Condition based maintenance of trains doors

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Abstract

As part of the project DUST financed by Vinnova, we have investigated whether event data generated on trains can be used for finding evidence of wear on train doors. We have compared the event data and maintenance reports relating to doors of Regina trains. Although some interesting relations were found, the overall result is that the information in event data about wear of doors is very limited.

Contents

1 Introduction

This report studies the use of train event data to find evidences of train doors wear. Maintenance reports are used as a source of data on component wear.

1.1 On the condition based maintenance

Condition based maintenance (CBM) aims at improving maintenance using condition data on maintained components. This capability of improving maintenance arises from:

- the availability of new types of data on components to maintain, for instance from sensors detecting heat, vibrations, energy consumption etc
- the availability of data on external factors that influences the wear
- the possibility to collect, store and transfer large quantities of data
- the support to CBM by a continuous development of methods and tools for data analysis, anomaly detection, diagnosis, prognosis etc

The potential of CBM is perhaps best manifested by automated assessment of the degree of wear. The possible gain is:

- effective use of the hours of work spent by the maintenance personnel
- efficient maintenance planning
- efficient coordination of maintenance and production
- avoiding costly production stops
- avoiding components to be worn down because of absence of service
- reducing costly manual inspections
- accurate maintenance requirements and service level agreements
- and not the least, making the most out of investments, by employing an efficient maintenance

2 Approach

The work presented in this report aims at studying the possibilities of railway rolling stock CBM in one particular case. The work focuses on using *train event data* for assessing the degree of wear of vehicle doors. The stream of events from the trains may reveal situations were service is needed, but not yet discovered by other means of failure detection. The idea here is to find out if there are easily observable patterns in the event data occurring as the result of wear. Since no data is available on the wear itself we cannot say directly if wear is revealed from the stream of events. Available though are reports on failures and maintenance. Some of these reports says that components have been worn down and service is needed. Hence, as a substitution to the wear status on its own, a possibility would be to use the maintenance reports. This report concerns comparison of event data with maintenance reports for finding evidences in the event data of that components have been worn down.

The initial step in the investigation was to visualize event data and maintenance reports, to get an understanding of the characteristics of them and what kind of relations we might expect to find. The next step would have been to automate the search for the appropriate relations, and model them statistically for use for prediction. Unfortunately the relations found were very weak and the causal directions ambiguous. Therefore the second step was not considered meaningful. Instead we report the various kinds of relations found by visualization.

2.1 The data used

The analyzed data is taken from 108 cars of Regina trains running in Mälardalen in Sweden between 2003-10-01 and 2004-04-19. Event messages are generated by several systems on the Regina trains. 113 of the message types relate to the doors, and these were selected for analysis. During the same period there were a number of maintenance reports of corrective maintenance on the trains. Again, all maintenance reports related to problems with the doors were selected.

2.2 Events and maintenance graphs

In the following we will use some graphs showing the occurrence over time of automatically generated *events* from trains and manual *maintenance reports*. Each such graph concerns one car. Figure 1 is an example of such a graph. Let us call these graphs event and maintenance graphs. The graph shows the events as short lines and the maintenance reports as longer lines. The maintenance reports are of three kinds

- an occurrence of a fault is reported (green)
- the need to replace a component is reported (red)
- completion of maintenance of a reported fault (blue)

Let us use *fault occurrence report*, *component fault report* and and *maintenance completion report* to refer to these three types of maintenance reports. In the maintenance graphs the colours green, red and blue, respectively, is used for the three kinds of maintenance reports. As will be seen from the diagrams in

Figure 1: An event and maintenance graph showing a lot of events taking place before maintenance

the continuation of this report, the train need not stand still or be taken out of service from that a fault is reported until maintenance is completed. The events are of two kinds: errors and non-errors. In the figures they are displayed in green and blue, respectively. In the context of this report, though, we need not distinguish between them. An example of an event classified as a non-error is the emergency opening of a door. An example of a event classified as an error is that it takes long time to close a door.

3 Examples

This section shows examples of the approach described above, which is to use train event data and maintenance reports to find if the event data shows evidence of wear.

3.1 After the service the events were fewer

Let us take another look at figure 1. The figure contains one fault occurrence report preceding two maintenance completion reports. Possibly one fault occurrence report is missing. We see that the events are quite evenly spread in the figure, but occurs a bit more frequent in following two intervals:

- in between the fault occurrence report and the first completion report.
- in a narrow time interval before the second completion report

The second one of these two intervals may have with events generated at the maintenance to do. The narrow time interval before the second completion report have both many and many kinds of occurring events. The first interval hints that there may be a connection between occurring events and a fault. There is also a slight increase in the number of occurring events before the fault occurrence report. This says that there may be a chance to find an evidence, in terms of an increased number of events, of a fault before it is reported. If an increase in the number of generated events is caused by a fault, then it is not strange that there occurs a lot of events between the fault occurrence report and the first completion report.

3.2 After the service there were more events

The figure 1 just discussed gave a vague support to use maintenance reports to for showing that there is an increase in the number of events preceding a fault. But the opposite is shown by the event and maintenance graphs for a lot of other cars. Take, for instance, a look at the figures 2 and 3. The graph in figure 2 gives an example of that the event frequency is lower before the replacement needed report than after. The graph in figure 3 gives an example of that the event frequency is lower before the fault completion report than after. In this graph of figure 3 it really looks as if the events start to turn up as a result of the service, not once but twice.

It is of course a known phenomenon that maintenance in itself may introduce new faults. It may also be the case that new components need to "wear in" for a while before working smoothly. Nevertheless, it makes it makes it more complicated if we hope to use the frequencies of events as an indication of long term wear.

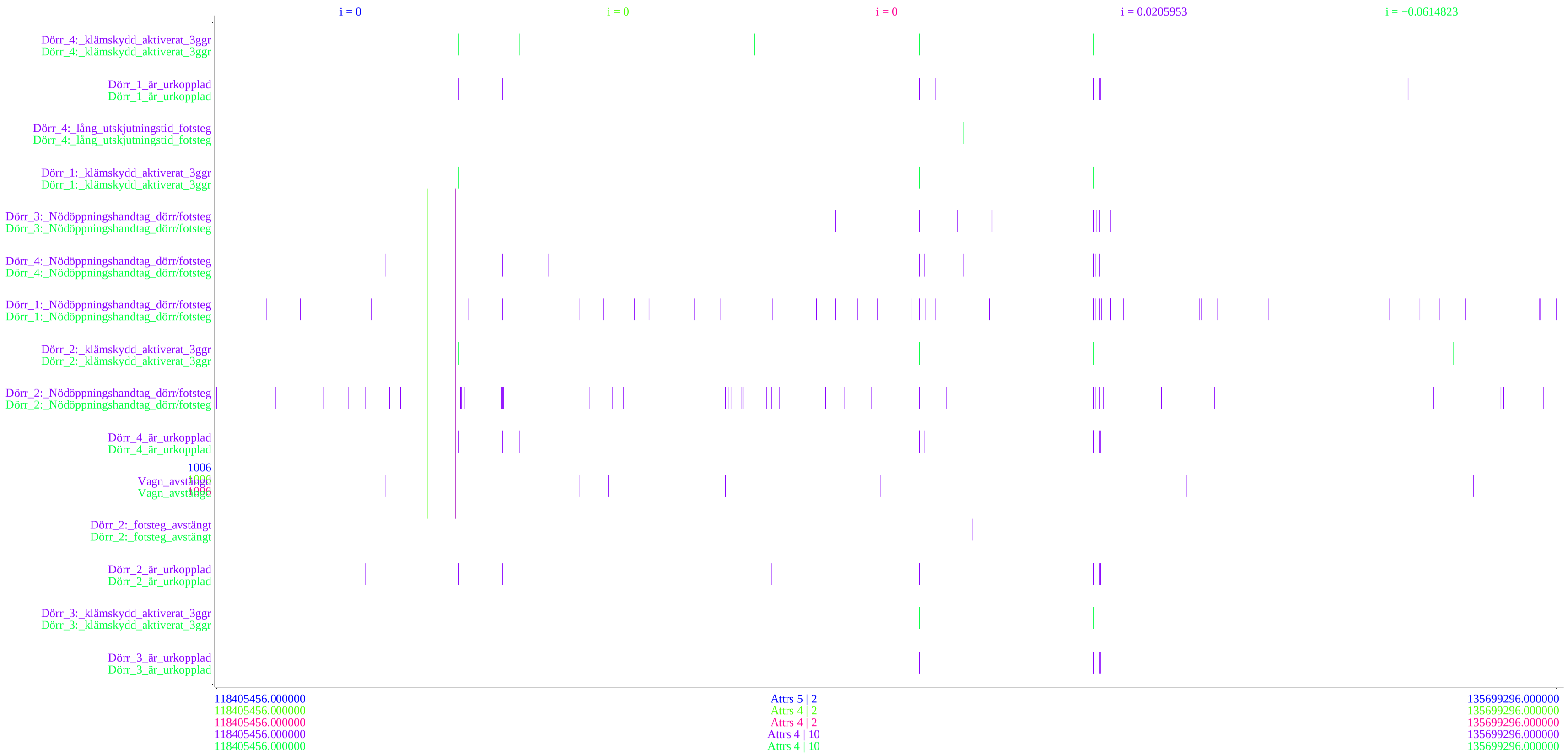

Figure 2: An event and maintenance graph for train 1006

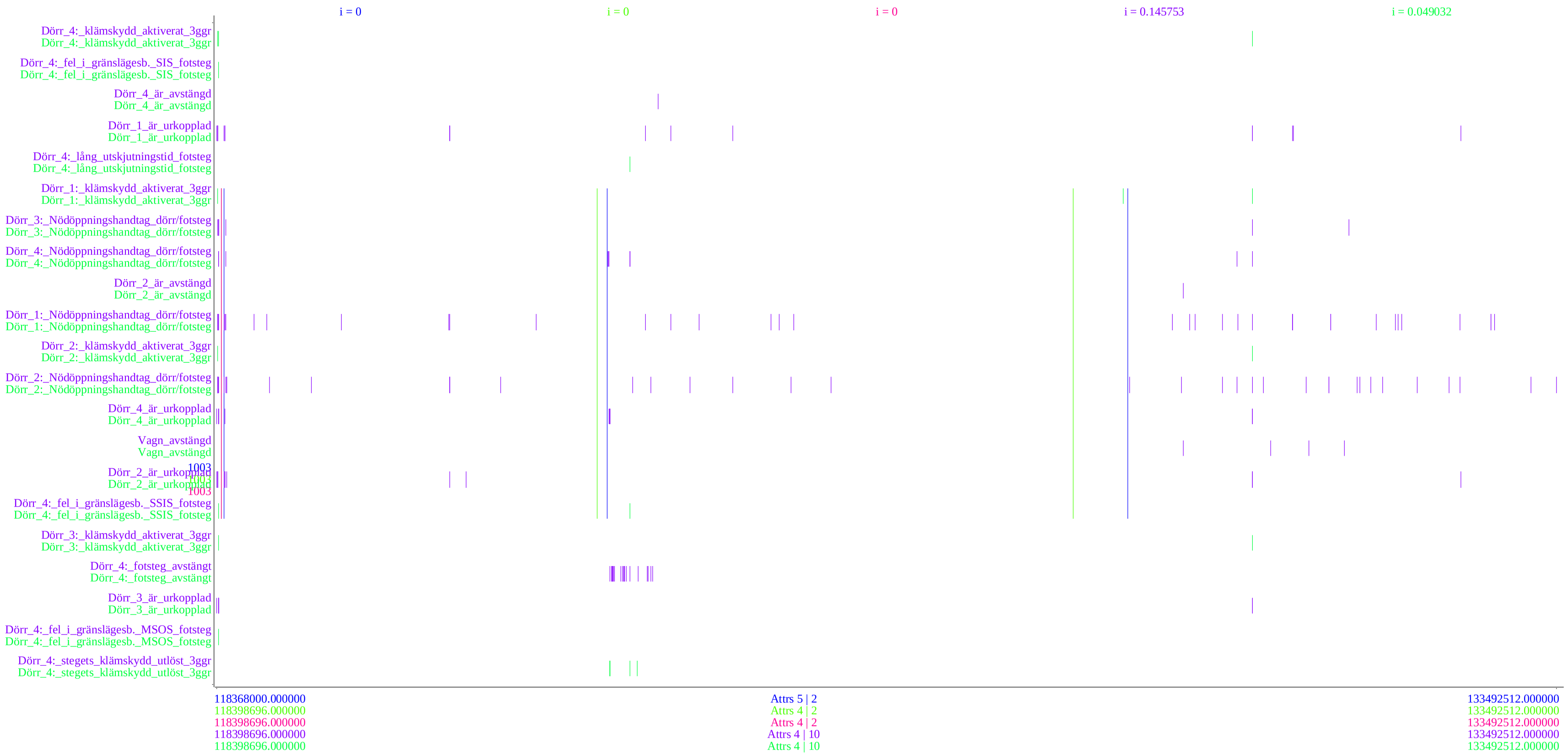

Figure 3: An event and maintenance graph for train 1003

Figure 4: An event and maintenance graph for train 1007

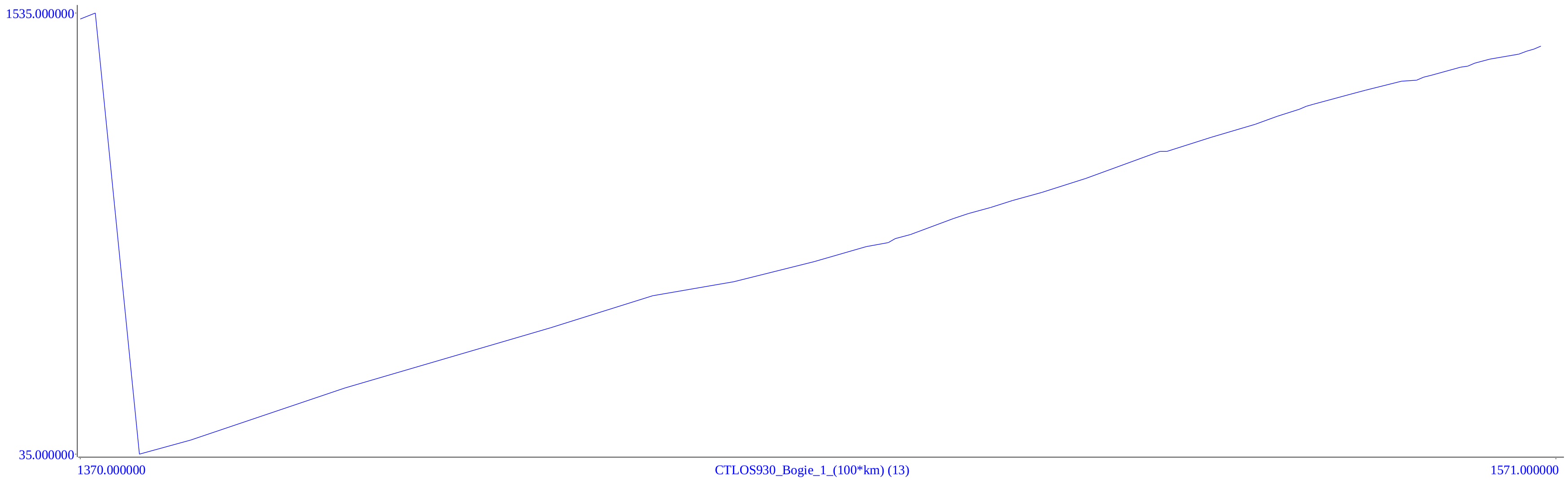

Figure 5: Time-distance graph of a train (1007)

3.3 The doors 1 and 2 more often encounters emergency openings than the doors 3 and 4

One more look at figure 1 reveals that the events with most occurrences are "emergency opening of door 2", "emergency opening of door 1" and "door 2 is off-line". The door 1 is not often off-line and there are few events at all concerning door 3 and door 4. That the doors 1 and 2 more often encounters emergency openings than the doors 3 and 4 is true for most of the cars. The figures 2,3 and 4 shows the same thing. One explanation though may be that service personnel uses emergency opening to enter and leave the train, and doors 1 and 2 are located closest to the driver's compartment.

3.4 Some events comes in periods

Let us now look at figure 6. The figure shows no maintenance reports. The events on the other hand shows a repeated periodical pattern. In six narrow time intervals in the figure there are more events and for a lot of types of events. It is likely that these events are generated by the periodical maintenance, perhaps as a result of some test.

3.5 Sometimes service takes place although no event occurred

Let us now look at figure 2 in which replacement needed report occurs some time after a fault occurrence report. We notice that the event frequency in fact is lower before the replacement needed report than after. In fact there are no events at all in a time interval ending with the replacement needed report and starting before the fault occurrence report. Hence, just as in figures 2 and 3, there is again no support to the claim that faults are preceded with an increased frequency of events. We cannot reject such an hypothesis either since, as mentioned in the introduction, we do not know how well the maintenance reports reflects the degree of wear, where the wear is assumed to give rise to a fault.

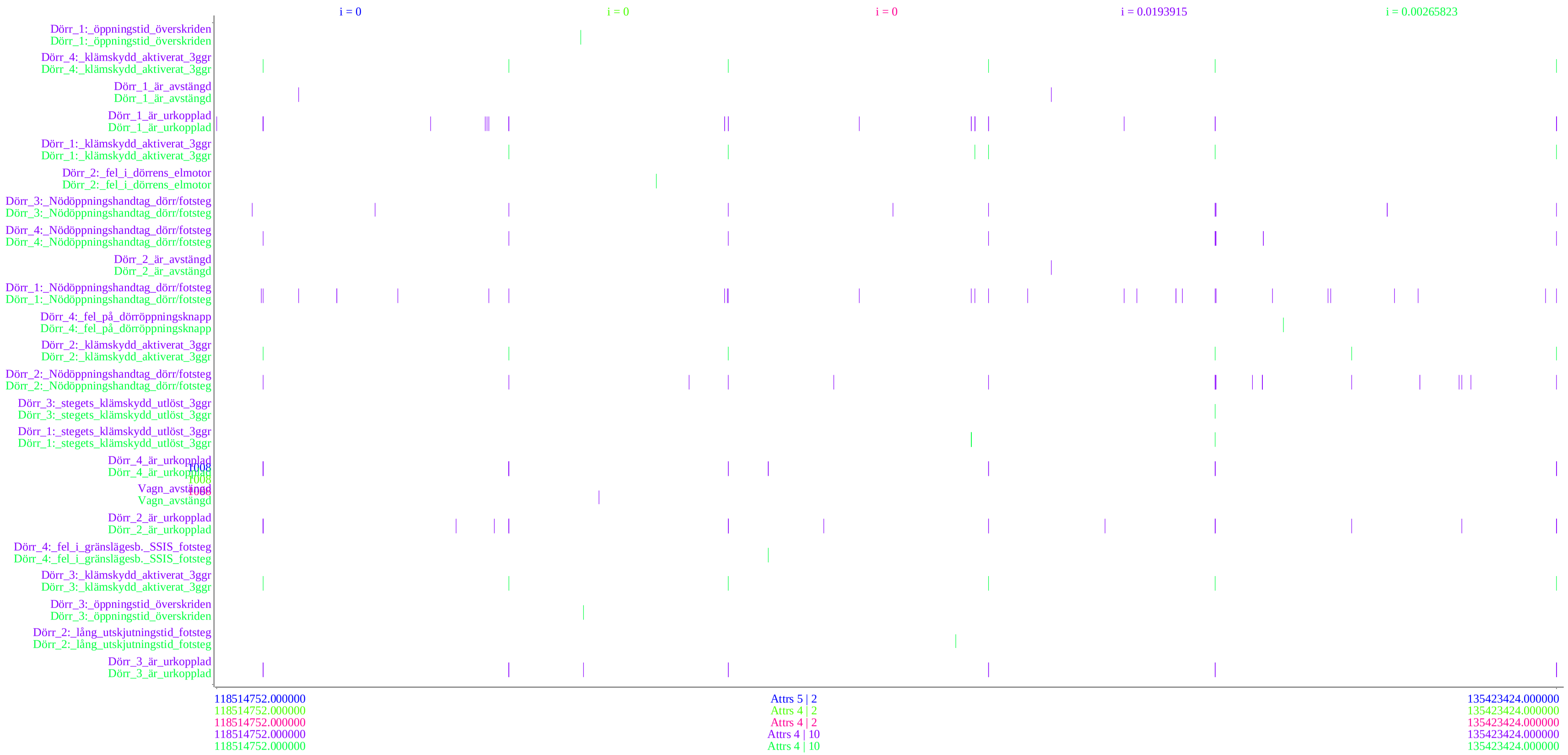

Figure 6: An event and maintenance graph showing events that are periodically repeated

3.6 Sometimes there are outbursts of events without service in response

Figure 2 also show us another thing. There are a pair of narrow intervals in which a lot of events occur. There are no maintenance report at all concerning those two intervals. Such outbursts of events without any related maintenance reports undermines the idea that the number of events is related to a service demand. Alternatively there are some external information not available to us that can explain such bursts.

3.7 There are no events when the train stands still

In figure 2 we observe to two distinct periods in the latter part of the event and maintenance graph without any events. In figure 7 a time distance graph is shown for the same period and car as that of figure 2. By comparing the two figures we see that the periods empty of events in figure 2 match periods in 7 with no increase in distance. That is, the car did not move at all during these to periods and must have been taken out of service. Such periods are detectable and hence possible to ignore if we aim at using the frequency of events as an evidence that a fault may soon arise.

3.8 Events may not occur even though the train is running

In the previous sections we saw examples of that there were periods which were empty of events, as a consequence of that the train was out of service. The reverse implication is not always the case. Just because a longer event free period shows up it isn't sure that the train is taken out of service. The graph in Figure 3 contains an anomalously long period completely absent of events. Figure 8 shows that the same car is running all the time during this period.

3.9 Don't blame the doors

Figure 9 shows a graph with time on the x-axis and, on the y-axis, both the number of door openings, for all four doors, and the distance the train has run. The four last of each of the group of five numbers on the y-axis are door opening counts. The tiny figures says that the number of times the doors 1, 2, 3 and 4 have been opened are 6323, 4632, 4451 and 3430, respectively. Hence, that the doors 3 and 4 are not opened, is not the reason for the few number of events concerning these two doors. Nor is it that the doors 3 and 4 are not opened, which is the reason for long periods without events taking place.

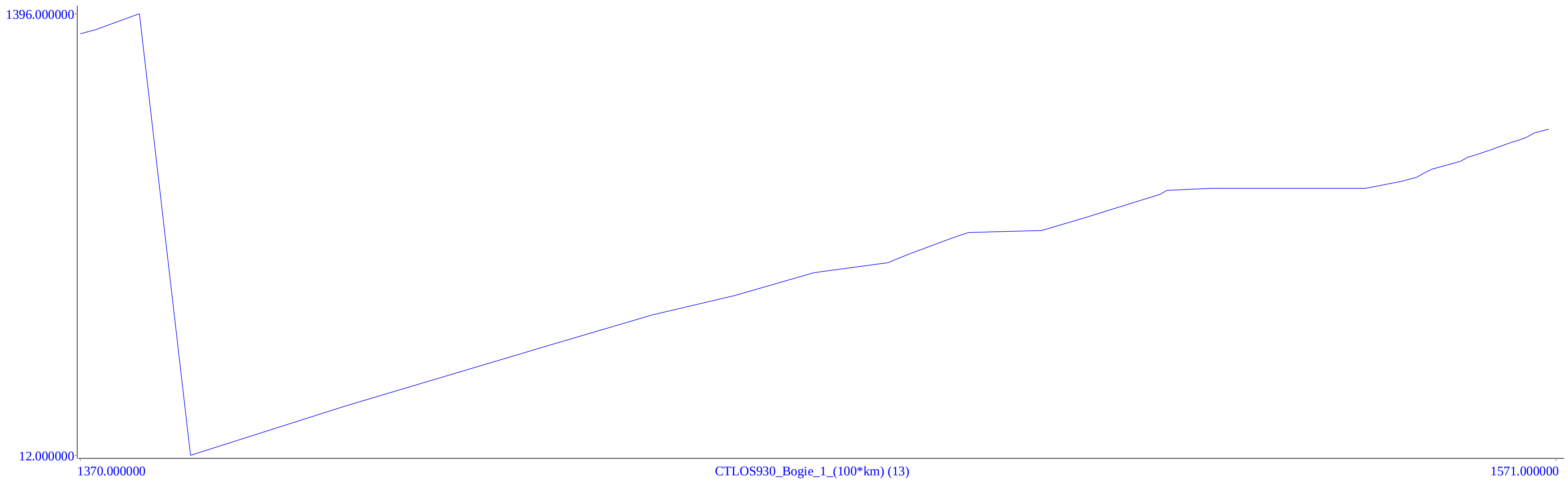

Figure 7: Time-distance graph of train 1006

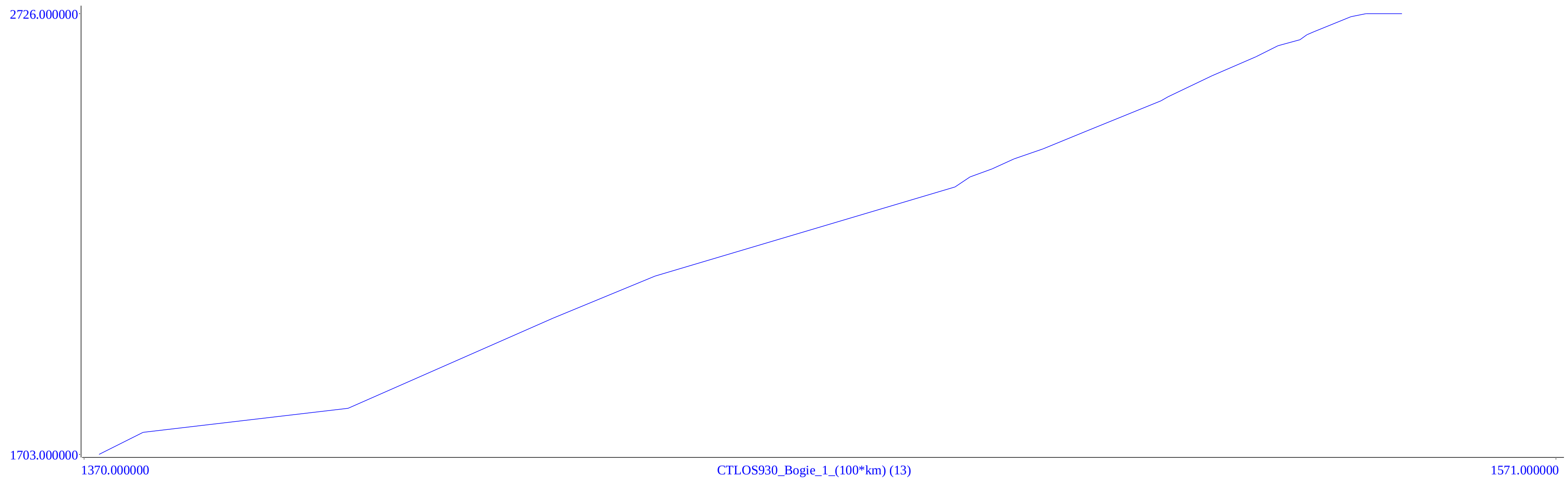

Figure 8: A time distance graph of a train 1003

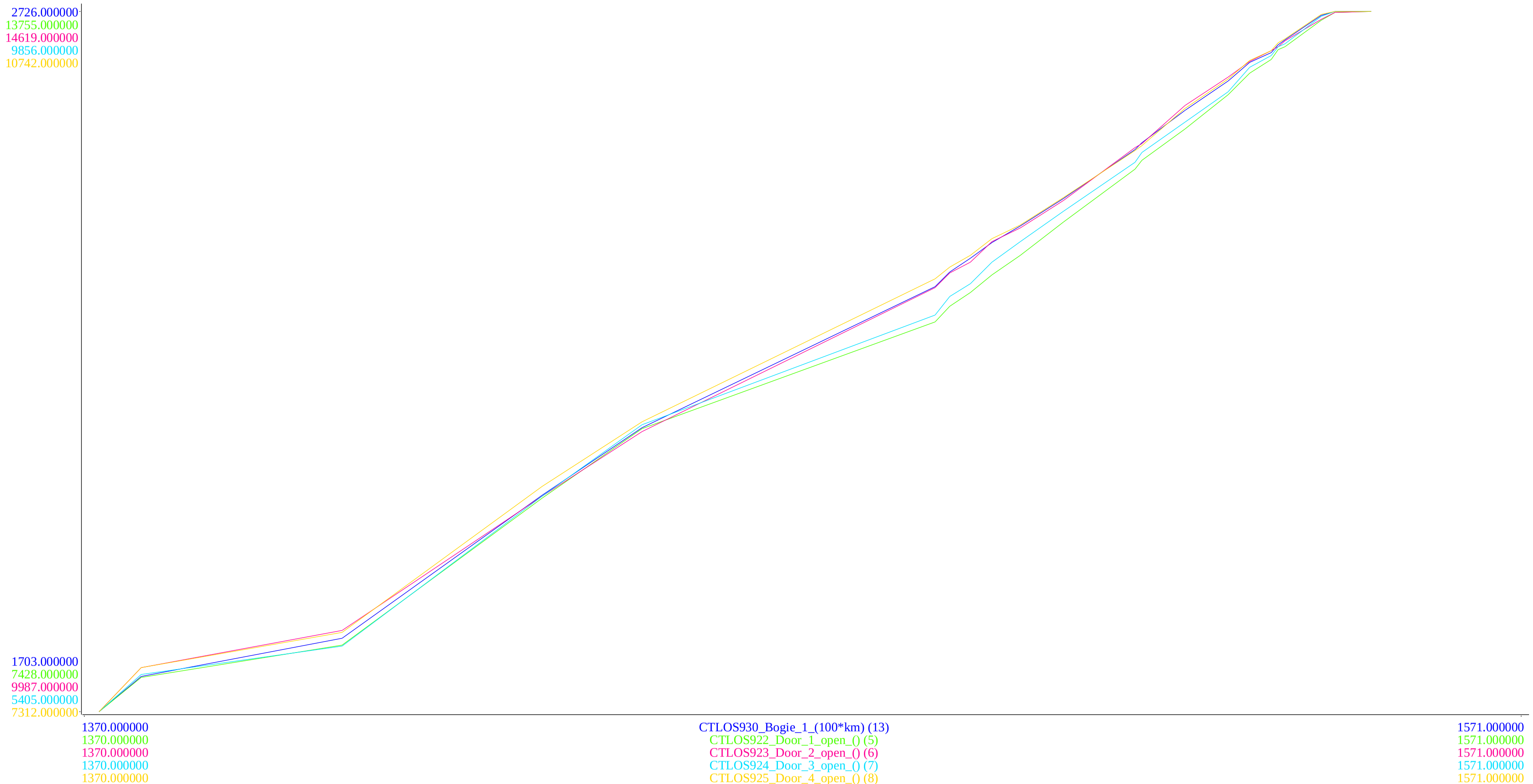

Figure 9: A graph for train 1003 with time on the x-axis and both distance and number of door openings on the y-axis

4 Conclusions

With the aim to find if there are any signs of wear in the event data generated on trains, we have made an unprejudiced examination of these event data and matching maintenance reports. The event data and maintenance reports are displayed in graphs for finding visual signs of that the event data reveals wear. In one such graph, figure 1, a vague hint indicated an evidence of what was searched for. There were fewer events after the reported completed service. However, other graphs, figures 2, 3 and 4 indicated rather the opposite. Some graphs shows distinct periodical patterns of event occurrences. Other graphs shows outbursts of events for short durations of time and yet other graphs shows periods empty of events none of which could be explained in terms of the given maintenance reports.

All in all, it is not easy to use maintenance reports as data on wear status for finding if wear may be detected in event data. One of the reasons for this, as it seems, is that the maintenance reports lacks too much information, hence leaving a lot of the irregularities in event data unexplained. By adding other sources of information perhaps a lot of these irregularities is possible to understand and possible to manage, such that event data still may be used as a source of data for constructing a new set of data that bears on wear.

Another likely explanation for the lack of a clear relation between event data and maintenance reports is that the event data contains very little information about the wear. This may be because the events are not designed for this purpose. To detect gradual wear of doors, it might be possible to use other signals more directly related to the wear, for example the precise timing of doors or door steps during opening and closing (rather than just an event to the effect that it was too slow) or the current through the electrical motors in the door system.

In summary, the event data of the design used in the Regina trains around 2004 is in itself is not sufficient for predicting or detecting wear or service demands of the door systems of the trains.