Rail4Future

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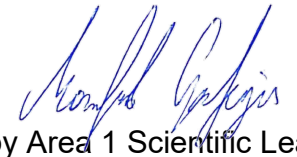

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1 Executive Summary

Evaluation in visualization research is critical as it ensures that the developed prototypes effectively communicate the intended data insights and meet the needs of the target users. Evaluation helps in assessing the prototype's usability, accuracy, and efficiency in supporting users in gaining insights into the visualized data.

We performed a qualitative user study to gain in-depth understanding of the participant's experiences, perceptions, and behaviors. We therefore interviewed five researchers that work in the fields of visual analytics, computer graphics and virtual reality. We set up semi-structured interviews, during which the participants had to work on different tasks regarding the three implemented use cases (wear and tear of tracks, bridges and switches) and we asked the participants to lead us through their thought processes and to comment on everything they notice besides the specific tasks, while setting up and performing the tasks. We report the task descriptions and continue with the documentation of each user interview.

The participants could solve the given tasks effectively, and visualizations were found to be intuitive. There were suggestions for future work, including further linking of different views.

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3 Abbreviations and Acronyms

Abkürzungen / Akronyme	Beschreibung
R4F	Rail for Future (Rail4Future)
OSM	Open Street Map

4 Problem Description

Evaluation in visualization research is critical as it ensures that the developed prototypes effectively communicate the intended data insights and meet the needs of the target users. Evaluation helps in assessing the prototype's usability, accuracy, and efficiency in supporting users in gaining insights into the visualized data.

Evaluation can serve as a catalyst for future research by uncovering limitations, gaps, and unexpected insights in the current prototype. Through a detailed assessment, researchers may identify areas where the visualization can be enhanced, such as by incorporating more sophisticated data analysis techniques or exploring new interaction methods. Additionally, evaluation might reveal unanticipated user needs or challenges, prompting further investigation into alternative approaches or the development of new visualization tools. These findings can inspire subsequent studies, leading to innovations that refine and extend the capabilities of visualization systems, ultimately contributing to the advancement of the field and its applications.

5 Impact on the Project

This report contains an evaluation of the visualization research prototype implemented for Rail4Future. Conducting an evaluation of the visualization research prototype has a significant impact by validating the effectiveness and relevance of the developed solution. This final assessment provides crucial feedback on how well the prototype meets its objectives and aligns with user needs. Moreover, the evaluation identifies any remaining issues or areas for improvement, offering insights that can guide future enhancements.

6 User Study

We performed a qualitative user study to gain in-depth understanding of the participant's experiences, perceptions, and behaviors. We therefore interviewed five researchers that work in the fields of visual analytics, computer graphics and virtual reality. We set up semi-structured interviews, during which the participants had to work on different tasks regarding the three implemented use cases (wear and tear of tracks, bridges and switches) and we asked the participants to lead us through their thought processes and to comment on everything they notice besides the specific tasks, while setting up and performing the tasks. We report the task descriptions and continue with the documentation of each user interview.

6.1 Task Description

6.1.1 Switches

Setup

- The metadata guiDefinitionSwitch.json is loaded
- The user sees a split-view of the views *Switches* and *SwitchSimulation*

Tasks

- Select switch T_R4F_23
- Use the time slider and observe how the AS value for the selected switch changes
    - What are the observations?
    - Does the tab *SwitchSimulation* provide an explanation for the observations?

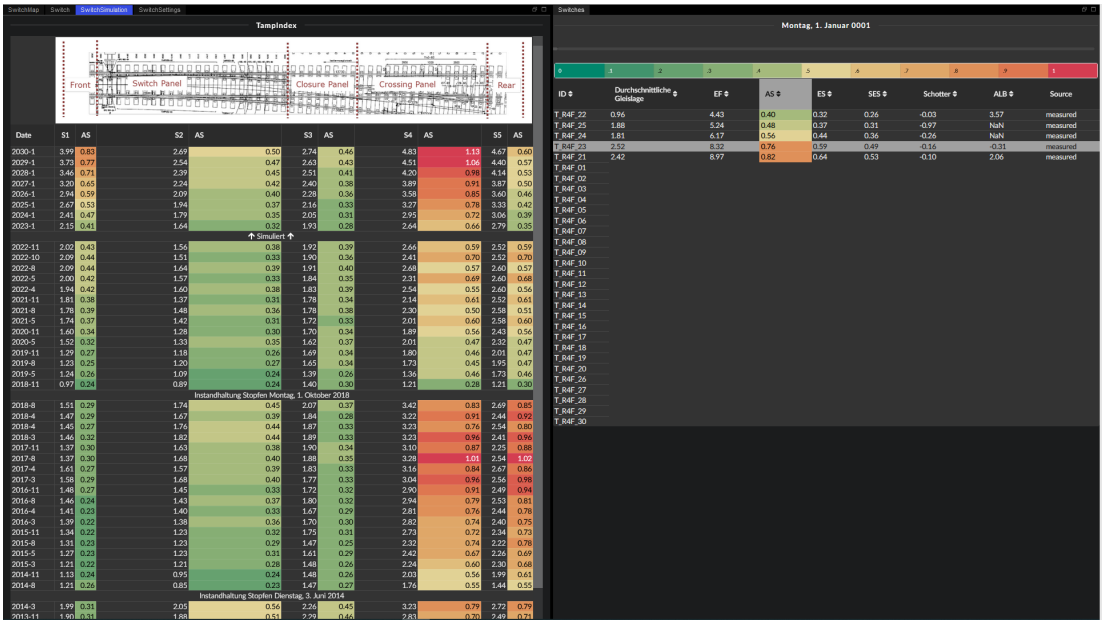

Figure 1

6.1.2 Tracks

Setup

- The metadata guiDefinitionWear.json is loaded
- The map icon for the parameter curvatureSoll in the tab *Track* is selected
- The simulation in *TrackSimulationInput* is executed for the whole track
- The user sees a split-view of the views *TrackMap* and *TrackSimulationResults*

Tasks

- Use the time slider and comment on your observations
- Do you have comments on how the tear and wear of the tracks correlate with the track positions

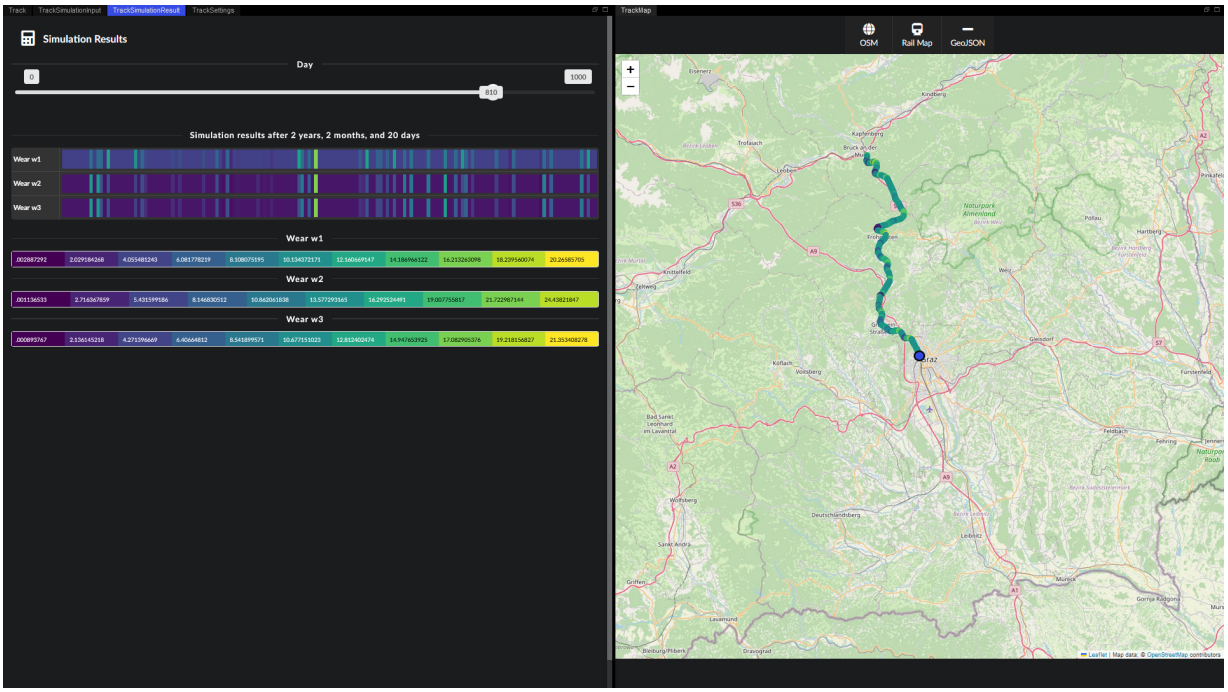

Figure 2

6.1.3 Bridges

Bridges: Task 1

Setup

- The metadata guiDefinitionBridge_Eschenau.json is loaded
- The bridge Salzachbrücke bei Eschenau is selected in the *Map* tab
- The user sees the tab *LoadScenario*

Tasks

- Create the following load model:
  - 2000 vehicles of type D_GZ1 pas the bridge during 1991-01-01 and 2001-01-01

- Start the simulation

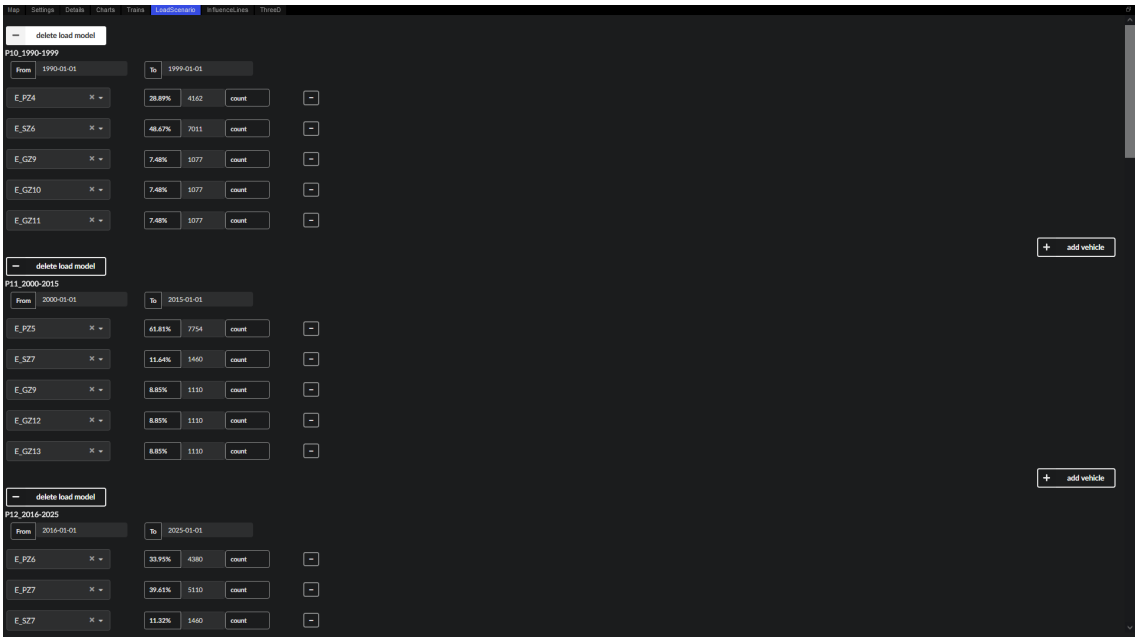

Figure 3

Bridges: Task 2

Setup

- The metadata guiDefinitionBridge_Eschenau.json is loaded
- The bridge Salzachbrücke bei Eschenau is selected in the *Map* tab
- The glyph-size in the *Settings* tab is set to 0.5
- The user sees a split-view of the views *ThreeD* and *Details*
- The simulation results within the *Details* view are loaded
- The threshold is set to 300

Tasks

- Analyze the simulation calculated_lifetimes_calibrated-validate:
  - How long is the remaining lifespan in years of the weakest detail point?
- How do the simulations vary?

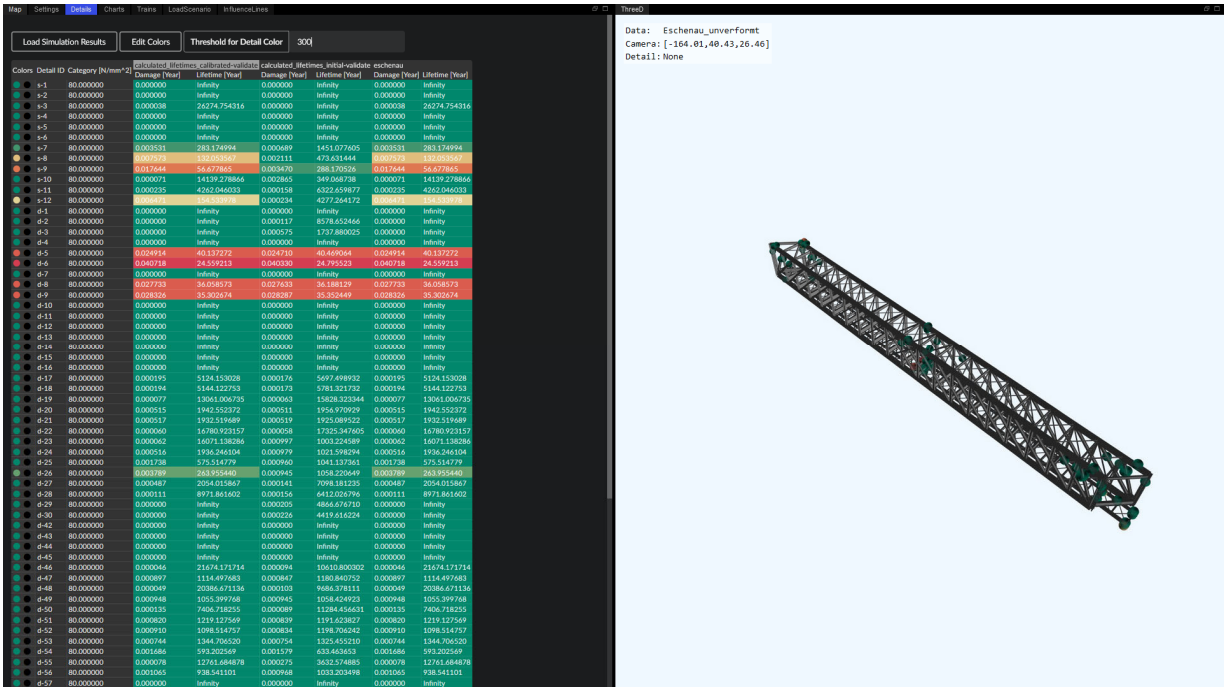

Figure 4

6.2 Interviews

6.2.1 Participant 1

6.2.1.1 Switches

AS Parameter Value Analyses: 15 minutes

The participant quickly realizes that the AS parameter fluctuates between worse and better values and concludes that maintenance work has taken place. They note that the values have remained consistently poor since 2022.

It is unclear to them, which column in the *SwitchSimulation* tab titled AS correlates to the column titled AS in the Switches tabs, as five parameters with the title AS are listed under *SwitchSimulation*. They suggest highlighting the corresponding title in the *SwitchSimulation* tab to establish the correlation and also to highlight the cell currently being viewed, as shown in Figure 5.

For users who do not have domain knowledge, highlighting the relevant value in the Switches tab would also aid with emphasizing the relevant value that is embedded within the values of the other switches, which also change while interacting with the time slider.

Finally, they note that although they noticed the line gaps in the SwitchSimulation tab, they initially confused those gap lines with headings, instead of recognizing them as data records. To counteract this, they suggest that the date of the respective maintenance measures could also be entered in the first column of the table and a separate column for maintenance measures could be added.

However, after detecting measurement information the user interface was intuitive to them and the color schemes support the participants to detect pattern across all switch sections.

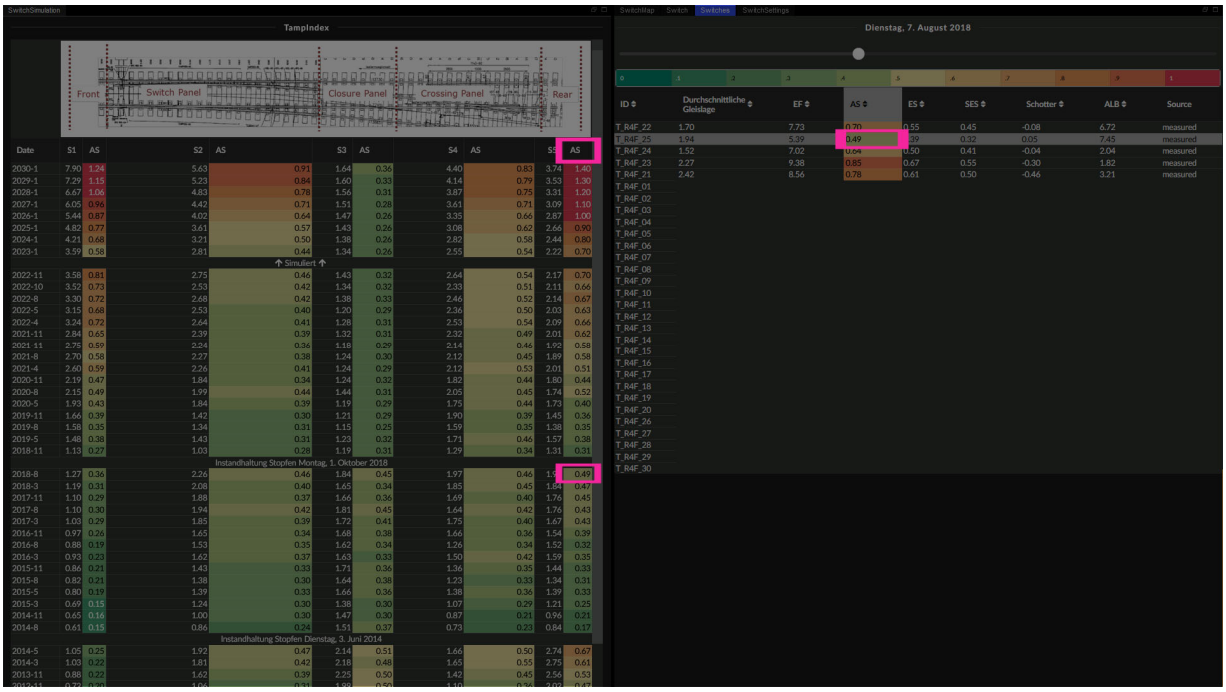

Figure 5

6.2.1.2 Tracks

Setup: 2 minutes

Here, the participant realizes that the settings window could be the start window to inform the user that data must first be loaded.

They would also like to see a visual indicator as soon as a new file name is manually entered in the settings that has not yet been loaded, to inform the user that there is a mismatch between the application state and the user input.

Observations in *TrackSimulation* View: 10 minutes

The participant notices that the legends w1, w2, w3 are not uniform, as there is one field less in the legend for w2. In addition, different values are entered for the legend lines, as shown in Figure 2. They note that this might lead to a false comparison of parameter values. Using the different color schemes helps to overcome the confusion.

The participant notices that the wear and tear increase over time and that w1 is affected the most. They notice the correlation between the wear of the individual parameters in certain track sections, which they consider to be very intuitive.

Correlations to the TrackMap: 5 minutes

Selecting the bins and the corresponding jump of the blue location point in the map view was also intuitive. The participant tries to draw conclusions as to why there is more track wear at certain points. They think the track sections with high wear are stations or other places where the train is slowed down. They find the map view very helpful for this task.

Other Observations: 5 minutes

There was a brief confusion as to whether the bins in the *TrackSimulationResults* tab represent time units or track units. This confusion was quickly resolved during the interaction with the application. They would like to see a visual linking between the position of the blue dot and the selected bin in the *TrackSimulationResults* tab, so that the correspondence between the map and the *TrackSimulationResults* tab is maintained even after selecting a bin.

They suggest coloring the blue dot according to the color value of the track section, since the blue dot overlays the track section on which it is located and the color value of the underlying track section is no longer visible (depending on the zoom level).

The participant would deactivate the interaction with the map. For them, this includes hovering over route sections and moving the location point, as these interactions do not lead to any changes in the other views. However, they would find it useful to reactivate the interactions in future work in order to be able to select track sections on the map, which are then highlighted in the *TrackSimulationResults* view.

6.2.1.3 Bridges

Create Load Scenario: 5 minutes

Deleting unnecessary load models and vehicles is intuitive. Changing the date and adjusting the vehicle type and the number of vehicles is also intuitive. The participant understands all the controls and their purpose without explanation. They suggest placing all controls on top of the page so that it is clear which interactions are available. The participant notes that the *add vehicle* button was too far away from the rest of the vehicle settings if the window is quite large. They would also find a *Delete all* button useful.

Analyses of Detail Points: 5 minutes

They quickly realize that the weakest detail point in the first simulation comes to the end of its life after about 25 years. The participant uses the threshold coloring to solve the task. The participant quickly realizes that two simulations are identical and one differs. They can determine which parts of the simulation differ more and which parts are more similar using the threshold parameter.

Other Observations: 10 minutes

The participant would like to see indicators in the *ThreeD* tab showing how the 3D model is positioned in the coordinate system. They would also appreciate a button to center the entire model again.

We implemented a keyboard shortcut to reset the camera view. In the expert settings we also added an option to show the coordinate axes with labels to determine how the 3D model is positioned in the scene.

They note that the linking between the detail point selection in the *ThreeD* and *Details* tabs is very helpful. The correlation between threshold and coloring was not entirely intuitive for the participant at first, but they then play with the threshold and find this parameter useful for estimating the remaining lifetime of the detail points.

The participant observes in the *ThreeD* view that the bridge seems to be most heavily loaded in the middle, if the threshold is set to 300.

They would like it if the values of a simulation could be sorted by remaining life span in the *Details* tab.

6.2.2 Participant 2

6.2.2.1 Switches

AS Parameter Value Analyses: 10 minutes

The participant observes that values exceed the value 1. They realize immediately that the value of the AS parameter fluctuates. They notice that the time slider goes through the entries and is not chronologically linear. The user recognizes that the image in the SwitchSimulation tab correlates to the columns below and that there are multiple columns titled AS, corresponding to the single switches sections.

The participant quickly sees the maintenance entries that explain the fluctuations in the AS parameter value. They suggest highlighting these lines more to prevent the user of confusing the gaps within the label with missing data entries. They suggest using maintenance icons.

As the fluctuations not only depend on the maintenance but also occur in between maintenance work, the participant uses the table entries to find correlations between seasons and improvements / deterioration of the switches.

Other Observations: 10 minutes

They suggest adding the simulation results to the time slider in order to see the whole simulation at once. They propose to use histograms or to colorize the slider.

6.2.2.2 Tracks

Setup: 2 minutes

During the setup of this task, the user suggests to not use the color red for the load metadata button, as this indicates an error.

Observations in *TrackSimulation* View: 5 minutes

The participant observes that contrary to the previous task the wear continuously increases. There is a peak wear in the middle of the track. They observe that the color scheme for this task is different than for the switches. We discuss the benefit of using varying color schemes to distinguish

different parameters, which aids the user to compare similar parameters by using similar color schemes whilst using different color schemes for disjoint parameters that have no semantic overlap. The participant thinks that the color scheme options are helpful. They would prefer uniform color values for parameters using the same color schemes though. They notice that the parameter w2 has one color section less than the other parameters.

Other Observations: 10 minutes

The user quickly understands that the simulation is measured in days. They suggest placing the current slider value over the slider instead of on the slider button as the value increases, which leads to an increasing size of the slider button.

They would disable the user interactions with the map, as the user interactions are not reflected in the tab *TrackSimulationResults*.

The participant has troubles using the OSM view on the map and appreciated the option to switch to the Rail Map view. They suggested to additionally offer the OSM view in grayscale to combine the advantage of having geographic details while having a distinct separation between the colored track and the background.

6.2.2.3 Bridges

Setup: 2 minutes

The participant appreciates the visual feedback of the loading icons during the setup of the use case *Bridges*, while loading the metadata.

Create Load Scenario: 2 minutes

The user managed to create the load scenario without introduction to the user interface. They mention that they would like to have a *clear all* button.

Analyses of Detail Points: 2 minutes

The participant notices that they would want to see a color legend. The weakest detail point is detected within a minute by exploring the data with the threshold parameter. After detecting the weakest point they easily find the entry in the table that declares the remaining life span of the detail point to be approximately 25 years.

The participant easily recognizes that the simulations with the titles *calculated_lifetimes_calibrated-validate* and *eschenau* are identical while the simulation *calculated_lifetimes_calibrated-initial* differs. They can easily name detail points that are similar between simulations and detail points that differ most by using the threshold parameter.

Other Observations: 5 minutes

The participant would appreciate the option to sort the detail points by life span. They explore the 3D scene and the interactions. They mention that they like the bidirectional linking of user interactions, as detail point selections in the 3D view are linked to detail point highlighting in the *Details* table and vice versa.

They would recommend highlighting selected detail points in the 3D view with a yellow circle.

They recommend to visually separate the simulations more clearly in the user interface by increasing the line thickness between the columns that separate the simulations.

6.2.3 Participant 3

6.2.3.1 Switches

AS Parameter Value Analyses: 7 minutes

The participant observes that the values for the parameter AS are fluctuating between better and worse values and that the values partially exceed 1. They are attentive to compare the value jumps with the date above the time slider. They observe that the values are getting bad at the end of the simulation.

The participant is not confused about the multiple AS parameters in the *SwitchSimulation* tab, as they focus more on finding patterns that explain the fluctuating AS values using the date information. They were aware that maintenance must be the reason for the value changes and they can confirm this in the *SwitchSimulation* tab. They compare the dates between the tabs and find the exploration helpful to understand the data.

They easily understand how the table correlates to the sections drawn in the switch image above the table.

6.2.3.2 Tracks

Setup: 2 minutes

The participant mentions during the setup of the use case that they would appreciate user feedback after activating the map icon in the *Track* tab. The visual feedback is implemented in the *Map* tab was not opened.

Observations in *TrackSimulation* View: 2 minutes

The participant sees the value fluctuations and observes that value w1 wears out faster than the other parameters. They further detect the correlation between the parameters. They see that the bins correlate with the track sections.

Correlations to the *TrackMap: 2 minutes*

During the analyses of the correlation between wear and track, the participant checks if the highest wear appears in the curves. They cannot confirm the hypothesis looking at the map and concludes, that the wear could be the highest in sections where the train changes speed, e.g. at railroad stations.

Other Observations: 5 minutes

The participant suggests disabling the interaction with the location point on the map or linking the interactions with the visualization in the *TrackSimulationResults* tab.

6.2.3.3 Bridges

Create Load Scenario: 2 minutes

The participant did intuitively set up the requested load scenario without explanation of the user interface.

Analyses of Detail Points: 3 minutes

They easily solve the task to find the weakest detail point and the corresponding value of the remaining life span. They also observe that the simulation runs *calculated_lifetimes_calibrated-validate* and *eschenau* are identical while the simulation calculated_lifetimes_calibrated-initial differs.

Other Observations: 5 minutes

They observe that the linking between the detailpoints in the *Detail* tab and *ThreeD* is not sufficient to detect without uncertainty which detail point is selected. They would appreciate an additional visual indicator besides setting the detail point in focus. Manually setting the color of the detail point aids the participant to determine the correlation between the detail points in the two views.

The participant appreciates the bidirectional linking between detail points in the *Detail* tab and *ThreeD* tab.

The participant is very impressed by the variety of implemented visualization techniques and likes the dynamic layout that gives the user the option to compose a layout specifically for a task.

6.2.4 Participant 4

6.2.4.1 Switches

AS Parameter Value Analyses: 5 minutes

The participant quickly sees the fluctuations in the AS parameter values. They concentrate on the year 2018 and they find the corresponding entry in the last column in the *SwitchSimulation* tab. They do not find the maintenance entries due to a language barrier.

6.2.4.2 Tracks

Observations in *TrackSimulation* View: 2 minutes

The participant sees that parameter w1 has the highest wear and they see the correlation between the parameter values.

Correlations to the *TrackMap: 2 minutes*

They concentrate on the curves on the track to find a correlation between wear and track position. They see that there is a noticeable behavior in the curves which does not aid to draw conclusions about increasing or decreasing wear.

Other Observations: 3 minutes

They observe that the interaction between the TrackMap and the TrackSimulation tab is one-directional. They recommend a visual feedback, which detail point is selected.

6.2.4.3 Bridges

Create Load Scenario: 2 minutes

The creation of the load scenario was intuitive and required no explanation of the user interface.

Analyses of Detail Points: 5 minutes

The participant quickly detects the remaining life span of the weakest detail point, using the threshold parameter to find the weakest detail point and the table entry to determine the life span.

They observe that the simulations *calculated_lifetimes_calibrated-validate* and *eschenau* are identical, while the simulation *calculated_lifetimes_calibrated-initial* differs and that the latter correlates in certain track areas with the other simulations.

6.2.5 Participant 5

6.2.5.1 Switches

AS Parameter Value Analyses: 3 minutes

The participant detects the value changes. After looking for an explanation in the *SwitchSimulation* tab they find the column header AS and look for correlations. They ignore the other columns with the same title. They quickly find the expected maintenance entries.

Other Observations: 5 minutes

They observe that the changing colors of the other entries in the *Switches* tab make it harder to focus on the relevant value that are visualized in the *SwitchSimulation* tab. They suggest using grayscale values for the other parameters.

They immediately see all the values above 1 in the table of the *SwitchSimulation* tab as those are noted in white color. After we give them the hint, that multiple columns with the header AS exist, they quickly realize due to the embedded image that the switch is divided in sections and that there exists a parameter AS for each section.

6.2.5.2 Tracks

Analyses of Wear Simulation: 2 minutes

The participant sees that the wear increases over time without positive jumps and they see the correlation between the parameter values.

Correlations to the *TrackMap: 5 minutes*

They first struggle to see which parameter is visualized on the map. After playing with the color schemes they realize that w1 is visualized. We explain that the visualized parameter can be set by clicking on the parameter name. They observe that the curves on the track have an unusual wear, though not necessarily a worse wear than other railroad sections. They conclude that there might be track sections like railroad stations that have a higher wear and partially confirms this hypothesis by looking on the map.

Other Observations: 5 minutes

They observe that the parameters legends use different values for the same colors if the same color scheme is selected. They appreciate the option to choose different color schemes to avoid confusions.

6.2.5.3 Bridges

Create Load Scenario: 2 minutes

The creation of the load scenario was intuitive and required no explanation of the user interface.

Analyses of Detail Points: 3 minutes

The participant quickly detects the remaining life span of the weakest detail point, using the threshold parameter to find the weakest detail point and the table entry to determine the life span. They set the threshold to 500 and then manually go through the entries with colors other than green.

They observe that the simulations *calculated_lifetimes_calibrated-validate* and *eschenau* are identical, while the simulation *calculated_lifetimes_calibrated-initial* differs and that the latter correlates in certain track areas with the other simulations.

Other Observations: 5 minutes

They would appreciate a feature to sort the detail points by life span. They appreciate the option to create task specific layouts.

7 Conclusion and Future Work

The user study shows that the users have various tools to explore the underlying data, which aids them to formulate hypotheses that they can further investigate. The participants were all eager to experiment with the user interface and to go through all the tabs and to try out different layouts.

7.1 Switches

7.1.1 Conclusion

The parameter value changes during the simulation were detected fast.

Visual linking between the parameter value in the *Switches* tab and the *SwitchSimulation* tab would be helpful to most of the participants to look for specific numbers in the table. The application generalizes to varying data specifications, therefore the information about the correlations between the selected parameter and the corresponding parameter entry in the *SwitchSimulation* table would have to be included in the underlying data.

All the participants were able to draw the conclusion that the parameter changes correlate with the wear over time and maintenance work.

7.1.2 Future Work

Some participants mentioned that they would like to have a visual indicator that emphasizes the relevant value belonging to the selected switch in the *Switches* tab. Suggestions are to use a selection box for the cell of interest or to use grayscale values for the other values.

Furthermore, some participants mentioned that it would be helpful to emphasize the maintenance entries more, e.g. by adding an icon or by integrating it more in the cell structure of the table.

One participant suggests adding the simulation results to the time slider in order to see the whole simulation at once. They propose to use histograms or to colorize the slider.

7.2 Tracks

7.2.1 Conclusion

All participants observed that the values are getting consistently worse over time. Two participants mentioned that the parameter values have correlating patterns and state that the user interface supports them in seeing these correlations. Two participants mention that they see a wear peak in the middle of the track.

All participants experiment with the color schemes to explore how this changes the user experience. It helps them to view the parameters as disjoint parameters and to avoid comparing the values.

Four participants use the Map view to hypothesize about the correlation between wear and track position. The split view between the Map tab and the TrackSimulation tab aids them to find interesting railroad sections. All participants conclude that there might be a correlation between track sections in which the train has to slow down and the increased wear.

7.2.2 Future Work

Two participants mention that they would appreciate a uniform color scheme for similar parameters to aid the user with the comparison of similar values.

All participants mentioned that they would appreciate a link between the map interaction and the *TrackSimulation* tab to select a bin in the *TrackSimulation* from the map.

One participant suggests changing the color of the blue dot according to the color value of the track section, since the blue dot overlays the track section on which it is located, and the color value of the underlying track section is no longer visible (depending on the zoom level).

One participant suggests adding an OSM map that offers a bigger contrast between the track colors and the map, e.g. using a grayscale map or a lower opacity for the map.

7.3 Bridges

7.3.1 Conclusion

The *LoadScenario* tab is very intuitive for users to navigate. Besides the task description they were not presented with an explanation of the user interface and were able to solve the task of creating a new load model.

All participants quickly solve the task of finding the weakest detail point and the corresponding value of the remaining life span. All participants use the threshold to filter the detail points to find the weakest detail point. All participants successfully compare the simulations and figure out that two simulations are identical whilst the third simulation differs and all can determine which sections of the bridge are similar and which are dissimilar.

7.3.2 Future Work

One participant suggested placing all controls in the *LoadScenario* tab on top of the page so that it is clearer which interactions are available. The participant also notes that the *add vehicle* button was further away from the rest of the vehicle settings if the window is quite large.

Four participants mentioned that they would appreciate a *Delete all* button in the *LoadScenario* tab.

Three participants mentioned that they would find it useful to have a feature to sort the detail points according to their remaining life span.

Two participants would appreciate an additional visual indicator for selected detail points in *ThreeD* tab, e.g. a yellow circle around the selected detail point.