



## Simulating freight-wagon grouping and train scheduling policies for Iran rail network: A study on exhausted emissions of diesel locomotives

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**ABSTRACT:** Because of the important role of Iran railway network in in-land freight transportation, appropriate freight-wagon grouping and train scheduling can significantly reduce the amount of emissions as well as fuel consumption. This paper evaluates the impact of different freight-wagon grouping and different train scheduling policies by using a simulation model of moving trains on the Iran rail network. Based on three related issues including train scheduling, wagon grouping and train formation, eight scenarios have been designed in addition to the do-nothing. Each scenario investigates the demand of freight transportation of the Iran rail network to determine locomotive emissions consist of CO<sub>2</sub>, SO<sub>2</sub>, PM, NO<sub>x</sub>, CO and HC. This study shows that simultaneous implementation of “un-necessary grouping” and “flexible scheduling” policies can lead to the lowest amount of total emissions.

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### 1- Introduction

Although transportation development can meet the human needs for the movement of goods all around the world, it can be one of the causes of air pollution. The US environmental protection agency (USEPA) has introduced six major emissions, including CO, NO<sub>2</sub>, SO<sub>2</sub>, PM<sub>2.5</sub>, PM<sub>10</sub> and Pb as the main indicators of air pollution which can threaten human health [1]. Focusing on rail transportation emissions, a large amount of research has been done for calculating exhausted emissions of diesel locomotives such as: Baily et al [2], Kean et al [3], Jorgensen et al [4] and Aly [5]. However, according to the authors' knowledge, there is no study about how tactical policies such as grouping (reclassifying) freight-wagons and scheduling trains in rail network can reduce the exhausted emissions.

### 2- Methodology

Considering the tractive effort of a train regarding the rise-and-fall restriction, there are three policies for grouping freight-wagons on the railways: (1) Non-reclassification policy which declares the situation with no change in freight-wagon classification. (2) Un-necessary reclassification that a train stops in a reclassification yard, whether there is at least one freight-wagon is waiting for the same destination. (3) Complete reclassification policy that each train stops and reclassifies at all classification yards through its path.

There are three common policies for scheduling the

departure time of trains (including freight-wagons) from each classification yard: (1) Pre-planned scheduling policy, which assigns a pre-scheduled departure time, according to the planned itinerary for a freight-wagon by its origin (2) Flexible scheduling policy which only sets the leaving time for each train in order to the hauling capacity of available locomotive in the yard. (3) Mixed scheduling policy which is a combination of the above policies. In other words, a train leaves the yard when at least one of the above policies is met.

A method for calculating locomotives emissions (HC, CO, NO<sub>x</sub> and PM) is defined by the EPA 2005 [6]. To determine the amount of CO<sub>2</sub> and SO<sub>2</sub>, a method is proposed by Bargin et al. based on the amount of fuel consumption [7]. The mentioned method uses the running resistance to calculate the fuel consumption. Finally, the total cost of emissions on human health can be estimated by the emissions costs proposed by Romilly [8]. He investigates CO<sub>2</sub>, SO<sub>2</sub>, PM, NO<sub>x</sub>, CO and HC and suggests the cost of 13.33, 220.69, 9788.84, 190, 10.43 and 30.3 Euro/ton for them, respectively.

### 3- Case Study

In this paper three grouping policies as well as three scheduling policies are assessed. These policies lead to nine distinct scenarios that are shown in Table 1.

**Table 1: List of the studied scenarios**

Scenario	Grouping policy	Scheduling policy
0 (Do nothing)	Non-reclassification	Pre-planned
1	Un-necessary reclassification	Pre-planned
2	Complete reclassification	Pre-planned
3	Non-reclassification	Flexible
4	Un-necessary reclassification	Flexible
5	Complete reclassification	Flexible
6	Non-reclassification	Mixed
7	Un-necessary reclassification	Mixed
8	Complete reclassification	Mixed

This study adopted a simulation model through .NET programming enhanced by Visual Studio 2012 software. The model, has been used for simulating each scenario and evaluating the cost of emissions in order to choose the best combination of policies. The real data provided by the Islamic Republic of Iran Railways (IRIR) [9] have been used to show the application of the simulation model in order to compare the nine scenarios presented in Table 1. The Iran rail network includes 224 stations, 44 classification yards, 1883 O-D pairs of demand, and approximately 13,000 km rail track (Figure 1) [10].

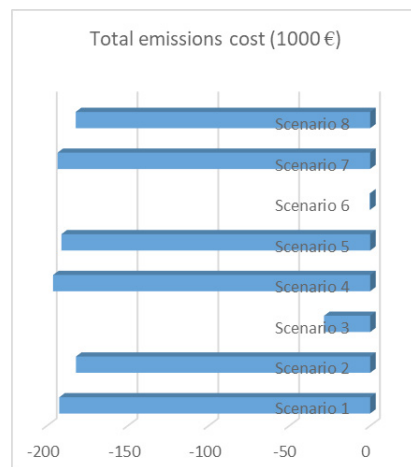
**4- Result**

Based on the methodology and output of simulation, the cost of emissions CO<sub>2</sub>, SO<sub>2</sub>, PM, NO<sub>x</sub>, CO and HC in each scenario has been obtained in the rail network of Iran for a period of 30 days. As illustrated in Figure 2, all of the investigated scenarios (except scenario no. 6) lead to lower cost of emissions in comparison to the do nothing scenario.

Focusing on the grouping policies, Table 2 illustrates that the amount of total emission cost significantly decreases by choosing a complete reclassification (i.e., scenarios no. 2, 5, and 8) in comparison with the un-necessary reclassification policies (i.e., scenarios no. 1, 4 and 8).



**Figure 1: Iran rail network**



**Figure 2: Differences between emissions costs of each scenario and the do nothing**

**5- Conclusion**

In this study, we computed the amount of emissions including CO<sub>2</sub>, SO<sub>2</sub>, PM, NO<sub>x</sub>, CO and HC by simulating grouping and scheduling policies for freight-wagons (trains) on the rail network of Iran. Therefore, eight scenarios have been examined and compared with the do nothing scenario (see Table 2). The outputs of simulation illustrate that average of total emissions cost significantly have been reduced by using un-necessary reclassification and flexible scheduling in comparison to the other scenarios (considering 95% confidence interval). As observed in Figure 2, not-reclassification of the freight-wagons in their path through origin to their destination can lead to increase in the amount of total emissions (considering 95% confidence interval).

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**Table 2: Comparing total emission cost by scenarios (95 % confidence interval)**

	Do nothing	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Do nothing	--	x	x	x	x	x	#	x	x
Scenario 1	✓	--	✓	✓	x	✓	✓	x	✓
Scenario 2	✓	x	--	✓	x	x	✓	x	#
Scenario 3	✓	x	x	--	x	x	✓	x	x
Scenario 4	✓	✓	✓	✓	--	✓	✓		✓
Scenario 5	✓	x	✓	✓	x	--	✓	x	✓
Scenario 6	#	x	x	x	x	x	--		x
Scenario 7	✓	✓	✓	✓	x	✓	✓	--	✓
Scenario 8	✓	x	#	✓	x	x	✓	x	--

“✓” Shown scenario in row have lower amount of emission (with confidence interval 95%)  
 “x” Shown scenario in row have higher amount of emission (with confidence interval 95%)  
 “#” shown we can’t comparing (with confidence interval 95%)

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