is higher is developed countries compared to developing countries.

4. **Track Maintenance Activities:** Track maintenance cost depends upon various track maintenance activities whether they are manual or mechanized etc.

5. **Work Windows (Work blocks):** Track maintenance cost depends work windows (work blocks). Nowadays, it is very difficult to get long work windows (work blocks), which increases the maintenance cost significantly.

6. **Track Inspection and Maintenance Policies:** Track maintenance cost depends track inspection and maintenance policies. Different railroad organizations have different policies, which lead to different maintenance cost.

7. **Operating Characteristics:** Track maintenance cost depends on operating characteristics.

8. **Budgeting and Accounting Practices:** Track maintenance cost depends on budgeting and accounting practices.

9. **Availability of Capital and Operating Funds:** Track maintenance cost depends upon the availability of capital and operating funds. If funds are available, preventive track maintenance can be done, which will minimize the possibility of sudden failures.
10. **Recordkeeping Procedures:** Track maintenance cost depends upon various recordkeeping procedures. Different organizations have different recordkeeping procedures, which lead to different track maintenance cost.

11. **Miscellaneous (e.g. Geographical, Cultural etc.) Factors:** Track maintenance cost depends upon geographical, cultural factors also.

h1. **Concept of Life Cycle Cost in Track Maintenance:**
Life cycle costs are the sum of the all costs of a specified track throughout its economic life, from the first installation through removal or replacement. Economic life is defined as a point in time where the trend of annual maintenance costs of an existing component of system of components exceeds a threshold value. A threshold value for identifying useful economic life is when repair costs have reached some percentage of the replacement and future maintenance costs.

The permanent way components of ballasted track are rails, sleepers (ties), fasteners, ballast, sub ballast and soil formation. Track is the system of materials from the subgrade to top of rail in ballasted track or from the bottom of a rail support device (fastener, block tie) to the top of rail in ballast-less track. It is recommended that the various components of track systems should be used for its economic life and this is considered as cost-effective maintenance practices for conventional track structure. One of the cost effective maintenance practices for ballasted track is the CTR in which all basic components are renewed. Whenever complete track renewal (CTR) is carried out, cost effective track components and materials should be installed. The most important cost effective component will be welded rails (SWR- Short Welded Rail or LWR- Long Welded Rail or CWR- Continuous Welded Rail) because they eliminate rail joints and can reduce maintenance costs significantly. This reduces the life cycle cost of track maintenance.

h2. **Technology Influence on Track Maintenance Cost:**
The improvements in maintenance costs are attributed to improvements in technology and practices. Track maintenance cost vary dramatically over time, usually beneficially.

The following sketch shows unit costs for major track cost components in the U.S. freight industry. They are based on the Association of American Railroads (AAR) Total Right-Of-Way Analysis and Costing System (TRACS), an empirically calibrated model of freight railroad maintenance-of-way (MOW) costs from 1970 to 2000. Rail cost improvements contributed the most to the overall cost savings. The total MOW costs fell 37% under the assumptions of this scenario, from $1.13/1000 GTM to $0.71/1000 GTM. The improvements in maintenance costs are attributed to improvements in technology and practices.
General Track Maintenance Approaches:

The railroad companies should not wait to do emergency restoration work after an accident due to track maintenance failure. Rather they should perform routine and special inspections of permanent way components on a regular basis and perform necessary manual, as well as mechanized maintenance. Railroad companies are advised to prepare and apply for preventive maintenance plans. At the long-term, preventive maintenance plans present lower overall costs than curative/crisis track maintenance.

- Preventive Track Maintenance
- Curative/Crisis Track Maintenance

The various preventive cost effective track maintenance practices are like the following:

1. **Track Switch Maintenance**: Cleaning of dirt, vegetation and greasing particularly of points and crossing components (moving parts) is essential for proper working of points and crossings.

2. **Regular Track Cleaning**: Leaves and garbage creates track fires and cause delay. They should be removed from the track.

3. **Rail Head Maintenance & Regular Rail Profiling**: The railhead should be cleaned frequently. In addition, railhead corrugation should be grinded. Also rail section should be profiled for smooth ride.

4. **Rail Welding**: Single rail panels should be converted to SWR (Short Welded Rails), LWR (Long Welded Rails) and CWR (Continuous Welded Rails) for various benefits.

5. **Pavement Sealing**: Pavement sealing should be done particularly at level crossings.
6. **Visual Track Inspection**: Visual inspection of track components at regular intervals to check its functions.

7. **Track Recording Car/ Measuring Vehicle Inspection**: Checking of track geometry using various track parameter measuring vehicles.

8. **Non Destructive Testing (NDT) of Rails**: Rails in service should be tested by NDT methods to detect flaws so that they can be replaced on time.

9. **Prioritization of Maintenance Effort based on Track Condition**: The maintenance effort should be directed to critical accident prone areas to avoid mishaps.

10. **Track Patrolling during Unusual Hot and Cold Weather**: The track patrolling should be done during unusual weather to prevent track failures (e.g. rail buckling & rail fracture etc.) as preventive measures.

i2. **The various curative/crisis track maintenance approach activities include emergency track maintenance services like the following:**

1. **Train Accident (e.g. Derailment) Repairs**: This includes repair of track and associated infrastructure due to damage caused due to train accidents, derailments.

2. **Storm Damage Repairs**: This includes repair of track and associated infrastructure due to damage caused due to severe storm e.g. One of such storm was Sandy in New-York in recent years.

3. **Repair of Damage caused by Unsocial Elements**: This includes repair of track and associated infrastructure due to damage caused by unsocial elements.

j. **For advanced maintenance strategies, the following are recommendations from operators (railroad companies) point of view:**

1. **Knowledge of Track Structure**: The railroad companies should know their track structure and implement maintenance policies according to that. They should not copy the maintenance policies and practices of other organizations as every organization have different features.

2. **Attention to the details related to Maintenance Costs**: The railroad companies should pay attention to the details of various maintenance costs.

3. **Adaptation of Maintenance Plans for Specific Goals**: The railroad companies should adapt maintenance plans according to specific contexts/goals (specific tonnages, speed & frequencies of the railways services).

4. **Possession and Updating of Maintenance Standards Compliant with the Regulations**: The railroad companies should possess and update maintenance standards compliant with the regulations.

5. **Training of Employees for Achievement of Objectives through New Technologies & New Methods**: The railroad companies should train the personnel on new technologies, new methods and objectives that to be reached.

6. **Importance of Asset Management to keep track of All Current Maintenance Problems**: The railroad companies should provide Importance of an asset management, formal document within “organization knowledge” that keeps track of all current maintenance problems.
7. **Learn from the Mistakes and Improve the Future Track Maintenance Strategies:** Any railroad organization should be ready to learn from the mistakes and improve the future track maintenance strategies to become cost effective.

k. **A Low-Cost Maintenance Strategy of Existing Turnouts:**

"Points and crossings are vital and the weakest part of the track structure which require baby care otherwise in term it will lead to many accidents / interruptions to normal traffic, if not maintained properly," wrote N.R. Kale et al., in their research on points and crossings maintenance on Indian Railways.

Railroads around the world consist of, huge number of turnouts, but only a small percentage of existing turnouts are entirely rehabilitated. Majority of the turnouts are rehabilitated with second hand materials or component wise replacement. For example, freight railroads in north America have approx. 280,000 turnouts of which only about 25% are ever replaced entirely (Bonaventura, C.S., Holfed, D.R., Zarembski, A.M., Palese, J.P., 2005).

Track work systems consisting of various types of turnouts with higher diverging speed can increase higher line capacity & better dynamics/mobility of the railroad system. The procurement of new high-speed turnout with change in existing infrastructure is a costly proposition and it needs huge upfront funding which many railroad companies cannot afford.

Keeping the above facts in view, the author proposes the necessity for turnout design-higher diverging speed in same footprint with low cost modification of existing turnouts. When a railroad vehicle negotiates a diverging portion of a turnout, lateral force is generated due to centrifugal action and varies due to unbalanced forces throughout the length of the turnout. It is desirable to keep the average lateral force exerted on the track infrastructure (turnout components) within the optimal range. In conventional turnouts, the lateral force is very high near the switch and frog area, which normally exceeds the optimal force. In redesigning the turnout for higher diverging speed in same interlocking footprint, the turnout geometry is to be redesigned so that average lateral force throughout the turnout portion remains within the optimal force.

This strategy is based on the author’s 2011 AREMA conference paper on Higher Diverging Speed Turnout Design in the Same Footprint. Special track work, including turnouts, can reduce a track section’s capacity by requiring speed restrictions in order to extend the turnout’s service life, and can be an expensive component to replace once that its service life ends. Modifying a rail system’s existing turnouts to be able to handle higher diverging speeds could increase line capacity and improve the dynamics and mobility of the system. A hypothesis developed by the author was presented at the AREMA 2011 Annual Conference in conjunction with Railway Interchange 2011 and proposes the possibility that developing low-cost upgrades to a system’s turnouts for higher diverging speeds may result in lower life-cycle costs and increased capacity by reducing lateral forces and acceleration, as well as component wear.

The following key steps are cost effective maintenance strategy for increasing the diverging speed in the same interlocking footprint of the existing turnout.

1. **Reduction of Switch Entry Angle:** Flatter entry angle reduces the angle of attack and reduced lateral forces resulting in increased passenger comfort. By reducing the switch angle, entry becomes smoother and flange force is reduced. The small switch angle is obtained by providing curved switches.

2. **Provision of Transition Curve in Diverging Portion of Track (Switch Rail, Lead Rail, Closure Rails etc.):** By provision of this item, higher speed on diverging track can be achieved at lower cost.
3. **Higher Cant Deficiency for Turnout Diverging Track Structure**: By provision of this item, higher speed on diverging track can be achieved at lower cost.

4. **Use of Kinematic Gauge Optimization or Thick Web Switches Technique**: This can be done to optimize transition geometry in the switch area.

5. **Provision of Special Type of Heel & Switch Plates with Braces**: This is done to withhold higher lateral forces.

6. **Provision of A Special Type of Frog with features such as: Reduction in Gap “V” at Crossing, Head-Hardened Crossing Material and Curved Crossing**
   These will result into low maintenance cost and higher speed on diverging track can be achieved.

7. **Provision of Check/Guard Rails Level Higher than Stock Rail or Inner Curve Rail**: This will relieve additional pressure on stock rail for movement in diverging track.

8. **Provision of Suitable Flange Way**: Depending upon the turnout number, flange way can be varied for smooth movement along the track. If the turnout is sharp, it is recommended to provide wider flange way. Use of a spring-operated switch-setting device can be used to ensure proper flange way clearance.

9. **Use of Heat-Treated Switch Tips**: It will help the switch tip take higher lateral force and function properly.

10. **Provision of Guarded Turnout**: This allows higher diverging speed with given lead length.

**(C) Conclusion:**

The railroad industry spends hundreds of millions of dollars every year on railroad track maintenance activities, routing large crews and heavy machinery throughout its extensive railroad networks. Effective planning saves on maintenance costs and resources and affects the safety and operational efficiency of the maintenance activities. The author would like to emphasize the need of proper planning in maintenance activities to achieve better operational efficiency, less maintenance cost and aiming for zero accidents. If railroad companies can save money by using various cost effective maintenance practices, it will help in providing credible services at lower prices to their customers. This is applicable for railroad companies carrying passengers or freights.

**(D) Future work:**

With an increasing pace of the changes in technology and the current economic downturn, organizations around the world are focused on more cost-effective and value-added technology related to the maintenance practices of conventional track structures and associated infrastructures. The author continues with his research on various cost-effective maintenance practices for conventional track structure to explore additional facts, which will be published in the future when available.

**(E) Acknowledgement:**

The author acknowledges the help of Ms. Purnima Prasad and Ms. Prayaga Prasad for proof reading this paper “various cost effective maintenance practices for conventional track structure”. The author sincerely thanks his professors at New York University (NYU) and officials at MTA-NYCT for their help and continuous encouragement.
(F) References:


© AREMA 2016®
(G) List of Exhibits

a. Exhibit 1: Typical Ballasted Track Section

b. Exhibit 2: Typical Track Section through Tunnel

c. Exhibit 3: Typical Ballast-less Track Section

d. Exhibit 4: The comparison of life cycle costs of Slab Track Austria vs. Conventional Ballasted Track systems.

e. Exhibit 5: Comparison between Ballasted and Ballast-less Track Systems

f. Exhibit 6: A Typical Turnout Configuration

g. Exhibit 7: Typical Light Maintenance of Track Structure

h. Exhibit 8: Typical Working of a Tamping Machine

i. Exhibit 9: Automatic (On Track) Tamping Machine of Track and Turnouts Plasser & Theurer UNIMAT 08 – 475/4S (Mechanized Track Maintenance)

j. Exhibit 10: Technology Influence on Track Maintenance Cost
(H) Disclaimer:

Even though the author works for MTA-NYCT, any opinions, findings and conclusions or recommendations expressed in this materials does not reflect the views or policies of MTA-NYCT nor does mention of trade names, commercial product or organizations imply endorsement by MTA- NYCT. MTA-NYCT assumes no liability for the content or the use of the materials contained in this document. The author makes no warranties and/or representation regarding the correctness, accuracy and or reliability of the content and/or other material in the paper. The contents of this file are provided on an “as is” basis and without warranties of any kind, are either expressed or implied.

(I) About The Author:

Avinash Prasad works for MTA-NYCT as a Civil Engineer Level–III. He has had more than 27 years of professional experience mostly with MTA-NYCT and foreign railways. Being a professional in United States and foreign railroad companies in various capacities (employee/consultant), he has extensive experience of various maintenance practices for conventional track structures. He is a Registered Professional Engineer and Land Surveyor in multiple states of United States and a Doctor of Philosophy Candidate at NY University. His ongoing doctorate degree at NY University major is construction management and minors are structural engineering & technology management. He also has double masters of science degree in civil engineering and engineering management from New Jersey institute of technology, NJ and bachelor of science degree in civil engineering (four-year civil engineering education from Patna university, India. He has more than 1000 hours of continuous professional education as instructor/participating professional (1990-2016) excluding formal education. He is a (NJ) state certified emergency medical technician (EMT), emergency medical responder (EMR), fire fighter (FF). He is a certified CPR, AED administer. He is also an active member of several professional organizations such as: AREMA, ASCE, PMI, AISC, NYSAPLS, IPWE, IRT and IIBE. He is a AREMA committee board member of Rail (2007-2011), Track (2007-present) and High Speed Rail Systems (2011-present). His technical papers were presented in earlier AREMA conferences and published in the RT& S (Railway Track & Structure) magazine multiple times.
Various Cost-Effective Maintenance Practices for Conventional Track Structure

By

Avinash Prasad
PE, LS, PhD(C), MSCE, MSEM
Disclaimer

• Any opinions, findings and conclusions or recommendations expressed in this materials does not reflect the views or policies of MTA-NYCT nor does mention of trade names, commercial product or organizations imply endorsement by MTA-NYCT.
• MTA-NYCT assumes no liability for the content or the use of the materials contained in this document.
• The author makes no warranties and/or representation regarding the correctness, accuracy and or reliability of the content and/or other material in the paper.
• The contents of this file are provided on an “as is” basis and without warranties of any kind, are either expressed or implied.

About The Author/Presenter

• Registered Professional Engineer, Land Surveyor
• Doctorate Degree Candidate at NYU with Double Masters of Science Degrees in Civil Engineering & Engineering Management from NJIT, NJ and Bachelor of Science Degree in Civil Engineering from India.
• State Certified Emergency Medical Technician (EMT), Emergency Medical Responder (EMR), Fire Fighter (FF) and a Certified CPR Administer.
• Member of AREMA, ASCE, PMI, AISC, NYSAPLS.

Author’s Salient Publications/Presentations

• Publication in RT & S-April 2013- Topic: Structural Evaluation of High rise Suspension Bridges
• Publication in RT & S-October 2011; Topic: Increasing diverging speed over turnout without changing basic infrastructure of track system
• Publication & Presentation in AREMA Conference 2011 Proceedings: Topic: Increasing diverging speed over turnout w/o changing basic track infrastructure
• Presentation in Seminars/Webinars;Topics: Advancement in Railroad Engineering; Suspension Bridge-Basic/Advanced Concept

Permanent way

• Track has been termed the permanent way.
• Ballasted Track: It is the system of materials from the subgrade to top of rail through sleepers(ties), fasteners, ballast and sub ballast.
• Ballast-less Track: It is the system of materials from the bottom of a rail support device (fastener, block tie) to the top of rail through sleepers(ties), fasteners.

Permanent way/Track Components

Ballasted Track Components
• Rail:
• Sleepers(ties):
• Fasteners:
• Ballast & Sub ballast:
• Soil Formation/Subgrade:

Ballast-less Track Components
• Rail:
• Sleepers(ties):
• Rail support device (fastener, block tie):

Exhibit 1

5 Typical Ballasted Track Section
Exhibit 4: Explanation

The comparison of life cycle cost of Slab Track Austria vs. Ballasted Track systems is performed. The following observations are made:

- After approximately about 20 years, the cost of construction and maintenance of the Ballasted Track is significantly higher than that of Slab Track Austria.
- Up to 20 years, the cost of construction and maintenance of the Ballasted Track is lower than that of Slab Track Austria.
- Estimated life time for Slab Track Austria is at least 60 years which is much longer than Ballasted Track System with 30-40 years.

Exhibit 5

<table>
<thead>
<tr>
<th>Description</th>
<th>Ballasted Track</th>
<th>Ballast Less Track</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Maintenance Input</td>
<td>Frequent maintenance</td>
<td>Less maintenance</td>
</tr>
<tr>
<td>2 Cost Comparison</td>
<td>Relatively low const. cost but higher life cycle cost</td>
<td>Relatively high const. cost but lower life cycle cost</td>
</tr>
<tr>
<td>3 Life Expectation</td>
<td>Poor life expectation</td>
<td>Good life expectation</td>
</tr>
</tbody>
</table>

Exhibit 6

Factors Controlling Maintainability of A Typical Turnout:

A. Toe of Switch (TTS): Kink in alignment
B. Toe of Switch: Change in curvature
C. Heel of Switch: Change in curvature
D. Toe of Frog: Change in curvature
E. Gap at the “V” of crossing
F. Heel of Frog: Change in curvature
G. Lead curve without cant/super-elevation
\textbf{Manual Track Maintenance}

- Through Packing is a strenuous work and its labor productivity is low. This includes the following steps:
  - Opening of ballast and loosening of rail fittings;
  - Examination of track and squaring of ties;
  - Gauging, sleeper (ties) packing and re-packing of joint ties;
  - Boxing the ballast section and clean-up.

- Manual track maintenance includes shallow and deep screening (cleaning) of ballast which needs additional manpower than Through Packing.

\textbf{Mechanized Maintenance or Mechanical Tamping}

Mechanized Maintenance or Mechanical Tamping:

Mechanical Tamping Methods:
- Off-Track Tamping:
- On-Track Tamping:

\textbf{Track Maintenance Strategies}

- Complete & Effective Mechanization of Track Maintenance
- Procurement of Latest State-of-the-art New Generation High Performance Track Maintenance Machines:
  - Implementation of Mobile Maintenance System
  - Integrated Implementation of all Aspects of a Track Modernization Project
  - Implementation of Cost Effective Maintenance Practices e.g. Complete Track Renewal (CTR)

\textbf{Mechanized Maintenance
Need of a Tamping Machine}

- Elastic new ballasted track system
- Deteriorated track system in service due to passage of train (application of train vibrational load for a long time)
- Imposition of speed restrictions due to disturbed track system
- Necessity of restoring the disturbed track to ideal track geometry/system to remove the speed restrictions.
**Exhibit 8**

### Typical Working of a Tamping Machine

- Applicable for ballasted track system only.
- Tamping machine tamping tines work with the same pressure and vibrate with the ideal frequency of 35 Hz.
- Achievement of homogeneously compacted elastic ballast bed through levelling, lifting, lining and tamping.

**Exhibit 9**

### Automatic (On Track) Tamping Machine of Track and Turnouts Plasser & Theurer

**Conventional Track Structure Maintenance Activities**

- Rail Maintenance
- Track Geometry Maintenance
- Tie and Fastener Maintenance
- Ballast Maintenance
- Track Inspection
- Emergency Track structure Maint. Services
- Underperforming Track Systems Maintenance
- Track Access Influence on Track Maintenance Activities

**Factors influencing Track Maintenance Cost**

- Track Material Costs-Life Cycle Cost
- Track Technology
- Track Labor Cost
- Track Maintenance Activities
  - Work Windows (Work blocks)
  - Track Inspection and Maintenance Policies
  - Operating Characteristics
  - Budgeting and Accounting Practices
  - Availability of Capital and Operating Funds
  - Recordkeeping Procedures
  - Miscellaneous Factors

**Life Cycle Cost Influence on Track Maintenance**

- Life cycle cost
- Economic Life
- A Threshold Value

**Recommendation:** The various components of track systems should be used for its economic life to be cost-effective maintenance practices for conventional track structure. Example-CTR in which all basic track components are renewed.
Technology Influence on Track Maint. Cost; Exhibit 10: Explanation

- Improvements in track technology and practices reduce the track maintenance costs.
- The Exhibit 10 shows unit costs for major track cost components in the U.S. freight industry.
- The total MOW costs fell 37% under the assumptions of this scenario, from $1.13/1000 GTM to $0.71/1000 GTM from year 1970 to 2000.

General Track Maintenance Approaches

- Preventative Track Maintenance
- Curative/Crisis Track Maintenance

Preventative Track Maintenance Approach Activities

- Track Switch Maintenance
- Regular Track Cleaning
- Rail Head Maintenance & Regular Rail Profiling
- Rail Welding
- Pavement Sealing
- Visual Track Inspection
- Track Recording Car/Measuring vehicle Inspection
- Non Destructive Testing (NDT) of Rails
- Prioritization of Maint. Effort based on Track Condition
- Track Patrolling during Unusual Hot/Cold Weather

Curative/Crisis Track Maintenance Approach Activities

This includes Emergency Track Maintenance services e.g.

- Train Accident (e.g. Derailment) Repairs
- Storm Damage Repairs
- Repair of Damage caused by Unsocial Elements

Advanced Track Maint. Strategies

[Operators (railroad companies) Point of view]

- Knowledge of Track Structure:
- Attention to The Details Related to Track Maint. Costs:
- Adaptation of Track Maint. Plans for Specific Goals:
- Possession and Updating of Track Maint. Standards Compliant with the Regulations:
- Training of Employees for Achievement of Objectives through New Technologies & New Methods:
- Importance of Asset Management to keep track of All Current Track Maintenance Problems:
- Learn from the Mistakes and Improve the Future Track Maintenance Strategies:
3A Low-cost Maintenance Strategy of Existing Turnouts (1 of 4)

- Unaffordable cost to most railroad companies in procurement of new high speed turnout with change in existing infrastructure.
- Higher line capacity & better dynamics/mobility of turnouts with higher diverging speed.

Keeping the above facts in view, the author proposes the necessity for turnout design-higher diverging speed in same footprint with low cost modification of existing turnouts.

3A Low-cost Maintenance Strategy of Existing Turnouts (2 of 4)

- Proposes the possibility that developing low-cost upgrades to a system's turnouts for higher diverging speeds may result in lower life-cycle costs and increased capacity by reducing lateral forces and acceleration, as well as component wear.

3A Low-cost Maintenance Strategy of Existing Turnouts (3 of 4)

1. Reduction of Switch Entry Angle
2. Provision of Transition Curve in Diverging Portion of Track (Switch Rail, Lead Rail, Closure Rails Etc.)
3. Higher Cant Deficiency for Turnout Diverging Track Structure
4. Use of Kinematic Gauge Optimization or Thick Web Switches Technique
5. Provision of Special Type of Heel & Switch Plates with Braces to Withhold Higher Lateral Forces

3A Low-cost Maintenance Strategy of Existing Turnouts (4 of 4)

6. Provision of A Special Type of Frog with Features such as: Reduction in Gap "V" at Crossing, Head-hardened Crossing Material and Curved Crossing
7. Provision of Check/Guard Rails Level Higher Than Stock Rail or Inner Curve Rail
8. Provision of Suitable Flange Way
9. Use of Heat-treated Switch Tips
10. Provision of Guarded Turnout

General Recommendations (For Railroad Companies)

- Emphasize the need of proper planning in track maintenance activities to achieve better operational efficiency, less maintenance cost and aiming for no accidents.
- Start with basic manual/mechanized track maintenance practices, followed by more sophisticated track maintenance practices to achieve goals (better operational efficiency, less maintenance cost and aim for no accidents).
- Providing credible service at competitive prices to customers using the saving through various cost effective track maintenance practices.

Future Work

- Demand of cost-effective track maintenance practices / methods due to an increasing pace of the changes in technology and the current economic downturn.
- Research and development in cost-effective track maintenance practices / methods using the concept of operation research and other advancements.
- Continuance of research on various cost-effective maintenance practices for conventional track structure to explore additional facts based on presenter's extensive educational and professional railroad experience.
Acknowledgements

My special thanks go to:

- Ms. Purnima Prasad and Ms. Prayaga Prasad for proof reading this presentation.

- New York University (NYU)'s professors [Fletcher H. (Bud) Griffis, P.E., PhD; Masoud G., PhD; Andrew Bates, PhD] for their guidance in preparation of this presentation.