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REDUCING WAGON TURNAROUND TIMES BY REDESIGNING THE OUTBOUND DISPATCH OPERATIONS OF A STEEL PLANT

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ABSTRACT

Dispatch of steel products by railways from the mills of an integrated steel plant, producing variety of products is a complex process with a constraint of strictly adhering to the permissible Wagon Turnaround Times (WTT). This operation faces further challenges when the WTT is proposed to be brought down by 75% while additional mills are being added for capacity expansion. This paper presents how re-engineering of the dispatch operations using simulation helped in reducing the WTT to the desired level. Our approach was to use a flexible push-pull based dispatch scheduling instead of the current pull and wait model. Our recommendations included decoupling railways operations from the internal mills thereby avoiding wagon set breaks and reassembly, investing in optimum number of captive locomotives and wagon sets, scheduling mechanism for captive locomotives, creation of an intermediate storage to stack products according to dispatch schedules and ensuring just-in-time material availability for dispatch.

1 INTRODUCTION

Products of a steel plant can be classified into two major categories – Longs and Flats. Long products include billets, blooms, rods and wires, structural shapes and rails, bars and tubes whereas flat products include slabs, sheets/plates, strips etc. Steel products cater to various sectors like construction, railways, automobiles, machinery etc. These products vary widely in nature depending on the size, shape and metallurgical properties of steel.

The finished products are produced in the plant at various rolling mills like rod mills, rail/structural mills, wire mills, merchant mills etc. The mode of dispatch of these products to customers or distribution centers is generally by road, rail or water. Once the products are ready at the mills, they are tagged, cooled, made ready for dispatch and stored in the designated storage areas. According to the dispatch schedule, the products are then loaded into the transport system and dispatched to the destination.

The transportation of products of high capacity steel plants are generally carried out through external agencies. The agency providing the services and vehicles, charges for demurrage, if the time of loading of the products, weighing and releasing the vehicles exceeds the mutually agreed turnaround times.

Our study was on an integrated steel plant with capacity expansion plans, producing variety of products and dispatching through railway wagons. An external railway agency provides the rakes (group of railway wagons) to the plant for loading it with different compositions of products, weighing and releasing the rake within the stipulated wagon turnaround times (WTT), beyond which demurrage costs being charged. The time components of the current WTT needed to be studied and analyzed in detail and re-designing of the outbound dispatch operations including appropriate changes in the layout needed to be proposed for bringing down the WTT by 75% with additional mills being operated after the expansion.

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2 THE EXISTING SYSTEM DESIGNAND IMPROVEMENT PLANS

2.1 Existing System and Dispatch Operations

The steel plant currently consists of three rolling mills producing different types of long products of different grades of steel. The dispatch system comprises of a railway network and an yard in which the rakes arrive, split, loaded with products at the mills, weighed, reassembled and released from the plant for dispatch. The existing mills, railway network and the rake movements for loading and dispatch operations is shown in Figure 1.

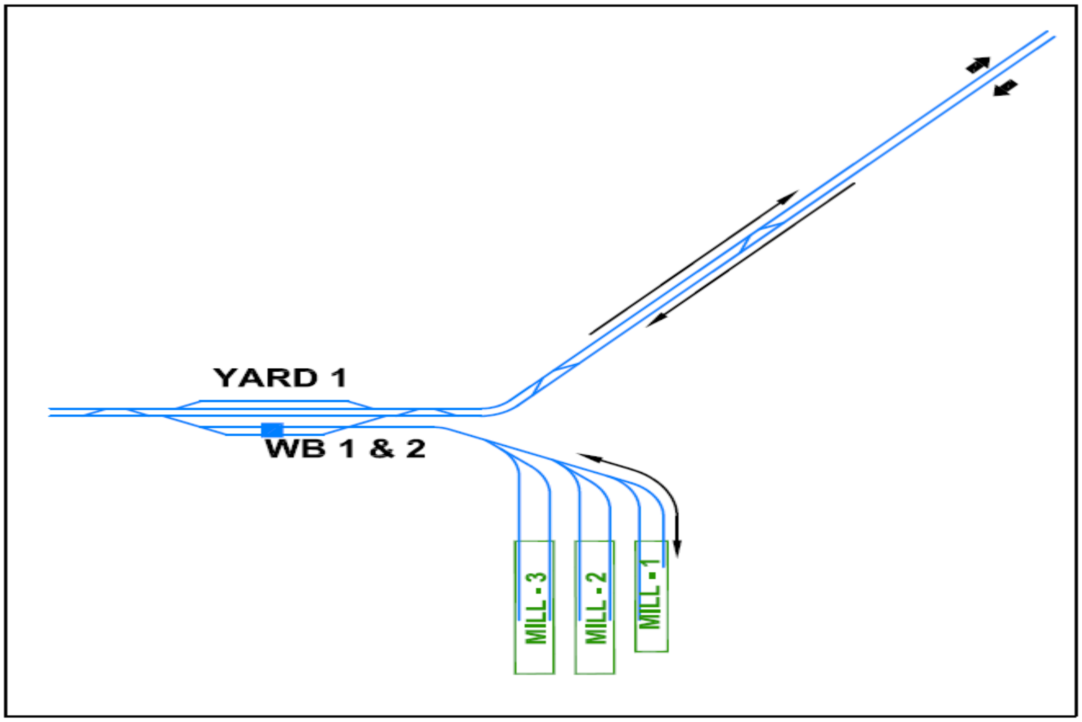

Figure 1: Description of the existing system.

At present, the empty rakes are brought to Yard 1 and are split into multiple hooks (hooks are group of wagons based on the composition of the products needed to be dispatched) and each hook is placed at the respective loading points in the mills by plant locomotives after tare weighing (weighing of empty wagons) on the static rail weigh-bridges in Yard 1. Hooks for Mill 3 can use only weighbridge WB1 and hooks for Mill 1 and Mill 2 can use both the weighbridges WB1 and WB2. The hook size at each loading point depends on the composition of product types to be dispatched as per the indent placed by marketing department. After loading, the wagons are brought to Yard 1 for weighing by plant locomotives. In case the load is less or more than that permissible by railways, the wagons are taken back to the mills for weight adjustment. After weight adjustment and final weighing, the hooks are gathered in Yard1 for full rake formation. On full rake formation and receiving clearance, the plant locomotive takes the full rake out of the plant for handing over to railways. 5 captive plant locomotives are used for the operation. Based on the above system of working, the WTT is about 24 hours which is within the current permissible limits.

2.2 Capacity Expansion and New Turnaround Times

With the growth of Indian economy, the 3P logistics providers like the railways were under pressure to improve their logistics efficiency. This resulted in imposing reduced rake turnaround time limits for their customers. As a part of this process, railways was planning to introduce a 6 hours turnaround times for the steel plant. At the same time, the plant was planning for a production capacity expansion. Four new mills were being added as part of the capacity expansion. These mills are to produce 3 additional types of products.

With additional production capacity and reduced turnaround times, the challenge was to accommodate the reduced WTT while handling additional dispatch volumes. This required us to look at a dispatch system design and process re-engineering options which could address these goals.

2.3 Designing the Capacity Expansion

The location of the four mills needed to be designed in a way such that they were by the side of the existing mills because of the location of the existing and augmented upstream processes. With the railway network already in place for movement of products from the existing mills, the new mills were to use the existing network with some augmentation following the same mode of movement of products. The mills, augmented railway network and the wagon movements for loading and movement operations after the expansion is shown in Figure 2.

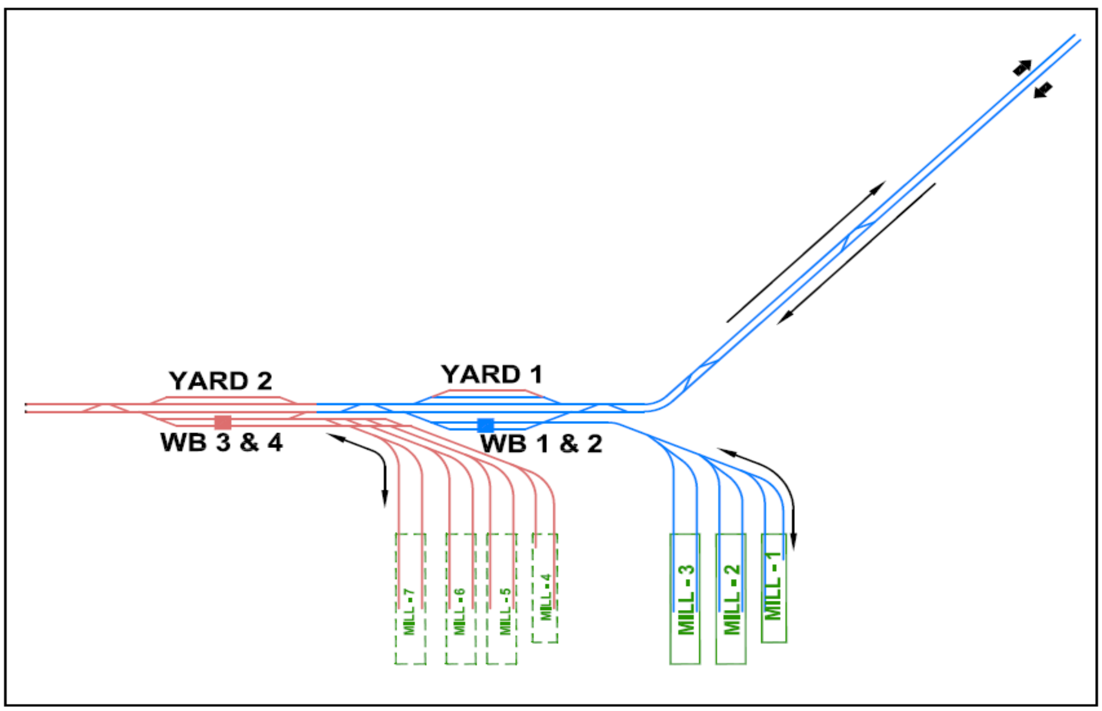

Figure 2: Description of the system after expansion.

A new yard (Yard 2) is introduced as part of railway network augmentation, for wagon shunting purposes and two weigh bridges were being added. For all the mills, wagon sets need to be brought from Yard 1, directly or via Yard 2 and placed at the respective mills by plant locomotives. After loading, the wagons are to be brought to weighbridges by plant locomotives for weighing. Wagons from the new mills can be weighed only on static rail weigh-bridges WB3 and WB4. A suitable dispatch strategy from Yard 1 needed to be designed which would also meet the requirement of reduction in WTT.

2.4 Reducing the WTT

The WTT for the existing product dispatch system using the same network setup and same mode of movement from the mills is 24 hours. With additional four mills in operation, it would be no better, because, with increased production, the traffic in the railway network is also going to increase.

For designing the dispatch operation, the reasons for the current WTT was analyzed and it was found that this could be due to the following operational constraints:

- Time for receipt and handing over of rakes;
- Splitting of rakes and reassembly;
- Availability of plant locomotives;
- Availability of cranes for loading at the mills;
- Non-conformity of dispatch based storage in mills; and
- Weighing of loaded wagons and adjustments within turnaround times.

This led to further analysis of the detailed time components of the current WTT, starting from the receipt of the empty rakes from railways at the railway yard till the point of handover of the loaded rakes to railways at railway yard. The contributions of the time components in the current WTTs are shown in Table 1.

Table 1: Contributions of the time components in WTT.

Time components	**Contribution** (%)
Receipt of rakes from the railways	5
Tare weighing of hooks	4
Movement and placement of hooks at mills for loading	5
Loading of products into wagons	27
Weighing at weighbridges and adjustments of the hooks	32
Movement of hooks to Yard 1 after strapping and final weighing	13
Waiting for arrival of other hooks and forming the full rake	7
Documentation and movement of rakes from Yard 1 to handover to railways	7

It is evident that the major contributors to the WTT are the rake handling components (73 %) rather than the loading operations components. The process of receipt, splitting, weighing, reassembly and handover of rakes is called rake handling. To overcome the constraints of rake handling, design options needed to be explored where the rake handling is minimum and thereby the WTT can be brought down to the desired level.

3 DISPATCH STRATEGY

The mills produce products and maintain a local inventory. The rakes, on arrival to the plant yard are split into multiple hooks depending on the requirement of the product types and sent to the corresponding mills where they are loaded with the products, weighed and moved back to the plant yard for reassembly and dispatched thereafter. The railways operations are involved directly with the mills and therefore the dispatch boundary is at the local mills as shown in Figure 3.

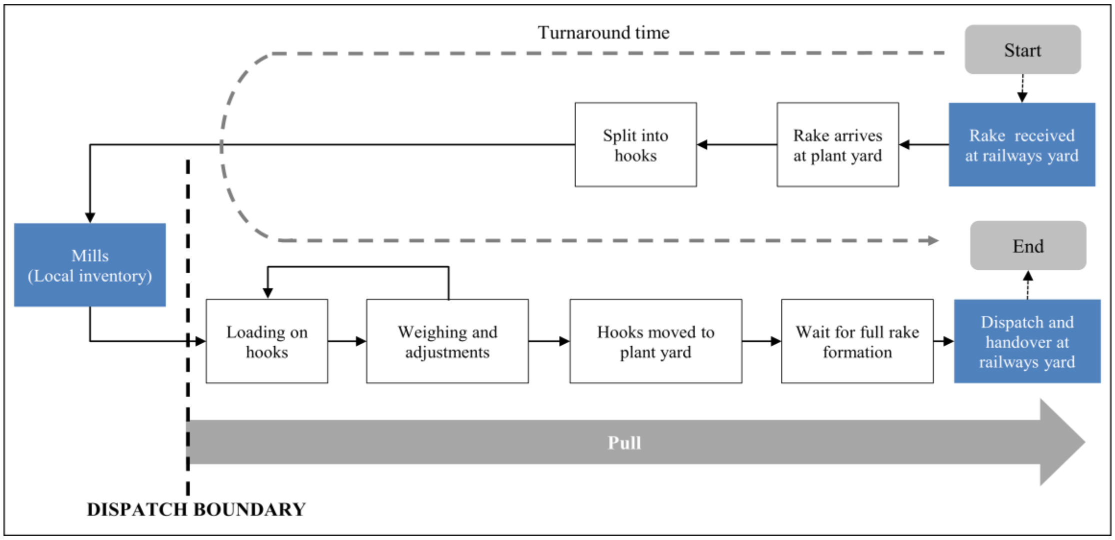

Figure 3: The existing dispatch strategy.

The WTT is calculated from the point the rake arrives at the plant yard till the point it is dispatched which includes all the rake handling activities, thereby making it high. We hypothesized that moving the push-pull boundary by moving the dispatch boundary (Simchi-Levi 2010) further out into a central storage will decouple the railways operation from the mills and will be limited to the central storage. This would help to avoid the wagon set breaks, reassembly and other rake handling activities thereby reducing the WTT to a large extent. The products could be moved from the local mills to the central storage using captive wagon sets and stacked according to the product dispatch schedules. The products could then be moved to the plant dispatch yard, loaded on the rake on arrival and dispatched. The new dispatch boundary is shown in Figure 4.

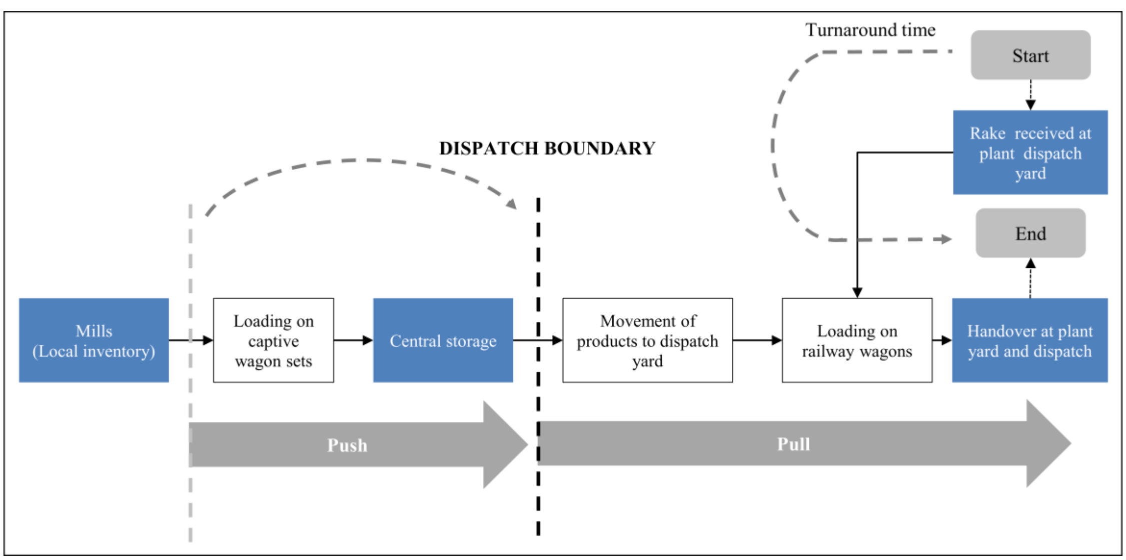

Figure 4: The proposed dispatch strategy.

With the proposed dispatch strategy, it is envisioned that apart from the reduction of WTT, the local mills will have significantly lower inventory of products because the products would be pushed to the central storage as and when accumulated. With the dispatch schedule remaining the same, due to lower WTT, the lead time for delivery would reduce and therefore the inventory at the central storage would reduce. This second order benefit would lead to a potential reduction of inventory by a factor of 4.

The movement of the dispatch boundary also requires corresponding logistics process modifications and captive equipment additions. The following modifications were considered:

- Railway engines bring the rakes to the plant dispatch yard, hands over to the plant and remain attached throughout the loading operations for taking the rake out of the plant after final formalities. For this, the railway tracks at the plant dispatch yard need to be electrified.
- The plant dispatch yard need to have loading bays which will be able to accommodate the entire rake. This would avoid the rakes split and reassembly and the entire rake could be loaded with products from the loading bays.
- The loading of rakes will be performed by highly efficient cranes which cannot be implemented inside the mills due to design constraints.
- The empty and loaded rakes could be weighed through in-motion weighbridges and hence the weighing times would not be part of WTT.

4 PROPOSED SYSTEM DESIGN

Intermediate Stock Yard (ISY) was proposed as a central storage where the products will be moved from the mills and stacked according to the market demand and distribution plans. A new plant dispatch yard, Yard 3, having four tracks and a loading bay for each was planned where the products will be made available from ISY after weighing and adjustments prior to the arrival of railway wagons for loading and dispatch.

In-plant railway system comprising of captive wagons and locomotives would be used to transfer the steel products from the mills to ISY. A set of wagons would be placed in each mill for loading of the products. The number of wagons in each set need to be standardized so that any wagon set can be placed in any mill. Based on the availability of products, wagon sets would be indented by the mills from the pool of captive wagon sets. After loading, the wagons will be weighed on the existing and proposed static rail weigh-bridges and taken to Yard 1 and thereafter to ISY.

After placement of loaded captive wagons at ISY, the products will be unloaded and stacked at earmarked places. Once the destination-wise product mix is known for a particular rake, the corresponding products could be loaded onto trucks/trailers, weighed and weight adjusted on road weigh-bridges and then unloaded on the loading bay along the designated railways track at Yard 3.

Railways need to place the rakes directly on the designated tracks at Yard 3 by pushing, after tare weighing of the rake on an in-motion rail weigh-bridge. The pre-weighed products already stacked wagon-wise along the length of the loading bay will be loaded on to the wagons by highly efficient cranes. After documentation, the rake will be handed over to the railways. The railway locomotive will draw out the rake directly from Yard 3. Final weighing of the loaded rake will be carried out on the in-motion weigh-bridge.

4.1 The Proposed System Design Layout

Engineering of the proposed design led to the layout as shown in Figure 5 below, with the intermediate stock yard, final loading bays, the path movement of products from the mills to ISY by captive wagon sets and thereafter to final loading bays by trucks/trailers and dispatch of products from the loading bay tracks by railways wagons.

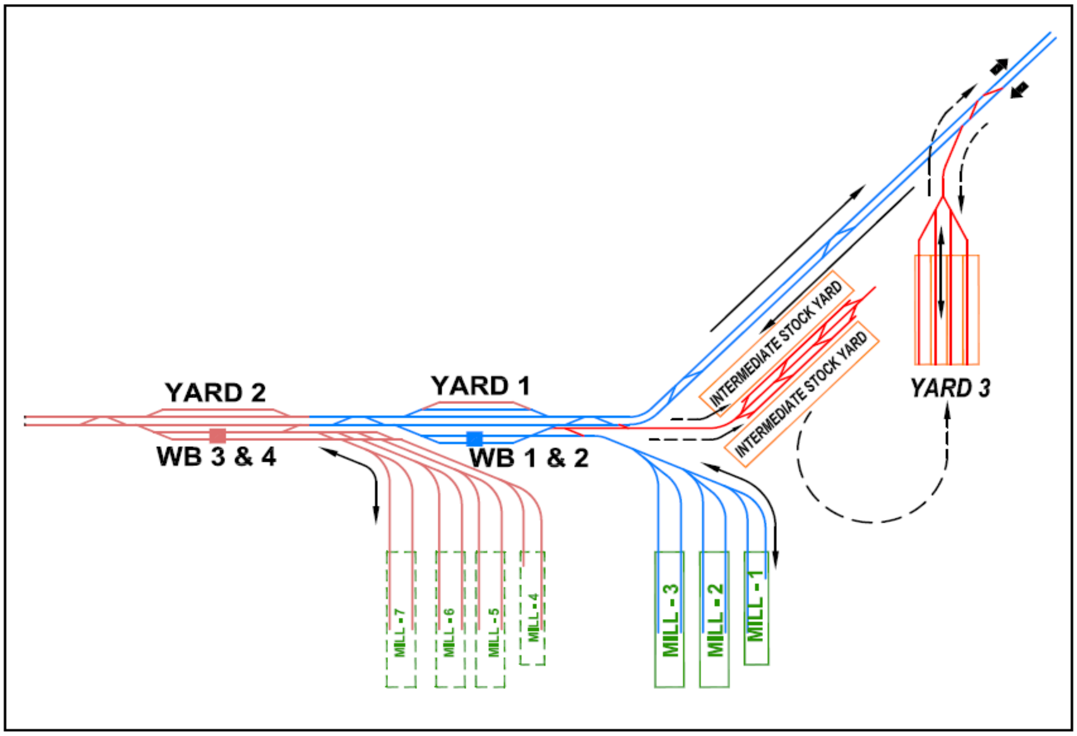

Figure 5: Layout of the proposed system.

4.2 System Design Verification

It was necessary to verify the proposed system design layout and the dispatch operations in terms of reduced WTT and the capacity handling volumes. Simulation has been used for steel product transportation and storage previously. Ueno et al. (1988) used simulation to show that proper configuration of facilities and suitable transportation rules contribute to the carriage efficiency and lead to the great reduction of transportation cost in steel works.

Considering the complexity of operations, variability in the production and dispatch (demand) and the interdependencies of the logistics parameters, it was decided to develop a discrete event simulation model of the system and analyze the results to conclude. The objective of the simulation model can be summarized as:

- Evaluate the adequacy of the proposed design and operations in terms of product handling volumes;
- Confirmation of adherence to the new stipulated WTT for the rakes;
- Determining the number of captive wagon sets and locomotives needed;
- Suggesting the optimum size of each wagon set; and
- Providing an indicative figure for the required logistics resources like trucks/trailers and cranes.

4.3 Simulation Modeling and Analysis

The simulation model was built using the Promodel Software to simulate the system with the additional mills. Rail movement could be conveniently modeled in the software using its feature of network path and entity driven simulation.

The approach followed in the model building was LEAP (Locations, Entities, Arrival, Processing). The first task in building the model was to identify the locations which included source locations, destination locations and intermediate locations where the entities will arrive at and exit from during the movement in the system. It was also necessary to identify the entities which will originate at the mills and exit from the plant dispatch yard; and the entities like wagon sets and rakes which will keep on moving in the system to facilitate movement of other entities. Also, resources like trucks/trailers, cranes, locomotives were created which will move the entities from one location to the other. Once the entities were identified and created, the arrival of the entities had to be modeled as per the arrival patterns. That included the products at the mills; and rakes at product dispatch yard for dispatching the products. The next task was to create the appropriate network path for railway wagon movements and rake movements. The network path and intermediate locations had to comply with the railway signaling policies for operations. The final step was to create the processing logics for the entities at a particular location and thereafter creating the routing logics for moving to the next location using the required resources.

The model was run with the increased production corresponding to the plant capacity expansion stage. One year production data of the existing mills and the empty rake arrival data was obtained from the plant. The one year production data and the rake arrival data was fitted into various distributions and best fit distribution was selected with the help of goodness of fit tests using the Stat Fit Software. The distribution pattern of the existing mills were applied to the new mills by matching the nature, size and volume of the products.

In order to incorporate the existing variability in the simulation model, the current practice of shift timings, maintenance downtimes for facilities, loading times and percentage of weight adjustments for final weighing was built in the model.

4.4 Results of Simulating

The time components involved in the WTT for the proposed system design would be as shown in Table 2. Railways is directly involved in all the activities except the wagon loading, which is going to be completely under plant operations.

Table 2: The time components of WTT in the proposed system.

Time components	**Value (minutes)**
Pre-loading activities after placement	25-30
Wagon loading	
Wagon preparation	50-60
Train examiner activities	50-60
Documentation formalities	25-30
Total turnaround time	**180 maximum**

The maximum time required for completing the activities where railways is involved is 3 hours. Hence, the wagon loading activity has to be completed within another 3 hours to maintain the desired WTT. This depends on the following:

- Sufficient number of cranes are available at the loading bays in yard 3 for loading; and
- The loading bays in Yard 3 are stacked with the products prior to the start of actual loading operations.

Considering parallel rake arrivals and loading activities at loading bays, the simulation model was run and scenario analysis was performed on the following parameters:

- The number of captive wagon sets and locomotives;
- Number of wagons in an wagon set;
- Scheduling options of the captive locomotives ; and
- Number of trucks/trailers, cranes at ISY and Yard 3 in order to ensure just-in-time material availability at the loading bays.

The resources required for just-in-time movement of the products from ISY to the loading bays of Yard 3 and loading the wagons within 3 hours were found to be as shown in Table 3.

Table 3: Resource requirement for movement of products from ISY to Yard 3 and loading in wagons.

Resource	**Numbers**
Mobile cranes at ISY	17
Truck/trailers	35
Cranes at each loading bays in Yard 3	4

The time to move the products from ISY to the loading bays according to the wagon composition, considering the current weight adjustment patterns, derived to be as an average of 6 hours 15 minutes while the confirmation of rake arrival time provided by railways to the plant is much before.

For movement of products from the mills to ISY, separate pools for captive locomotives - a dedicated pool of locomotives (Pool-1) for movement of wagon sets between the mills and Yard 1, and another pool (Pool-2) for movement of wagon sets between Yard 1 and ISY, turned out to be the optimum solution. The required resources in this area turned out to be as shown in Table 4 and the utilization of the locomotives in Pool-1 and Pool-2 are found to be 67% and 54% respectively.

Table 4: Resource requirements for movement of products from the mills to ISY.

Resource	**Numbers**
Locomotives in Pool-1	6
Locomotives in Pool-2	3
Captive wagon sets	15
Wagons in each captive wagon set	8

It could be concluded that with the proposed system design and operations, it would be possible to dispatch the products at the desired volumes per year while the WTT will be well within the reduced limits of 6 hours, provided, the resources are available as suggested. The actual wagon loading time could be within 160 to 180 minutes with the usage of highly efficient cranes at the loading bays.

5 CONCLUSION

The paper presents an approach for designing the outbound dispatch operations of the steel plant with expanded capacity constrained by additional requirement of reduction in turnaround times and verification of the design with the help of simulation. There were limited options available for position of the new mills and the transportation mode for moving the materials out of the mills. Hence redesigning the dispatch scheduling was suspected to be the solution. The recommendations included decoupling external railways operations from the mills, investing in captive locomotives and wagon sets, scheduling mechanism for captive locomotives, creation of an intermediate storage to stack products and ensuring just-in-time material availability for dispatch. However, these proposed recommendations in operations needed to be verified and simulation was used to verify the results. The outputs of the simulation were as per the expected requirements in terms of dispatch volumes and turnaround times. Simulating the system also helped in deriving the logistics resources required for the operations. The proposed design is accepted by the steel plant for its implementation.

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