The Impact of Visualizing Uncertainty on Train Trip Selection
Annex

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Part I
Study Data and Visualizations

1 Description of the Train Trips

Attribute	TO1	TO2	TO3
Departure	$\approx$	b $\prec$ a	a $\prec_S$ b
Arrival	a $\prec_S$ b, b $\prec_D$ a	b $\prec$ a	b $\prec_S$ a, a $\prec_D$ b
Travel duration	a $\prec_S$ b, b $\prec_D$ a	b $\prec$ a	a $\prec_S$ b, $\approx_D$
Transfers	no transfers	2 in a and b, longer in a	1 in b
Delays	a's delay meets deadline (C2)	never critical	critical transfer
Alternatives	none	none	1 for b's transfer

Table 1: Attribute-wise comparison of the two train trips TO1–TO5 per decision situation. (a denotes the first, b the second trip; $\approx$ similar for a and b; shorter/earlier with a: a $\prec$ b; according to schedule: $_S$; according to (maximum) expected delays: $_D$)

Attribute	TO4	TO5
Departure	a $\prec$ b	$\approx$
Arrival	$\approx$	a $\prec_S$ b, b $\prec_D$ a
Travel duration	b $\prec$ a	$\approx_S$, b $\prec_D$ a
Transfers	2 in b	1 in a and b
Delays	never critical	critical transfers
Alternatives	none	1 for each transfer

Table 2: Attribute-wise comparison of the two train trips TO1–TO5 per decision situation. (a denotes the first, b the second trip; $\approx$ similar for a and b; shorter/earlier with a: a $\prec$ b; according to schedule: $_S$; according to (maximum) expected delays: $_D$)

TO1 *Direct influence of train delay on the arrival time:* Both train trips depart at the same time and have no transfers. The travel duration with the first connection is shorter according to the schedule while the travel time with the second connection is shorter according to the (maximum) expected delays.

TO2 *Influence of delay on transfer time:* Departure and arrival times of the two trips are similar whereas the travel duration with the second trip is slightly shorter. Each trip has two transfers. The transfer durations of the first connection are longer according to the schedule but shorter according to the expected delays at the transfer stations.

TO3 *Influence of a critical delay on arrival time via potential miss of a connecting train:* The travel duration of the first trip is longer but the trip contains no transfers. The second trip contains one transfer that is also critical, i.e., the connecting train of the second connection might be missed due to the expected delays. If the connecting train is missed, the arrival time of the second trip is before the arrival time of the first trip. If the connecting train is reached, the order of the arrival times is vice versa.

TO4 *Trade off between travel duration and transfers:* The arrival time of both trips is similar. The first trip contains no transfers but departs earlier, i.e., its travel duration is longer. The second trip contains two transfers but none of them is critical (i.e., the connecting trains will most probably will be reached).

TO5 *Influence of arrival time due to critical delay:* Each of the trips contains one transfer of equal duration. The connecting trains in both trips might be missed due to the delay of the preceding trains. The arrival time of the first connection is earlier if the connecting train is reached and later otherwise.

2 Visulizations of the Train Trips

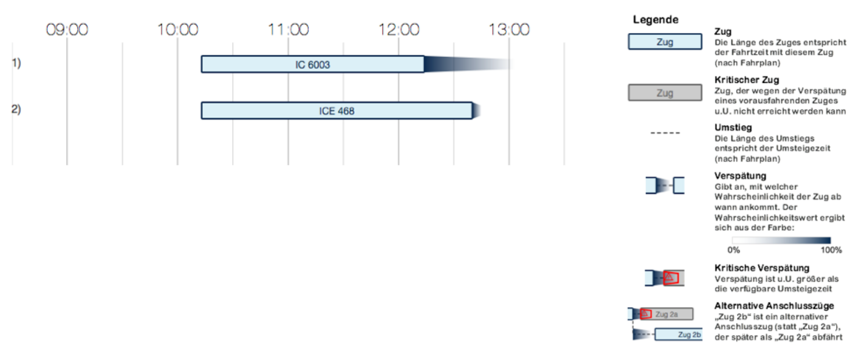


Figure 1: Train Trips TO1 displayed with design D_{cum}

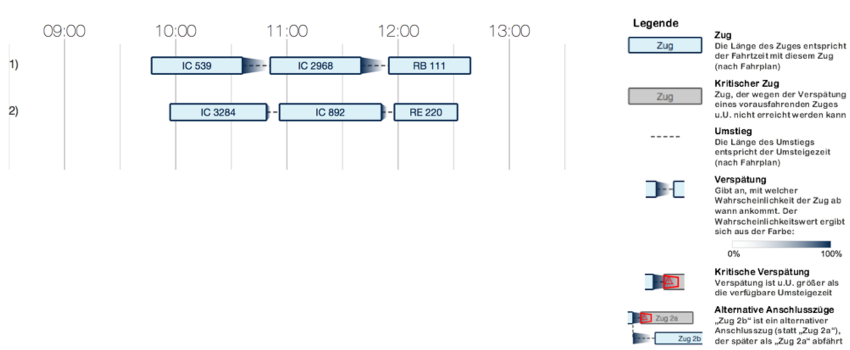


Figure 2: Train Trips TO2 displayed with design D_{cum}

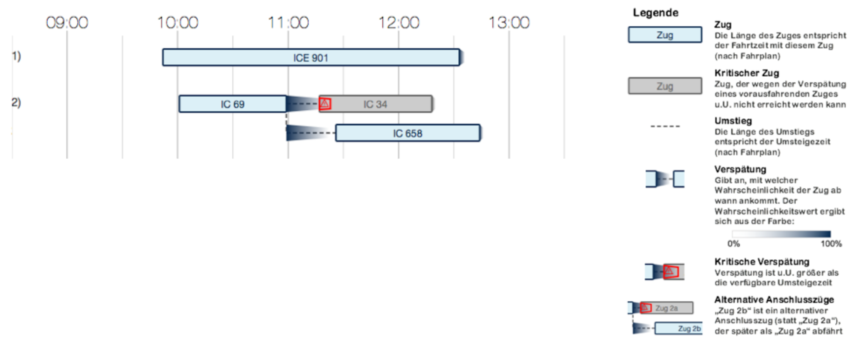


Figure 3: Train Trips TO3 displayed with design D_{cum}

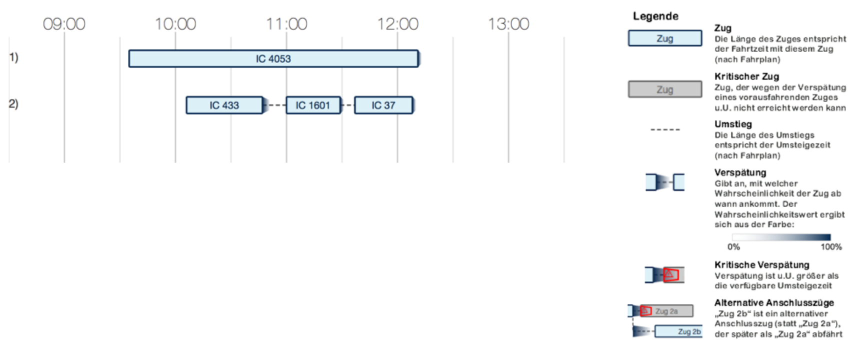


Figure 4: Train Trips TO4 displayed with design D_{cum}

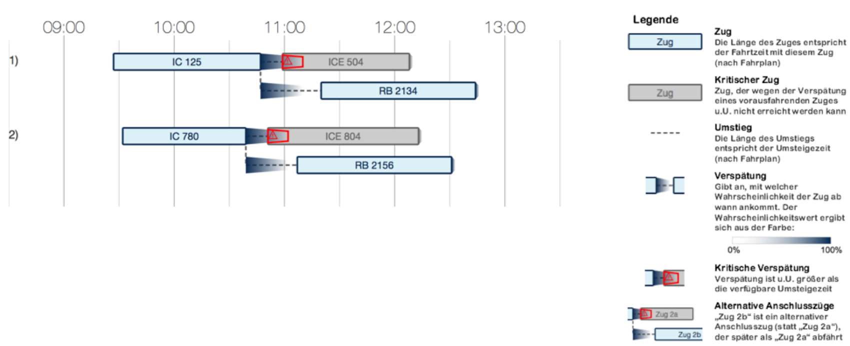


Figure 5: Train Trips TO5 displayed with design D_{cum}

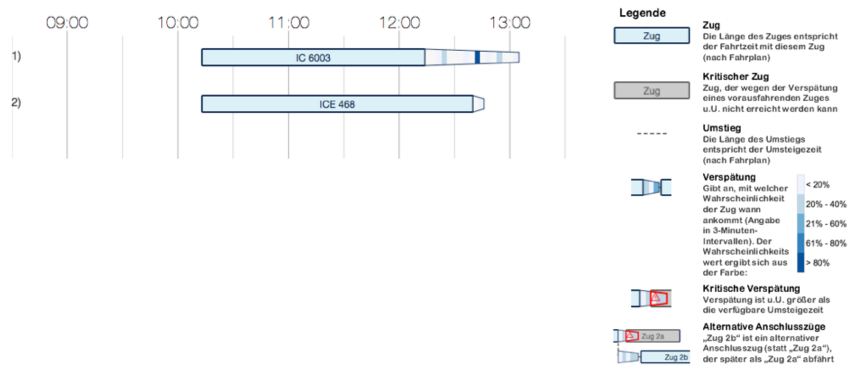


Figure 6: Train Trips TO1 displayed with design D_{noncum}

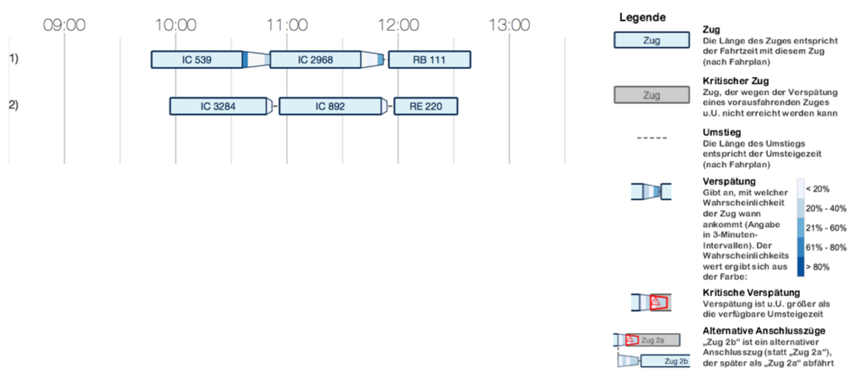


Figure 7: Train Trips TO2 displayed with design D_{noncum}

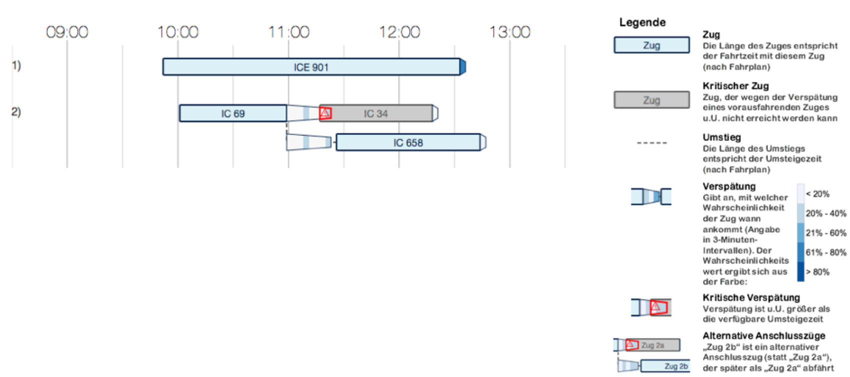


Figure 8: Train Trips TO3 displayed with design D_{noncum}

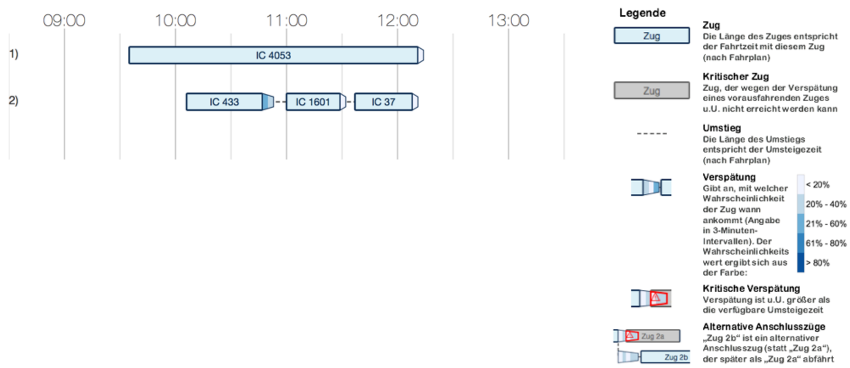


Figure 9: Train Trips TO4 displayed with design D_{noncum}

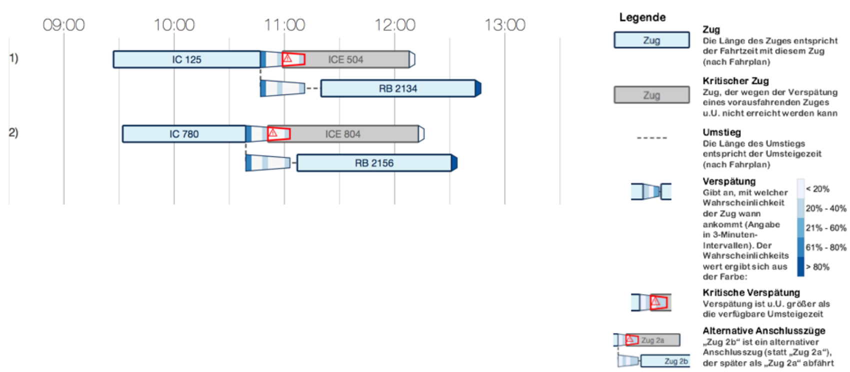


Figure 10: Train Trips TO5 displayed with design D_{noncum}

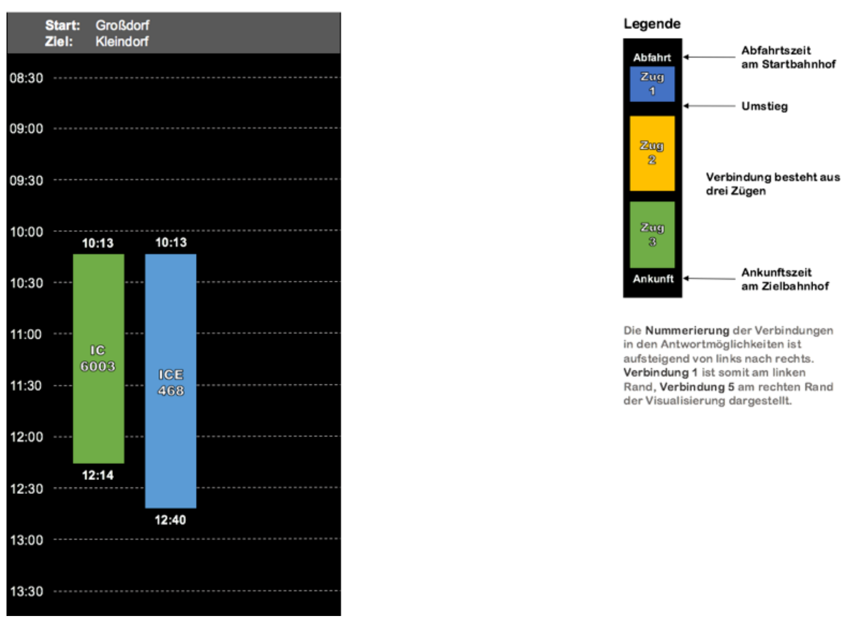


Figure 11: Train Trips TO1 displayed with design D_{vis}

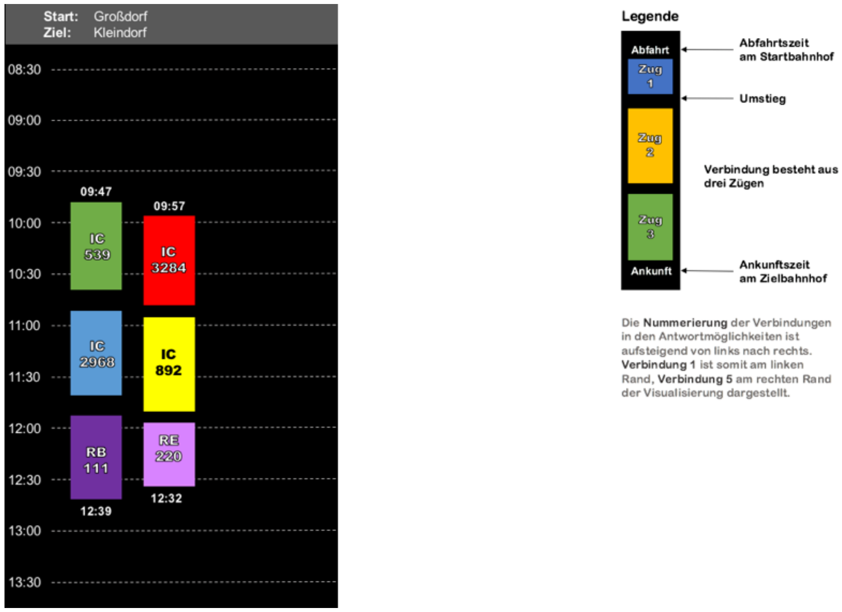


Figure 12: Train Trips TO2 displayed with design D_{vis}

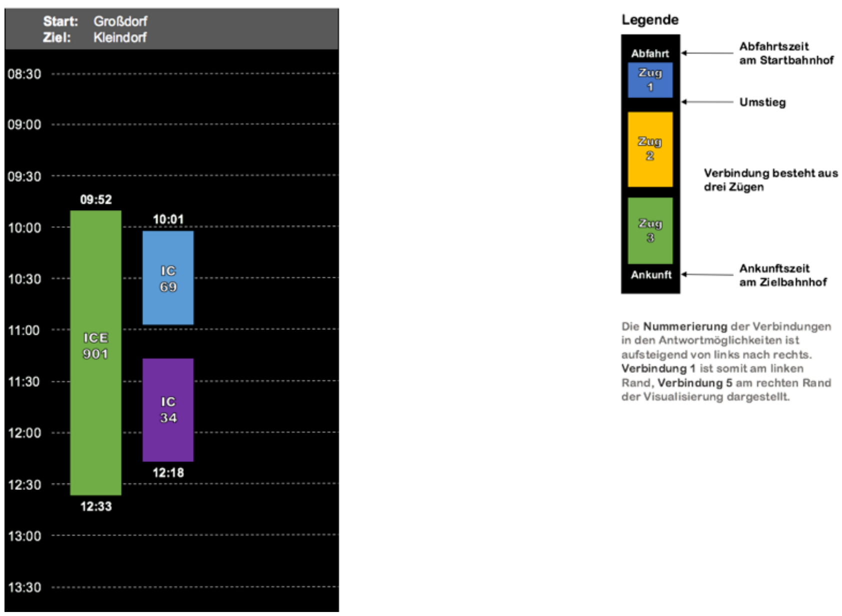


Figure 13: Train Trips TO3 displayed with design D_{vis}

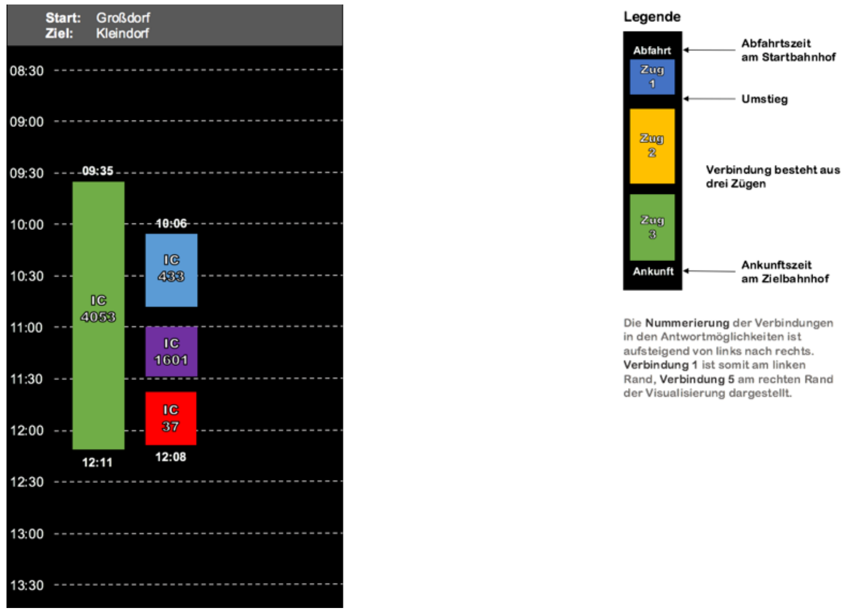


Figure 14: Train Trips TO4 displayed with design D_{vis}

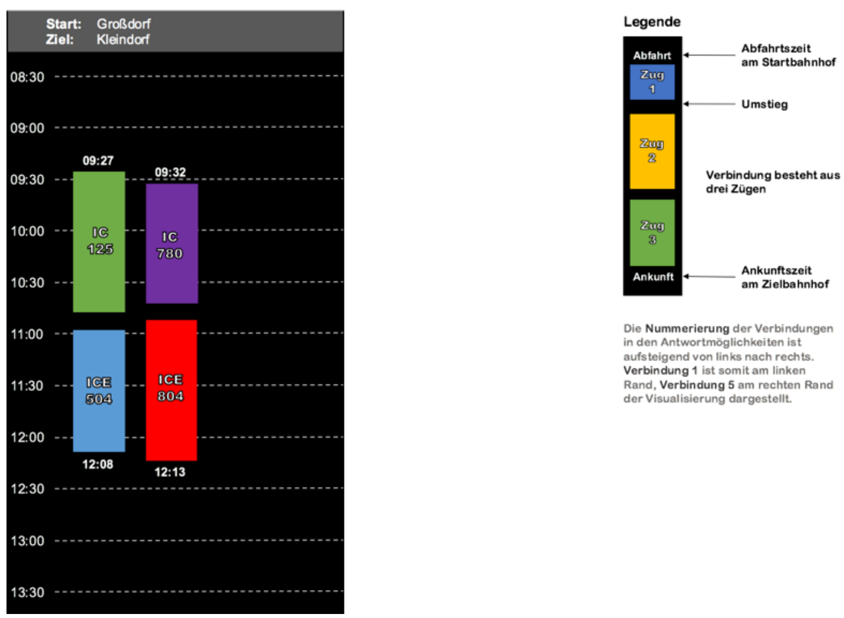


Figure 15: Train Trips TO5 displayed with design D_{vis}

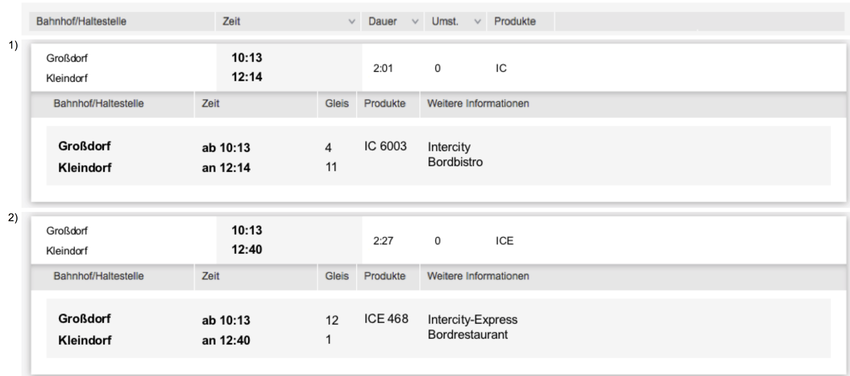


Figure 16: Train Trips TO1 displayed with design D_{text}

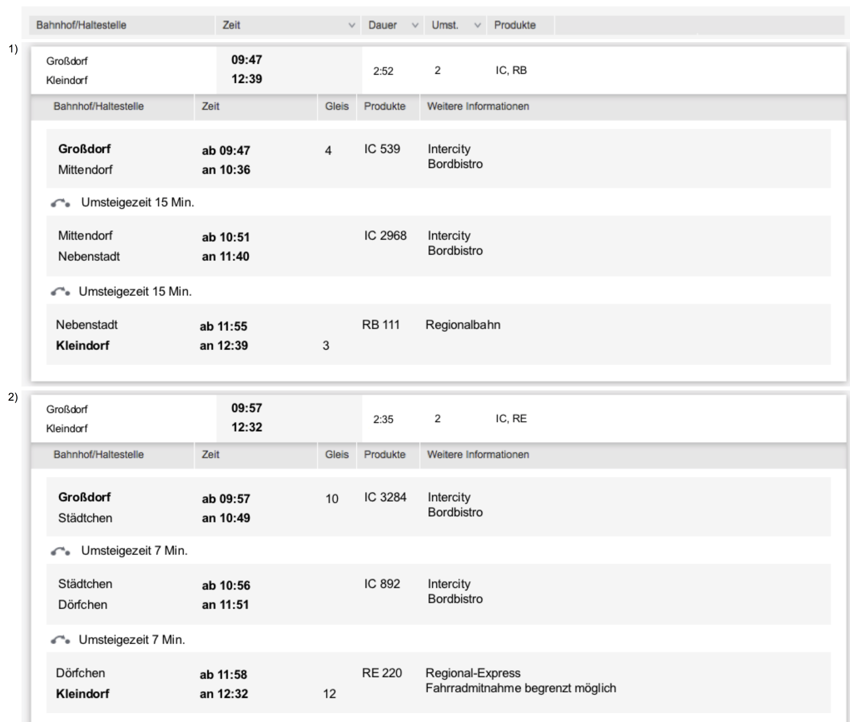


Figure 17: Train Trips TO2 displayed with design D_{text}

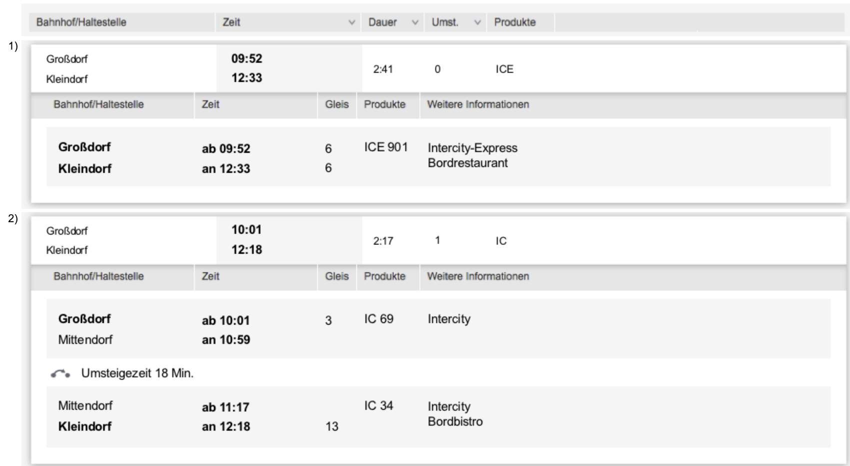


Figure 18: Train Trips TO3 displayed with design D_{text}

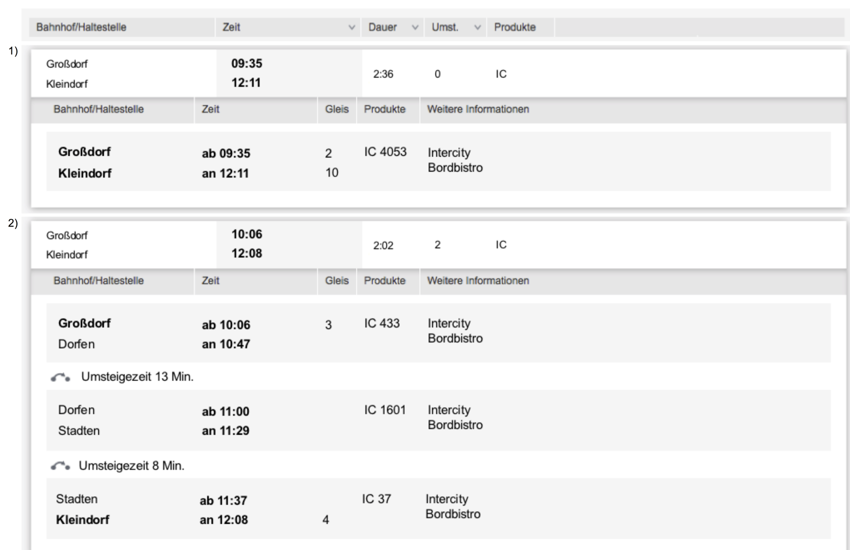


Figure 19: Train Trips TO4 displayed with design D_{text}

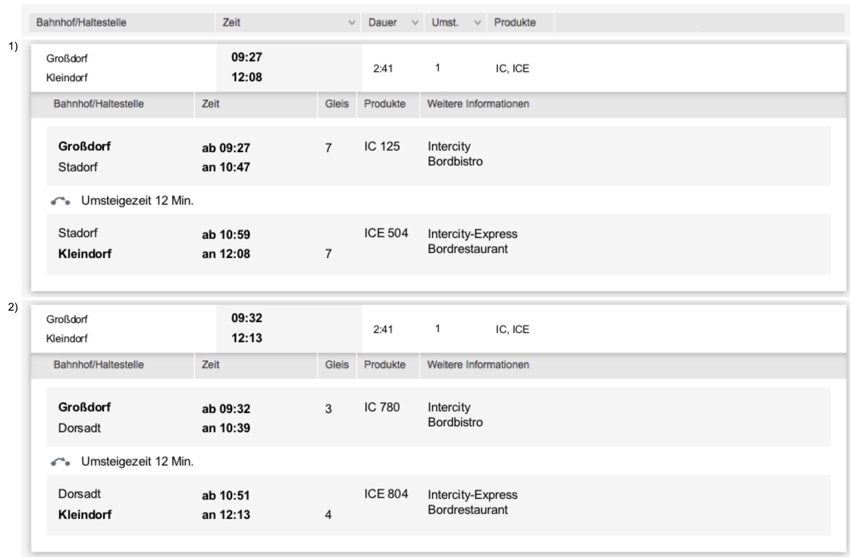


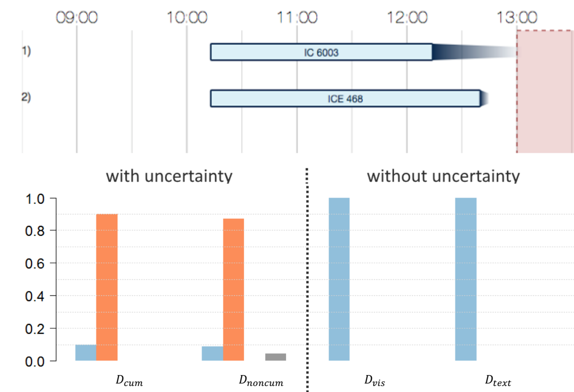
Figure 20: Train Trips TO5 displayed with design D_{text}

Part II

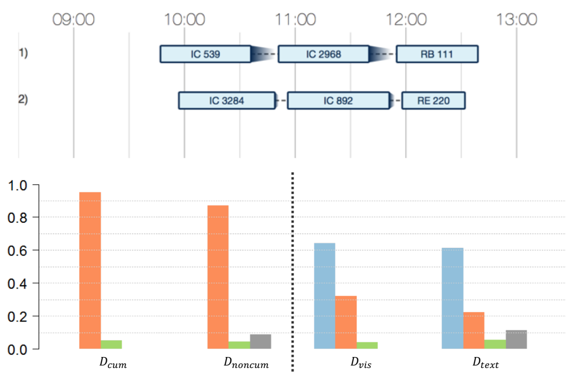
Study Results

3 Decisions

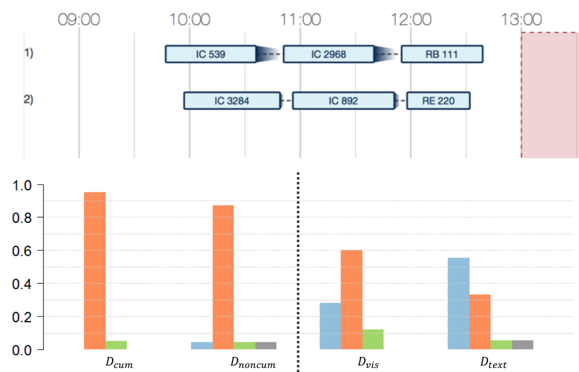
(c) Train connections TO1 and temporal constraint C1



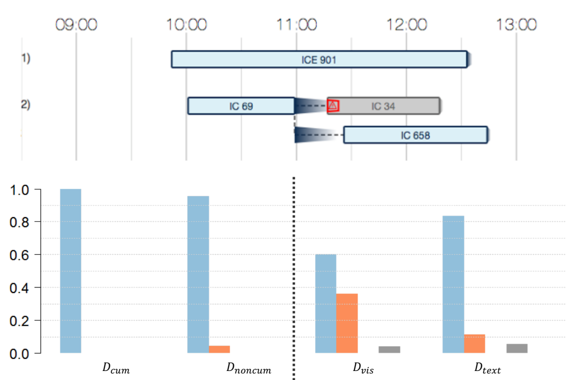
(d) Train connections TO1 and temporal constraint C2



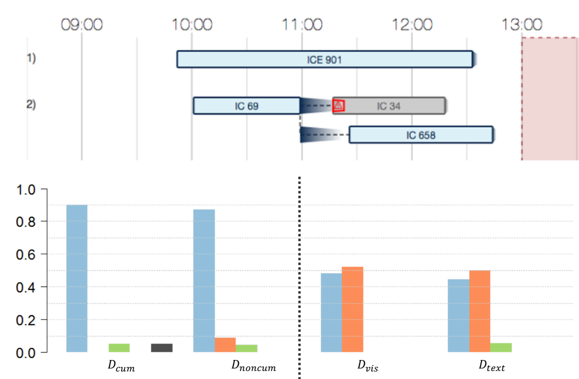
(g) Train connections TO2 and temporal constraint C1



(h) Train connections TO2 and temporal constraint C2

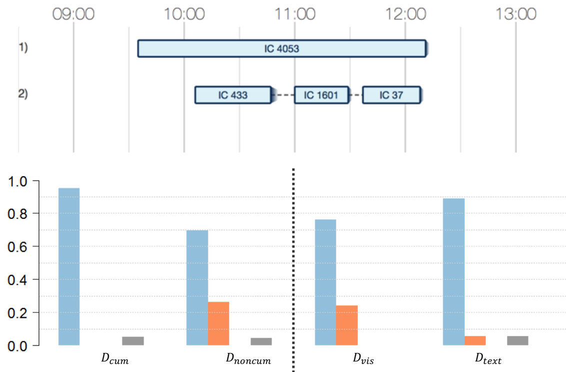


(k) Train connections TO3 and temporal constraint C1

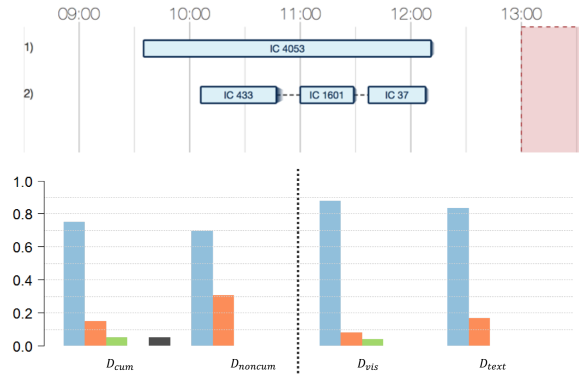


(l) Train connections TO3 and temporal constraint C2

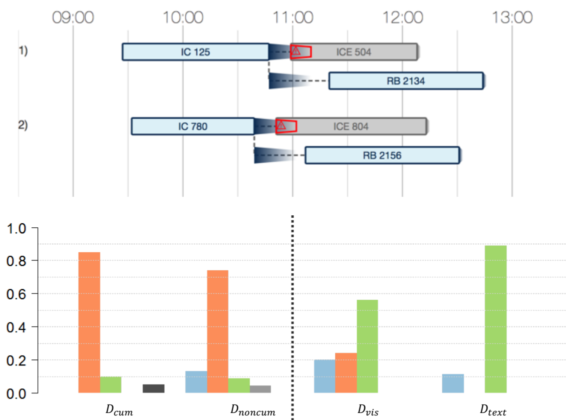
Figure 21: Distribution of the decisions for each situation composed of a set of train connections TO1–TO5 and a temporal constraint C1/C2. The values are relative to the number of answers for each design. *Option 1*, *Option 2*, *For me, both trips are of equal value*, *I can not decide based on this depiction, because: [text input]*, and *I don't know* Above each bar chart the decision situation is displayed with D_{cum}.



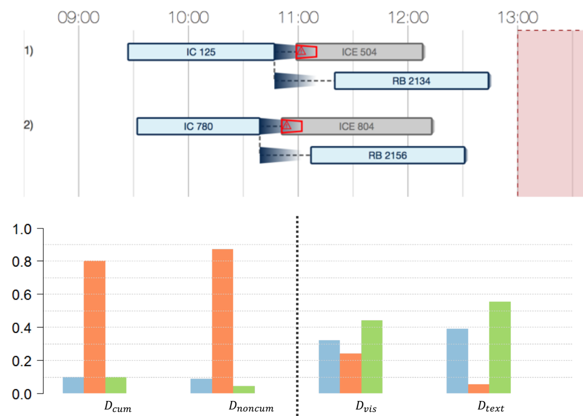
(c) Train connections TO4 and temporal constraint C1



(d) Train connections TO4 and temporal constraint C2



(g) Train connections TO5 and temporal constraint C1



(h) Train connections TO5 and temporal constraint C2

Figure 22: Distribution of the decisions for each situation composed of a set of train connections TO1–TO5 and a temporal constraint C1/C2. The values are relative to the number of answers for each design. *Option 1*, *Option 2*, *For me, both trips are of equal value*, *I can not decide based on this depiction, because: [text input]*, and *I don't know*

4 Statistical Evaluation

4.1 Dependence on the Availability of Delay Uncertainty

The *Fisher's Exact Test* showed that the decisions on train trip selection significantly depend on the availability of delay uncertainty visualization for eight out of ten decision scenarios (cf. Table 3).

	C1	**C2**
TO1	< 0.001 ***	< 0.001 ***
TO2	< 0.001 ***	< 0.001 ***
TO3	< 0.001 ***	< 0.001 ***
TO4	1	0.281
TO5	< 0.001 ***	< 0.001 ***

Significance levels: p-value < 0.001: ***, < 0.01: **, < 0.05: *

Table 3: P-values according to *Fisher's Exact Test* for decisions depending on the availability of delay uncertainty information in the visualization.

4.2 Dependence on the Design of Connection Display

We tested whether decisions differ depending on the type of display with *Fisher's Exact Test*. We specifically analyzed two cases: with uncertainty (D_{cum} and D_{noncum}) and without uncertainty (D_{vis} and D_{text}).

	C1	C2
TO1	< 0.001 ***	< 0.001 ***
TO2	< 0.001 ***	< 0.001 ***
TO3	0.001 **	< 0.001 ***
TO4	0.047 *	0.336
TO5	< 0.001 ***	< 0.001 ***

Significance levels: p-value < 0.001: ***, < 0.01: **, < 0.05: *

Table 4: P-values according to *Fisher's Exact Test* for decisions depending on the design of train trip display.

		D_{cum} vs. D_{noncum}	D_{vis} vs. D_{text}
TO1	**C1**	0.002 ** °	0.752
TO2		0.74	0.396
TO3		1	0.116
TO4		0.023 *	0.106
TO5		0.332	0.04 *
TO1	**C2**	1	1
TO2		1	0.115
TO3		0.593	0.729
TO5		0.839	0.32

Significance levels: p-value < 0.001: ***, < 0.01: **, ¡ 0.05: *

Bonferroni corrected: p-value < 0.0002: °°°, < 0.002: °°, < 0.008: °

Table 5: P-values according to *Post-hoc Fisher's Exact Test* for decisions depending on the type of delay display and depending on whether display is visual or text.

4.3 Dependence on the Existence of an Arrival Deadline

TO1	TO2	TO3	TO4	TO5
† < 0.001 ***	† 0.096	0.029 *	0.789	† 0.08

† includes the decision that both connections are of equal value

Significance levels: p-value < 0.001: ***, < 0.01: **, < 0.05: *

Table 6: P-values according to *McNemar Test* for decisions depending on the time constraint.

	D_{cum} & D_{noncum}	D_{vis} & D_{text}
TO1	0.004 **	
TO2	1	† 0.039 *
TO3	1	0.034 *
TO4	0.221	0.724
TO5	1	† 0.096

† includes the decision that both connections are of equal value
Significance levels: p-value < 0.001: ***, < 0.01: **, < 0.05: *

Table 7: P-values according to *McNemar Test* for decisions depending on the time constraint for designs with uncertainty (D_{cum} & D_{noncum}) and without uncertainty (D_{vis} & D_{text}).

	D_{cum}	D_{noncum}	D_{vis}	D_{text}
TO1	0.023 *	0.248		
TO2	1		† 0.059	0.48
TO3	1		0.505	0.046 *
TO4	1	0.248	0.134	0.617
TO5	1	0.48	1	

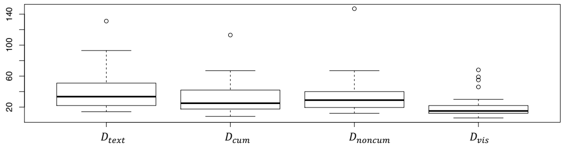
† includes the decision that both connections are of equal value
Significance levels: p-value < 0.001: ***, < 0.01: **, < 0.05: *

Table 8: P-values according to *McNemar Test* for decisions depending on the time constraint for each design.

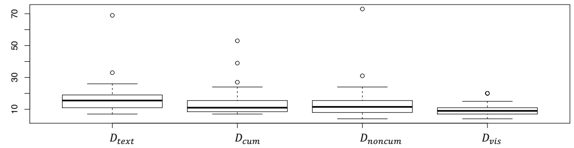
5 Decision Making Durations

Decision Situation		D_{cum}	D_{noncum}	D_{vis}	D_{text}
TO1	**C1**	33,33	35,40	30,32	41,33
TO2		29,67	19,15	19,29	49,72
TO3		18,38	16,65	16,64	33,50
TO4		13,33	20,55	12,07	24,56
TO5		24,04	29,45	17,43	32,67
TO1	**C2**	15,00	15,45	14,11	18,28
TO2		17,33	16,15	13,14	34,22
TO3		11,38	14,05	17,00	29,22
TO4		11,54	10,65	11,86	25,78
TO5		17,25	27,15	13,75	25,00

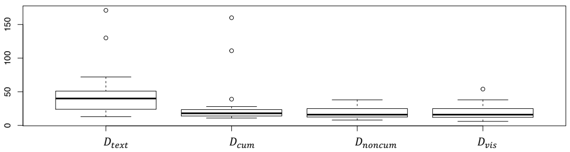
Table 9: Decision Making Durations



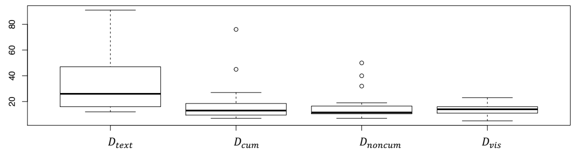
(a) TO1 C1



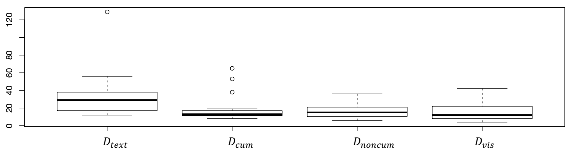
(b) TO1 C2



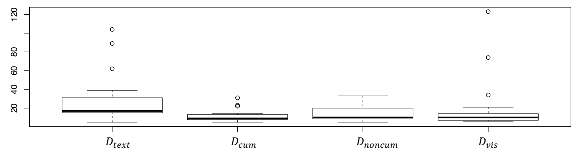
(c) TO2 C1



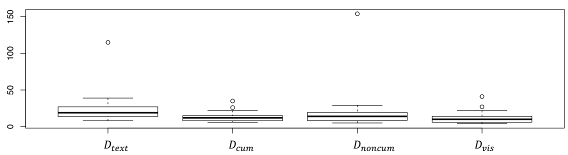
(d) TO2 C2



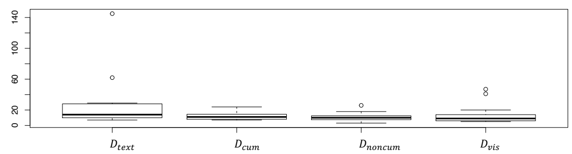
(e) TO3 C1



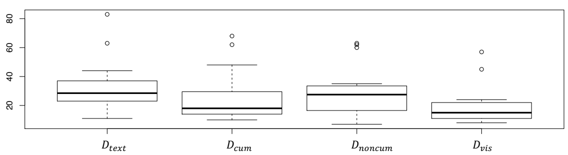
(f) TO3 C2



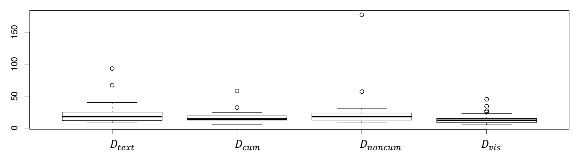
(g) TO4 C1



(h) TO4 C2



(i) TO5 C1



(j) TO5 C2

Figure 23: Decision Making Durations