UNIVERSITY OF NIS FACULTY OF MECHANICAL ENGINEERING

THE SIXTH INTERNATIONAL CONFERENCE
TRANSPORT AND LOGISTICS

til
2017

TOWARDS INTELLIGENT MANAGEMENT OF DECISION MAKING PROCESSES IN MARSHALLING YARDS

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Abstract

Marshalling yards play important role in freight railway transport. Planning operational procedures in a marshalling yard is a very complex problem. Mostly, classification procedures in marshalling yards are planned manually by highly experienced dispatchers. The fact that marshalling process depends on experience and decisions made by one or more dispatchers put this process in group of decision making and high risk processes. In that sense, automation of decision making processes in marshaling yards in real time seem to be big challenge for increasing efficiency and reliability of rail freight services. It means that intelligent decision support system as part of real time yard management system (RTYM) can be solution for automation challenging task. Concept solution of real time management system regarding decision making process with special attention to deviations is described .

***Key words**: marshalling yards, single wagonload, decision making process, intelligent decision support system, real time yard management system, heuristic approach, machine learning*

1 INTRODUCTION

Marshalling yards have a decisive impact on accuracy, availability and cost efficiency of rail freight services. The cost competitiveness and the reliability of freight services need to be considerably improved so that rail freight can be in a position to offer a cost-effective, attractive service to shippers that helps to take freight away from the already congested road network. In order to provide customer tailored services mentioned above, marshalling yards are inevitable for doing some improvements and optimization.
Main processes of marshalling yards may take 10–50% of trains total transit time. Marshalling processes still involve much manual planning and improved decision support and analysis tools are of the high importance.
Therefore, according to [1], the objective is to achieve the same level of flexibility and accessibility as the other means of continental intermodal transport and to achieve even better reliability improvement of planning and operation of marshalling yards needs to be done. In that sense, an efficient and effective operation of marshalling yards is at the heart of the future single wagonload (SWL) freight service in Europe and close connected with modern real time marshalling yard management system.
Planning the operational procedures in a railway marshalling yard is a very important and complex problem. In most cases, classification procedures in marshalling yards are planned manually by highly experienced dispatchers. The fact that marshalling process depends on experience and decisions made by one or more dispatchers put this process in group of decision making and high risk processes.
Investigation and process recording in different marshalling yards shows that there are no documented or systematic rules or guides to help operators with the planning tasks.
Analysis of two marshalling yards in Serbia and one in Bulgaria, and data collected from literature research show that classification procedure is the most influent procedure in marshalling yard, regarding overall time that one train or single wagon spend in marshalling yard. Nowadays, the point of view for planning and scheduling tasks has changed. Due to the fact that real world is uncertain, imprecise and non-deterministic, there might be unknown information, breakdowns, incidences or changes, which become the initial plans or schedules invalid. Thus, there is a new trend to cope with these aspects in the optimization techniques, and to seek robust solutions.
Regarding marshalling yard management problem, it means that challenge in seeking and finding optimal solutions is deeply connected with occurred deviations in decision making processes in marshalling yards. The capability to handle deviations by real time optimization is the key challenge. To define and select good enough real time optimization algorithm and to find optimal or near optimal solution decision making processes and their deviations in marshalling yards should be described.

2 MARSHALLING PROCESS AS DECISION MAKING PROCESS

The problem of marshaling yards' operations planning not only has a complex model and intractable algorithm, but also a lot of uncertainty factors exist. Different countries, different regions and different production environments vary their description methods, in addition to optimization objectives and constraint conditions. It is very difficult for researchers from related fields to learn from each other and experimental results cannot be compared.
As it described in detail in [2], the main marshalling process by following a wagon through its life cycle in a standard marshalling yard is presented. The processing of a wagon in

a marshalling yard begins with the arrival of a train. This train is called inbound train. Every inbound train gets assigned to a suitable track in the receiving yard (RY), where the trains are inspected and their wagons are decoupled.

Decoupling refers to the separation of wagons that do not share the same destination. Wagons that appear sequentially on a track and share the same destination are called a block. In most cases those blocks stay together and are processed jointly throughout the process. After the separation is completed, the wagons are pushed over the hump by a shunting engine. The hump enables the wagons to enter the classification bowl without external propulsion by following a downhill system of tracks and automated switches. At this point three important decisions in respect to performance have to be made. Those are the following three decisions:

- **Roll in sequence**

The hump can only be used for the roll-in of a single inbound train at a time. Since there is no way for a wagon to overtake a preceding wagon on a track, all wagons that have been rolled-in before other wagons are standing strictly before them. That is why the roll-in sequence is very important. In addition, the hump is operated at its capacity limit in order to process as many inbound trains as possible. This results in the need to select the next inbound train to be rolled-in from the already processed trains. This number increases and makes this decision more difficult as the yard approaches its capacity limit.

- **Outbound train assignment**

Every wagon has to leave the shunting yard with a suitable outbound train. All wagons have a predefined destination which allows for identification of possible outbound trains serving this destination. Usually wagons will be assigned to the next eligible outbound train, but other aspects can be taken into account which may lead to different assignments. This decision is driven by the need to reduce the number of wagons in the classification bowl (fewer outbound trains per destination) and the need to minimize marshalling effort (more outbound trains per destination).

- **Classification track assignment**

This decision assigns a certain track in the classification bowl to a wagon. With this information the automated guidance system can lead the wagon to that track. This decision is trivial as long as there are more tracks than outbound trains. Unfortunately, this precondition is rarely met in the real world. In general, a classification track stores wagons for more than one outbound train. The idea is to keep the number of tracks per outbound train as small as possible. This decision is based on characteristics of other outbound trains at a certain track and the location of the tracks already hosting wagons of a certain outbound train.

The sum of these three decisions determines the position of every wagon in the classification bowl. This information is very important from the perspective of Railway Undertaking and availability of monitoring wagons by operators as one of the requested goals of the project. The actual position of each wagons on classification bowl and its place related to other wagons on classification bowl are of the highest importance either for optimization of marshalling process either for visual representation.

The classification bowl consists of a number of large, parallel tracks, each of which can be used to store wagons. The tracks can only be entered by un-propelled wagons rolling-in via the hump from one end, and by shunting engines from the other end. At some point in time before the scheduled due time of an outbound train, the train has to be prepared and cleared for exit.Marshalling process refers to collecting wagons from their respective tracks, called source tracks, and moving them to a common track, called the building track. This building track is dynamically chosen from all suitable tracks in the Classification bowl or Departure Yard for each marshalling problem instance. When all wagons are on the building track they are joined together and become the outbound train. Outbound trains often consist of one or more blocks. A block refers to wagons that share the same destination. Most commonly the blocks correspond to the planned stops of the outbound train. This enables the train operator to deliver the wagons at their respective destination feeder line with minimal effort by just decoupling the last block at each stop.

There are generally two ways of marshalling a train:

The first way: The track assignment can be made in such manner that all wagons standing on a track can be pulled back on the hump and being rolled-in a number of times until the wagons of the outbound train are standing consecutively on a track in the classification bowl. Depending on the number of roll-ins, this process is referred to as single- or multi-stage sorting.

The second way: A shunting engine can be used to collect the wagons from their respective tracks and transfer them to the building track manually. This is sometimes referred to as flat shunting and in our case takes place between the Classification bowl and the Departure yard.

The underlying planning problem of this alternative process in depth can also be discussed. The final stop of a wagon is the Departure yard. It is used to delay the exit of outbound trains until they are due.

In addition, there can be area called the Sorting bowl. This area is used to marshal outbound trains that have a large number of sequence constraints (multiple blocks), which can not be met efficiently using the main process. The sorting bowl has its own hump and operates independently from the main shunting yard.

The problem of marshalling a train is considered by using a single shunting engine. This problem is embedded in a sequence of decisions that have to be made in order to transform inbound trains into properly composed outbound trains.

In practice, these decisions are made in a just - in - time decisions and are not subject to overall optimization because of the fact that important information becomes available in time and decision are generally time-critical and irrevocable.

These decisions are the following [2]:

1. Track assignment in receiving yard for inbound train.
2. Roll-in sequence of inbound trains.
3. Marshalling by humping

(a) Assignment of individual wagons to actual outbound trains.

(b) Assignment of individual wagons to tracks in the classification bowl.

4. Marshalling by shunting engine

(a) Selection of building track.

(b) Assembling outbound train by a sequence of pull-out operations.

5. Track assignment in departure yard.
6. Exiting sequence.

Many marshalling yards in Europe use more than one sorting mechanism. Some of them do not use any theoretical sorting mechanism at all. In some cases, it is combination of theoretical background and experience. There are a number of reasons that prevent typical European marshalling yards to utilize the very efficient shunting based upon repeated roll-ins. The main reasons are highly uncertain arrival times of inbound trains and the unfavorable ratio of number of blocks to number of classification tracks due to certain characteristics of the European railway system. These uncertain arrival times in combination with limited track capacity in the Receiving yard force shunting yard operators to utilize the hump at its capacity limit in order to guarantee the availability of receiving tracks for incoming trains. Trains can not wait in front of a yard for a receiving track to become available, because they would block other freight or passenger trains. As a result, repeated roll-ins that would consume both track capacity in the Receiving yard as well as time of the hump are rarely executed. Furthermore, heterogeneous marshalling yard designs result in a high number of block sequence constraints due to operational or commercial requirements that further complicate the track assignment problem, hence creating the need for a second marshalling mechanism that does not consume scarce resources. The number of blocks per track and the number of tracks, used to store blocks assigned to the same outbound train, can be very high, making the second marshalling step based on flat shunting more complicated and worthy of optimization.

As a conclusion of this marshalling process description from the perspective of decision making processes, the following issues can be marked:

- there are different types of marshalling yards and it is very difficult to make generalization for potential scenarios
- marshalling process is very complex process from decision making aspect
- there are many constraints related to decision making
- there are lots of variants of marshalling process that lead to different decisions

To conduct the analysis it is very important to use proper and sufficient information. This information should be relevant to the problem solution and should help to make criteria to evaluate different options.

3 DEVIATIONS IN DECISION MAKING PROCESSES IN MARSHALLING YARDS

Deviations in decision making process could be objective and subjective.

Objective deviations could be a result from:

- Lack of information;
- Large number of data that have to be considered;
- A need of conducting many repeated observations, surveys, etc.
- Real time deviations in information flow
- Priorities that must be considered

Subjective factors could be:

- Incorrect information processing,
- Incompetence in solving problems;

There are 7 specified real time deviations in information flow described below.

- **Deviation of the incomming trains from the plan**

The composition of freight trains is prescribed by timetable ie. annual traffic plan of trains. However, the real composition of the train may deviate from the plan. Each station from which the train is arriving have to send the analysis of the train to the next station after the train left the station. In this way, the marshalling yard during the day collect information about trains and wagons that come to the station as well as their final destination. Marshaling yard, on this way, has data on the composition of the train before the train arrives at the station. In case of train delays and limited yard resources, static user-defined rules and decision-making - based only on the experiences of the yard dispatcher - cannot ensure that yard operations are performed according to the priorities of punctuality and cost- efficiency.

- **Deviations in individual wagons modification**.

In carrying out the planned tasks, in the marshalling yard can arise unplanned situations such as found commercial or technical malfunction of individual wagons in train. The decision on the actions to be taken on that occasion (extraction of wagon, etc.) brings the train dispatcher in agreement with an operator who is represented in marshaling yard.

- **Unexpected repair or breakage of sections of rail line**.

Sometimes unexpected repair or interruption on sections of rail line can occur. In this case the train must stay at the marshaling yard and occupy extra space.

- **Unexpected repair or breakage of wagons.**

Sometimes the inspection shows that a certain wagon has problems and could not be used. In this case the wagon must be removed from the marshaling yard somehow and repaired later.

- **Deviations or incorrect weight of incomming trains or wagons**.

Many times the weight of the wagon does not correspond to the weight in the documents. The load must not exceed the permissible gross weight per axle, weight per meter and load profile of the respective tracks. Higher gross vehicle weight shall be placed, in principle, to the front of the train.

- **Priorities in cases of congested infrastructure or other priority policies**.

Priorities that must be considered in marshalling yards' schedule. While each rail company has different wagon priority policies, normally a wagon's priority value is expressed in EUR/wagon-hour and is usually determined according to one or more of the following conditions:

- The type of goods (merchandise) loaded in the wagon.
- The wagon's consignor (some shippers receive referential treatment with regards to rate and/or guaranteed arrival date).
- Whether or not the wagon has been designated as "special" (e.g., a refrigerator car, a tank car, or a double-stack wagon).
- Whether or not the wagon is "foreign"; i.e., the wagon is owned by another railway company.

There must be criteria for organization of marshalling yard functioning in case of "priority". Usually the first criterion is extra payment. The following priority criteria recognize the importance to society of a service. In determining priority criteria, a special attention is to the importance of services for freight, and in particular of international services for freight. The procedures to be followed and the criteria to be used in case of priorities have to be determined in reference to the particular marshalling yard.

Where infrastructure has been declared to be congested, the infrastructure manager performed a capacity analysis and then follows the criteria policy for this particular marshalling yard.

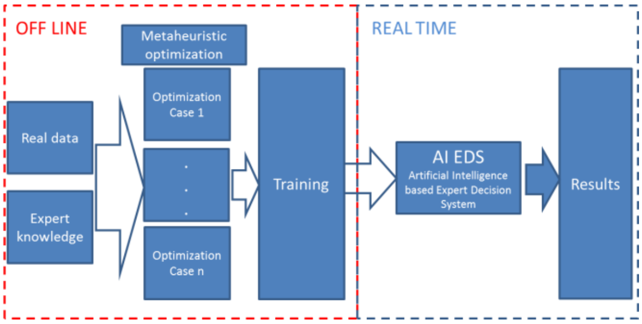
Extraordinary requests. The marshalling yard manager meets the extraordinary requests by preparing an individual plan as quickly as possible.

Intelligent decision making on a real-time basis will be required and become a strategic element of automation and optimization in marshalling yards.

4 CONCEPT SOLUTION

In most of operating companies there still does not exist active optimization tool as decision support for the dispatchers at real time. One reason may be that it is hard to come up with a standard approach. The schedules that need to be generated depend highly on the particular infrastructure of the marshalling yard, the configuration of inbound and outbound trains, and the requested objective. Thus, methods for computing schedules of high quality have to be tailor-made to the actual situation.

In order to reach above mentioned issues, a real-time marshalling yard management system will be designed to enable the optimization of available resources and planning of marshalling operations and to achieve defined specific goal of decreasing overall transport time and costs associated with cargo handling in existing infrastructure. The crucial part of Real-time marshalling yard management system is decision support system. The core of all research and innovation activities is directed to design and implement algorithm for real-time optimization.



It means that the heart and advances beyond the state of the art will be the part of information system for optimization named Optimization module. The concept solution for Optimization module is shown in Fig. 2.

Advance beyond state of the art is machine-learning based decision system that can give optimal or near-optimal solution for marshalling yard operations in real time. In order to choose the optimal marshalling yard model with a maximum savings of time sorting, selected models will be firstly tested using Monte Carlo simulation method. Using Monte Carlo experiments will enable us to choose the mathematical model. Using the most appropriate yard model will allow maximal sorting time reduction as well as the sorting costs.

Developed models can then be used for marshalling yard operations optimization. In our research we suggest determination of the best heuristic or meta-heuristics optimization algorithm (regardless the time of optimization), based on pre-defined criteria and one of the multi-criteria decision methods. This optimization cannot give real-time solution for marshalling yard management, so in our work we suggest using the optimization results as a training data for machine learning decision system. The trained machine learning system will then give the optimal or near-optimal solution of marshalling operations in real time. Real-world environments consist of several optimization problems. Decision makers in marshalling yards must face with several problems at once. Usually, scientific community solves each problem independently.

However, optimizing one of them (minimizing or maximizing) does not need to lead to the optimal solution. That is why a decision support system has to be developed to handle more than one optimization problem from the marshalling yard by using some of the above approaches [3]. By combining optimized solutions in one integrated system, operators can be assisted to decide the most appropriated solution in each particular scenario.

5 CONCLUSION

Nowadays, the point of view for planning and scheduling tasks has changed. Due to the fact that real world is uncertain, imprecise and non-deterministic, there might be unknown information, breakdowns, incidences or changes, which become the initial plans or schedules invalid. Thus, there is a new trend to cope these aspects in the optimization techniques, and to seek robust solutions.

Regarding marshalling yard management problem, it means that challenge in seeking and finding optimal solutions is deeply connected with occurred deviations in decision making processes in marshalling yards. The capability to handle deviations by real time optimization is the key challenge.

ACKNOWLEDGMENT

The paper is a part of the research done within the project H2020 Shift2rail SMART – Smart Automation of Rail Transport.

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