mined. Obviously the only data available may not represent today's practices so up-to-date data are needed to validate the procedure. Efforts should be made to determine if shifted loads are more susceptible to damage than loads that have not shifted.

An extensive bibliography on loss and damage is presented elsewhere (9).

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Economic Design Methods for Automated Miniyards

ARTHUR W. MELHUISH

ABSTRACT

Changing traffic patterns and operating methods will continue to reduce the number of cars to be classified in yards. This trend promotes a need for economically designed, built, and operated miniyards. Such small-scale yards can be designed in ladder track or balloon formation, both with minihumps and suitable for 1,000 to 2,000 cars per day throughput. To attain low-cost, efficient operation of these yards they will need to be automated in an economical manner with automatic route setting and simple car speed control. The system described in this paper could control the humping procedure to give continuous, discontinuous, and manual modes of car throughput as appropriate to the measured rollability category and track address for each car.

The concept discussed here is that of an unpretentious economic electronic system to both detect and signal on the hump, and to interface with the automatic route setting.

Significant cost savings in retarder control can be made in the initial design stages by

- Using a minimum practical design rollability value (1) and
- Adopting a double standard for car running performance (i.e., accepting those cars that will only reach clearance along with those that will sustain separation).

To compensate in operation for the dilution of the initial design criteria, supplementary operating aids are proposed to

- Control car separation in ladder track yards (in coordination with the route setting controls) by determining car release interval periods according to track destination and thus signal the release of each car and
- Detect cars that have rollability values outside the design bandwidth and then signal appropriate actions.

LADDER TRACK YARD

General

The throughput in ladder track yards depends on operator experience and judgment in the cutting to ascertain adequate separation.

Although some degree of performance is achieved by operator knowledge of destination and by observation, it is thought that the operation, and thereby throughput efficiency, could be enhanced by providing a suitable timing and signal aspect system to control the cutting sequence.

The criteria for the use of the system would be

- Continuous retarder control imposed in the yard to administer the speed of the cars and
- The movements of point switches supervised by automatic route setting.

Such a system could not be applied in a yard where the car speed would not be controlled, but, by imposing retarders to continuously control the speed of all cars to a known value, it is possible to predict the initial separation period needed for the various switch destinations.

With the advent of small self-contained retarders of the Dowty type, which can be installed through the turnouts, it is now possible to impose such retarder control in ladder track yards. The Dowty-type retarder is a small, self-contained hydraulic unit that is quite different in concept and application from the large clasp retarders that have traditionally been used in North American yards.

The purpose of the system would be to create a controlled initial separation between cars at the beginning of the run so that the last ladder track switch, common to the routes for two consecutive cars, could be operated.

The initial separation period would also be kept to a minimum to promote a good throughput rate. In addition, with the speed measurement facility within the system, cars with rollability factors outside the design parameters could be detected and appropriate actions initiated.

Economic Design Parameters

The cost of the retarder equipment in a yard is proportional to

- The car throughput rate. For this type of yard, which is only intended to handle low throughput rates, this value will be low, on the order of 1,000 to 2,000 cars per day.
- The maximum distance from hump crest to clearance marker. This distance is exceptionally high in ladder track formations but can be made acceptable by using continuous speed control and by employing supplementary aids to signal the discontinuous humping moves dependent on car destination.
- Allowable car separation. This distance can be kept to a minimum by employing car detection devices in place of track circuits that are dependent for length on the maximum distance between trucks.
- Maximum axle weight. This value is considered standard for all yards.
- Maximum rollability value. This factor has a prominent effect on yard cost and performance and therefore needs to be kept as low as practicable in the design stages. For the purposes of discussion, the yard shown in Figure 1, with 2 lb per ton minimum rollability and dual maximum values of 5 lb per ton to sustain separation and 8 lb per ton to reach maximum clearance, is assumed. To enable a practical operation to be based on such a narrow design rollability bandwidth, a supplementary operating system could be used to categorize rollability, determine car address, and signal appropriate operating modes and actions.

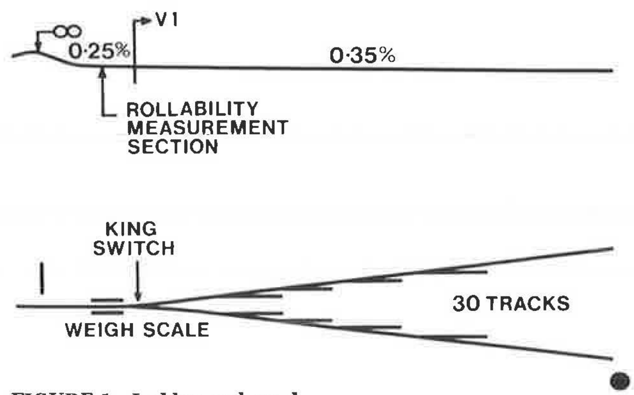

FIGURE 1 Ladder track yard.

Description of Yard Design and Performance

Figure 1 shows a ladder track yard made up of 30 class tracks with an accelerating hump and a weigh-scale track.

Cars would be cut loose at the apex to accelerate down the hump and over the weigh scale to arrive at the King switch with velocity V_1. The weigh-scale track would have a gradient of 0.25 percent so that a 5 lb per ton rollability car would traverse it at constant velocity.

Retarders would be installed on the hump and in the King switch to control the maximum speed to V_1. This retarder control would continue throughout the switches on the ladder lead tracks so that the nominal velocity (V_1) is maintained throughout.

A profile would be selected to ensure that

- A 5 lb per ton rollability car would accelerate to V_1 and continue with constant velocity along the ladder lead tracks and

• An 8 lb per ton rollability car would roll past the farthest clearance marker.

After establishing a constant nominal velocity, by applying continuous control, it is possible to construct a time-distance curve, as shown in Figure 2, to establish the variable release interval periods (RIPs). RIPs can be established for every switch, but for illustrative purposes a simplified method has been adopted here that uses only three different periods (i.e., RIP minimum, RIP mean, and RIP maximum) compatible with the minimum, mean, and maximum distances to run.

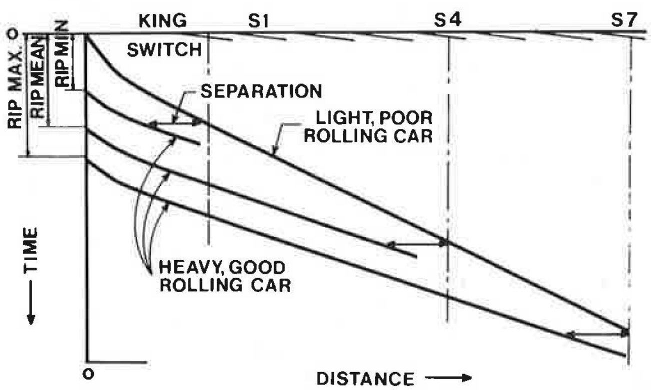

FIGURE 2 Time-distance curves.

Conceptual Study of Supplementary Operating Aids

Suitable process control programs for the supplementary operating aids and the route progression system would need accommodation within a minicomputer with a suitable timer appended. An interface would be needed to receive signals from three car detectors and a manual switch and to transmit commands to a two-aspect color light signal (Figure 3).

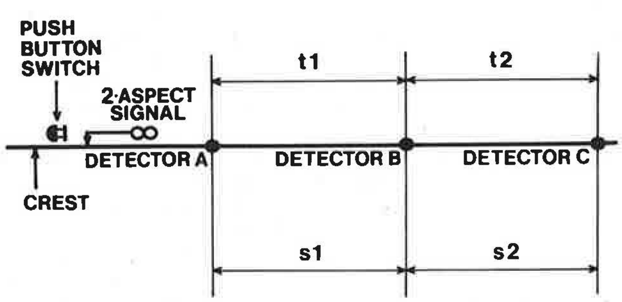

FIGURE 3 Signal and detection equipment—hump track.

Two consecutive timed sections of equal length (S1 and S2), would be located between the hump and the King switch. The measurement of the time taken for a car to traverse the first section would be stored and used as the base time (t_1). The measurement of the time taken (t_2) for a car to traverse the second section would be compared with the recording from the first section to determine the car rollability category.

If $t_2 > t_1$, the car would be exhibiting a higher rollability tendency than that acceptable within the design for sustaining separation. (Note that the gradient of 0.25 percent on the weigh-scale track is equal to the design rollability ratio of 5 lb per ton.) In this event the system would adopt the manual mode and the operator would visually monitor the car's progression through the yard.

The basic operation shown in Figure 3 is envisaged as follows:

1. Signal aspect at green. Leading car can be released.
2. Detector A activated. Start first timing period (t_1) and the RIP signal aspect to red. Interrogate route setting program to obtain addresses of leading and following cars.
3. Determine last common ladder track switch for both car destinations. If common switch is King, select minimum RIP; if switches S1-S4, select mean RIP; and if switches S5-S7, select maximum RIP (Figure 2).
4. Detector B activated. End first time period (t_1) and start second time period (t_2).
5. Detector C activated. End second time period (t_2).
6. Compare t_2 with t_1 to ascertain rollability category.
7. If valid, go to Step 8. If invalid go to Step 9.
8. At end of selected RIP, signal aspect to green. Next car can be released.
9. Adopt manual mode. Activate flashing red alarm signal aspect. Operator to monitor car clear through system.
10. Operator activates manual push button switch. System reverts to automatic mode with signal aspect at green. Next car can be released.

Additional Facilities for Consideration

In this study the aim has been simplicity in the system design. With an expanded design study, preferably for a nominated project, it is believed that a practical system could be attained. The need to achieve a simple design with economy of costs is fully recognized. But, on the other hand, it is also recognized that in development the system could be extended to provide additional refinements, such as

1. Radar speed measurement could be used to measure car velocities from which acceleration could be determined and thus rollability factors for an enhanced number of categories.
2. Cars indicating a rollability value above 8 lb per ton could be detected and rejected from running through the yard by use of a reject track. The reject track could be via S1 (Figure 2) or constructed by adopting a lap switch for the King switch position.
3. The process control program would include an RIP for each individual switch; this could be further embellished by introducing a maximum rollability value appropriate for the distance to run to each switch and judging each car's compatibility during operation.
4. The theoretical RIPs should be adjustable in the commissioning stage in order to make allowance for operator reaction time.

BALLOON FORMATION YARD

General

This type of yard layout was originally adopted to overcome the large difference between maximum and

minimum distances to the switches experienced in ladder track yards. A balloon yard is designed for higher car thoughput rates than is a ladder track yard, and this throughput would be achieved by employing a constant humping velocity. Therefore the RIP associated with discontinuous humping is not needed. However, supplementary operating aids could be usefully employed to determine rollability categories and thus accept or reject cars as applicable.

A suitable car retarder system would need to be employed to ensure car separation in the switching area and to control overall car performance, together with automatic route setting.

For normal operations the humping speed would be constant and the separation sustained for cars having average (R avg) rollability values. A maximum design rollability factor (R max) could be determined to ensure that all cars within this limit clear the switching area. By measuring the rollability and categorizing at the hump, the following appropriate actions could be signaled.

1. The majority of cars will have average rollability values and the humping process will be continuous.
2. If the rollability value is above average but below maximum the humping would stop for the operator to visually monitor the car's progress through the switching area.
3. If the rollability value should be above maximum the car could automatically be switched to a reject track to prevent congestion in the switching area.

Predicted Economies

Example 1

Figure 4 shows the basic features of a small balloon yard that should be capable, in approximate terms,

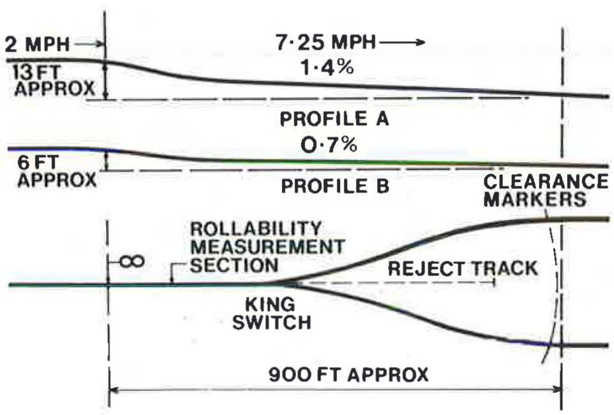

FIGURE 4 Track diagram and switching area profiles.

of handling 180 cars per hour over the hump, which, with an operating efficiency of 40 percent, should result in a throughput of 1,700 cars per day.

By adopting a design rollability ratio of 28 lb per ton maximum, it would be possible to cater to the car performance of 100 percent of the fleet. To cater to this maximum rollability ratio, and to sustain separation for the car rollability bandwidth of 2 lb per ton to 28 lb per ton, the hump crest would need to be on the order of 13 ft above the clearance markers (profile A in Figure 4). Approximately 12.2 ft of retardation energy head would be needed to control the heavy, low rollability cars in the switching area.

Example 2

By adopting rollability values of 2 lb per ton minimum and 10 lb per ton to sustain separation, 90 percent of the car population could be serviced. If a 14 lb per ton maximum, to reach clearance, were adopted, an additional 6 percent of the car population could be serviced. If supplementary operating aids were applied to assist the humping process, 90 percent of the cars could be continuously humped at 2.0 mph and a cumulative 96 percent of all cars would pass clearance. Four percent of the cars (i.e., those with above 14 lb per ton rollability) could be switched to a reject track to avoid stalling in the switching area. Continuous humping would be interrupted for 10 percent of the cars, when a manual mode of operation would be adopted.

If it is assumed that a car would take 1 min to clear the switching area, with the humping stopped, the average throughput could be on the order of 168 cars per hour or 1,600 cars per day when operating at 40 percent efficiency.

A hump height of only 6 ft above the clearance markers would be needed to cater to the rollability bandwidth of 2 lb per ton to 14 lb per ton (profile B in Figure 4). Approximately 5.2 ft of retardation energy head would be required in the switching area to control the heavy, low rollability cars.

A comparison of the examples reveals that the diluted design criteria employed in Example 2, compensated for by the application of the supplementary operating aids, could achieve an estimated 43 percent saving in the required switching area retardation energy (i.e., retarder costs) for only a 5.9 percent reduction in car throughput. Because of the variations in different types of retarder system performance and price, and also the international variations in exchange rates and in labor and material costs for supply, shipment, and installation, no attempt has been made to convert the 43 percent saving in retardation energy into a monetary value.

CONCLUSION

In this paper the aim has been to describe the proposed system in basic and simple terms. There is no doubt that the system could be enhanced and expanded to include more rollability categories, distances to switches information, and car performance data.

Traditionally, ladder track yards and small hump yards, where high throughputs are not required, have been designed to rely heavily on manual operation. In recent years, some automatic route setting systems have been employed in these types of yards, and perhaps now, with the addition of a car retarder speed control system, the way is open to employ new methods to improve operating efficiency.

A system of supplementary operating aids as described herein could be a way to reduce the initial capital cost of miniyards and might thereby encourage both designers and operators to adopt full automation for small, low-throughput yards and thus reap the benefits of improved operating efficiency.

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