2017 INFORMS RAS Problem Solving Competition

Data Analytics for Railroad Empty-to-Load Peak Kips Prediction

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Problem statement, datasets and description, and more information about the competition can be found at the following link: http://connect.informs.org/railway-applications/awards/problem-solving-competition

IMPORTANT DATES:
June 01, 2017: registration of participation open
July 15: Deadline for submitting a clarification question
September 10, 2017: Submission of solution and report
October 10, 2017: Announcement of finalists
October 22, 2017: Finalist presentation at the INFORMS Annual Meeting, and award ceremony

DISCLAIMER: The problem described here addresses one of the most important issues in railway operations and safety. Please note that missing data may have been deliberately included in the datasets. Good luck with the competition!

May 15, 2017

Data Analytics for Railroad Empty-to-Load Peak Kips Prediction

1. Introduction

Peak kips denotes the total vertical force a wheel imposes on the rail. A "Kip" is a unit of force that is equal to 1,000 pounds-force[1], and it can be measured by track-side detectors. The higher the peak kips, the more damage will be imposed to both the wheels and tracks. Railroads use this measure to detect whether there are any defects in either the tracks or the wheels. An alarm will be triggered if the peak kips value is above or equal to 90, and the involved cars need to be set out for inspection and repair (if necessary) either immediately or at the next available repair location. Although immediate action is not required for wheels with peak kips values close to 90, the damage to tracks and wheels might deteriorate (and the peak kips of a defective wheel may further increase) if the defective wheels are not fixed in time.

However, setting out a car when it is loaded will cause a lot of loss to railroad company. The shipment might get delayed and the network traffic might suffer from unnecessary disruptions. Therefore, the railroad has an incentive to proactively identify problematic wheels/cars and exclude them from being used for future shipments.

This project aims at building a predictive model which can be used to project the peak kips of a currently empty car when it is used under the next loaded status. This implies that the projection will be calculated when the car is empty. This model will help the railroad company exclude the problematic wheels/cars from the next trip.

2. Problem description

2.1 Problem statement

Peak kips consists of two components:

$$\boxed{\text{Peak kips} = \text{average kips} + \text{dynamic kips}}$$

where

Average kips is the static part of the peak force associated with the weight of the car (when the car is empty, average kips should be low; when the car is loaded with heavy commodities, the average kips will be fairly high);

Dynamic kips is the part of the peak force caused by wheel tread defects.

Furthermore, **dynamic ratio** is defined as the peak kips divided by average kips. This captures the portion of the total force that is due to impacts (as compared to weight). Figure 1 illustrates the relationship between peak kips, average kips and dynamic kips.

[1] You can find more information about kip through the wiki page: https://en.wikipedia.org/wiki/Kip_(unit)

As it is implied by the above equation, peak kips of an empty car is always less than that when the car is loaded. Additionally, a defective wheel will cause more impact than the non-defective wheels under loaded status. This provides a reason why the peak kips of some wheels suddenly jumps from below 50 to above 100 when the cars become loaded. Figure 2 shows how the peak kips of a wheel transitions between empty status and loaded status.

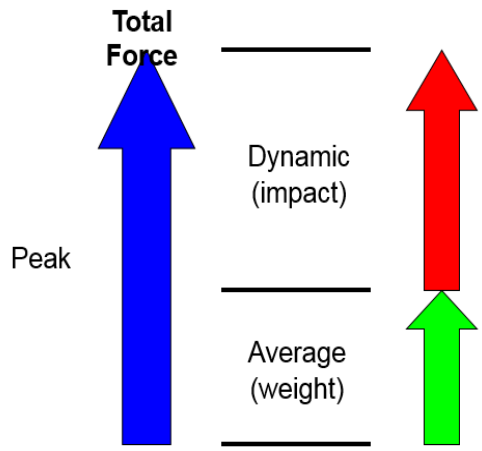


Figure 1: Graph representing relationship of peak kips, average kips and dynamic kips

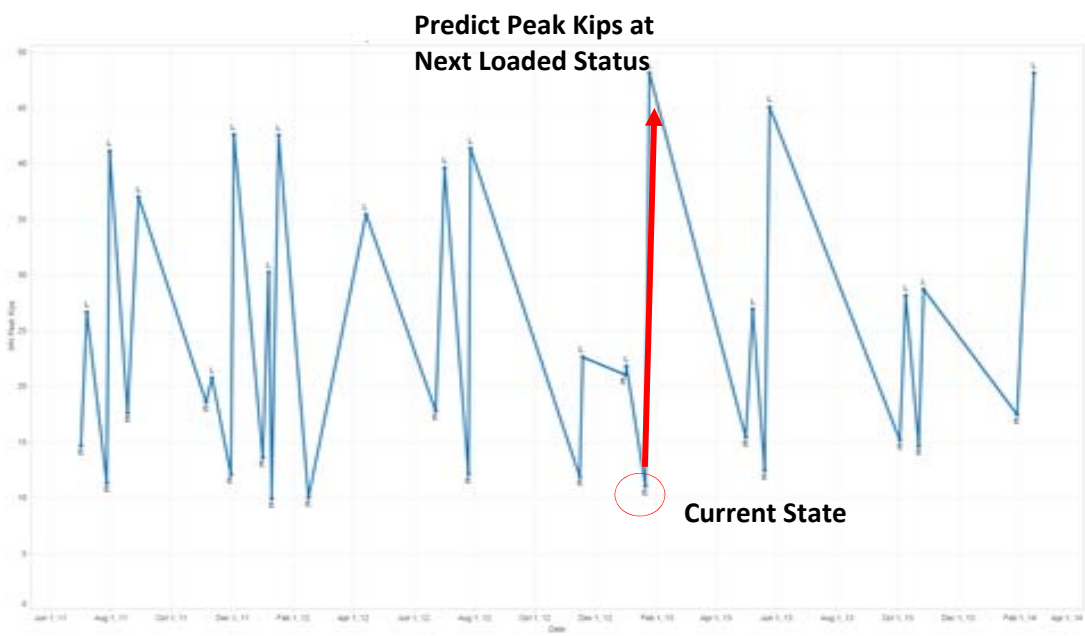


Figure 2: Peak kips of one wheel transitioning between empty and loaded status

This project aims to predict the peak kips value of an empty car at the next loaded status, which can be used as a preventative measure before a car is assigned to loads. Empirical datasets from trackside detectors will be provided for model training and testing.

There are two folds to this challenge:

(1) Predict the actual peak kips value at the next loaded status. The desired solution should be for the difference between actual and predicted kips value to be within +/- 2 kips for 90% of observations **in the test dataset**;
(2) Predict **whether any alarm** will be triggered at the next loaded status. We will consider any peak kips reading ≥ 90 as a positive event ("an alarm"). The evaluation criterion is getting true positive rate as high as possible while minimizing the false positive rate **in the test dataset**.

2.2 Factors

Factors that may have a correlation with the peak kips values can be summarized into four categories:

(1) Equipment-related. This includes (but not limited to):
- Weight of the equipment, i.e., **eqp_grs_tons** in the input dataset
- Speed of the equipment, i.e., **edr_eqp_spd** in the input dataset
- Equipment type, i.e., **aar_ct_c** in the input dataset[2]
- Wheel type, i.e., **grs_rail_wgt** in the input dataset
- Previous peak kips readings of the wheel, i.e., **whl_peak_kips** in the input dataset
- Previous average kips readings of the wheel, i.e., **whl_avg_kips** in the input dataset
- Previous dynamic kips readings of the wheel, i.e., **whl_dyn_kips** in the input dataset
- Previous dynamic ratio of the wheel, i.e., **whl_dyn_ratio** in the input dataset
- Age of the wheel, i.e., **age** in the input dataset
- Location of the wheel in the equipment, i.e., **axle_side** and **eqp_axle_nbr** in the input dataset

(2) Location-related. This includes (but not limited to):
- Location of the detectors, i.e., **vndr_edr_nme** in the input dataset

(3) Time-related. This includes (but not limited to):
- Month/year of the readings[3]

(4) Vendor-related. This includes (but not limited to):
- Vendor of the WILD detectors, i.e., **edr_vndr** in the input dataset

2.3 Assumptions

(a) To make the problem specific, assume we will aim to predict the next loaded status **within 10 days** of the previous empty status;

(b) Assume we will be only interested in predicting the loaded status with the immediate previous status being empty (i.e., E -> L);

[2] One can also parse **trn_id** in the input dataset to get train type, train symbol, etc.
[3] One can parse **vnder_edr_ts_cst** in the input dataset to get month/year information.

(c) Assume WILD detectors give accurate kips readings when speed of the equipment is greater than 20 MPH;

(d) Assume empty equipment with peak kips value ≥ 90 is not of interest.

3. Data and Example

3.1 Data description

There are two datasets provided, **kips_training.csv** for model training and **kips_testing.csv** for model testing, respectively. Participants are expected to train models using the training dataset provided and test their models on the **test** dataset.

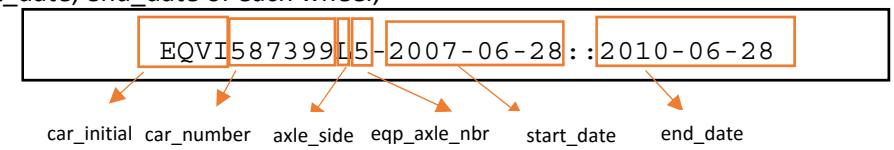
The provided input datasets display kips readings of wheels along their lifetime with some related characteristics. The format is as follows:

unq_whl_id	vndr_edr_ts_cst	vndr_edr_nme	edr_vndr	age	load_empty	whl_peak_kips	……
EQVI587399L5-2007-06-28::2010-06-28	03SEP2009:17:42:00	BAGD	SALIENT	798	L	35.89	……
EQVI587399L5-2007-06-28::2010-06-28	12SEP2009:14:51:00	COCH	SALIENT	807	E	17.21	……
EQVI587399L5-2007-06-28::2010-06-28	03OCT2009:01:34:00	PEST	SALIENT	827	L	33.54	……
EQVI587399L5-2007-06-28::2010-06-28	05OCT2009:11:55:00	COCH	SALIENT	830	L	35.17	……
……	……	……	……	……	……	……	……
EQVI587399L5-2007-06-28::2010-06-28	01JAN2010:07:44:00	COCH	SALIENT	918	E	17.64	……
EQVI587399L5-2007-06-28::2010-06-28	03JAN2010:07:26:00	PEST	SALIENT	920	E	22.75	……
EQVI587399L5-2007-06-28::2010-06-28	05JAN2010:05:33:00	PEST	SALIENT	922	L	34.60	……
……	……	……	……	……	……	……	……

Table 1: Format of the input dataset

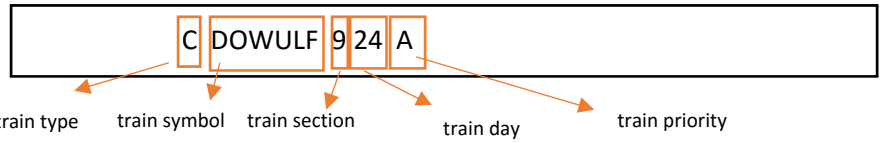
The columns in the input dataset are as follows[4]:

(1) unq_whl_id : unique identifier consisting of car_initial, car_number, axle_side, eqp_axle_nbr, start_date, end_date of each wheel;



(2) load_empty : binary variable indicates whether the equipment is loaded or empty. L = loaded, E= empty;

(3) trn_id : train identifier consisting of Train Type, Train Symbol, Train Section, Train Day, Train Priority. A unique trip consists of Train ID and Departure Date concatenated. A car may be involved in multiple trips;



(4) vnder_edr_ts_cst : timestamp of the kips readings;

(5) vndr_edr_nme : unique identifier of a WILD detector

(6) edr_vndr : vendor of the sensor, two possible values - PRT, SALIENT;

(7) age : the age of the wheel at the time of the WILD measurement (in days);

(8) axle_side : binary variable indicates the side of the equipment that the wheel is attached to. L = left, R = right ;

(9) eqp_axle_nbr : the axle number within the equipment where the wheel is at;

(10) eqp_seq_nbr : the location of the car in the train if the first car on the train = 1;

(11) whl_avg_kips : average kips value ;

(12) whl_peak_kips : peak kips readings;

(13) whl_dyn_kips : dynamic kips value;

(14) whl_dyn_ratio : calculated dynamic ratio value;

(15) edr_eqp_spd : the speed of the wheel at the time of the WILD measurement;

(16) eqp_grs_tons : the tonnage of the equipment that the wheel is a part of at the time of the WILD measurement (1 ton = 2000 pounds);

(17) tare : weight of the car when empty (in tons);

(18) aar_ct_c : AAR unique designation of car type;

(19) eqp_grp : grouping of different cars by car type ;

(20) grs_rail_wgt: wheel type. The type of the wheel which represents the tonnage that the particular wheel type can sustain, along with the other wheels attached as part of the same car. A car generally has multiple wheels of the same type attached to it;

(21) Kipdays : represents the cumulative stress that a wheel is subjected to over time due to impact loads. Kip-Days start accumulating when: Peak ≥ 65 Kips OR Dynamic ≥ 30 Kips OR Ratio ≥ 3.0; -999 if conditions are not met for KipDays5;

[4] Participants will need to parse the specific columns to get more detailed information they need. For example, they can parse column of "trn_id" to get train type, if desired.

(22) rpr_why_cd: code indicating the reason given to a wheel defect at the time of the repair at the end of the lifetime of the wheel. **This variable can not be used in prediction model, however, it will provide insights of the data**.

3.2 Example

Table1 provides an example. Assume the information known is:

unq_whl_id	vndr_edr_ts_cst	vndr_edr_nme	edr_vndr	age	load_empty	whl_peak_kips	……
EQVI587399L5-2007-06-28::2010-06-28	03SEP2009:17:42:00	BAGD	SALIENT	798	L	35.89	……
EQVI587399L5-2007-06-28::2010-06-28	12SEP2009:14:51:00	COCH	SALIENT	807	E	17.21	……
EQVI587399L5-2007-06-28::2010-06-28	03OCT2009:01:34:00	PEST	SALIENT	827	L	33.54	……
EQVI587399L5-2007-06-28::2010-06-28	05OCT2009:11:55:00	COCH	SALIENT	830	L	35.17	……
……	……	……	……	……	……	……	……
EQVI587399L5-2007-06-28::2010-06-28	01JAN2010:07:44:00	COCH	SALIENT	918	E	17.64	……
EQVI587399L5-2007-06-28::2010-06-28	03JAN2010:07:26:00	PEST	SALIENT	920	E	22.75	……

Table 2: One example – information known

And we want to predict **the next loaded status** as follows:

unq_whl_id	vndr_edr_ts_cst	vndr_edr_nme	edr_vndr	age	load_empty	……	Predicted whl_peak_kips
EQVI587399L5-2007-06-28::2010-06-28	05JAN2010:05:33:00	PEST	SALIENT	922	L	……	?

Table 3: One example – case to be predicted

Comparing your prediction with **actual whl_peak_kips**, it is a **win** if:

[5] One can refer to section 5 for more informatin on Kipdays calculation.

unq_whl_id	vndr_edr_ts_cst	vndr_edr_nme	edr_vndr	age	load_empty	whl_peak_kips (actual)	Predicted whl_peak_kips
EQVI587399L5-2007-06-28::2010-06-28	05JAN2010:05:33:00	PEST	SALIENT	922	L	34.60 /no alarm	Within 2 absolute kips difference /no alarm

Table 4: One example of win criteria

Participants will need to aggregate the probability of total wins (and confusion matrix for the classification problem) on the **test** dataset to provide evidence of model performance.

4. Desired Solution Format

The solution should contain the following information:

First, prediction of actual peak kips values and the corresponding prediction accuracy within ±2 kips on the **test** dataset. Participants should provide the probability of how many observations have predictions of peak kips value within ±2 kips of the actual peak kips values;

Second, prediction of positive event (peak kips >=90) and the corresponding confusion matrix on the **test** dataset. Moreover, participants should also provide the average number and accuracy of daily alerts sent for the **test** dataset.

Participants should provide a complete report covering data cleaning methods, prediction model used, and prediction results (e.g., accuracy) as well as the source codes.

5. Background Information

5.1 WILD Detector

WILD (Wheel Impact Load Detector) is the widely used device to monitor vertical wheel forces and detecting defective wheels. The basic component of a WILD system is the track mounted sensor array (Figure 2). There are two basic types of sensors, the original sensors are based on strain gauges and measure force and the new type is based on accelerometers and measures rail motion. The sensors are installed at strategic places along the track to monitor passing trains to investigate specific safety related symptoms. If a wheel passing by has flat spots, it will create much higher impact loades than non-defective ones. The data gathered for each axle is automatically recorded on a database by the signal processor and the control PC. It is then transmitted to the railway control center or depot maintenance center for remote monitoring and diagnosis.

Figure 3: Wheel sensors (left circle) and the accelerometers installed on track

5.2 Kip-Day

Kip-Days represent the cumulative stress that a wheel is subjected to over time due to impact loads. It starts accumulating when Peak ≥ 65 Kips **OR** Dynamic ≥ 30 Kips **OR** Ratio ≥ 3.0. Once it is started, each day the Kip-Day value goes up by the highest Peak Kips reading up to current, subsequent peak kips readings less than the highest reading since the start have no impact on the calculation. The example of calculation is shown as follows:

DAY	PEAK WILD READ	ADD	KipDays
1	58	0	
2		0	0
3	52	0	0
4	61	0	0
5	68	68	68
6	63	68	136
7		68	204
8	66	68	272
9		68	340
10	74	74	414
11		74	488
12	71	74	562

Table 5: Example of Kip-Days calculation

Note that if the initial peak kips reading is 68 kips, then 68 will be added every day until another WILD pass higher than 68 is read. Then the new higher value will be used until another WILD pass higher than that value is read.