Appendix A: Additional recommendations

In this document, recommendations, each coming from a single person, are evaluated. Figure 1 gives an overview of all recommendations, coming from multiple experts or from a single person. In order not to exclude individual recommendations based on quantitative relations alone, these are evaluated in the context of other interview sections on the same generalized topic. Multiple identical statements coming from the same person are scored as a single statement. For example considering the statement "1 Trigger event for all measures better" can be evaluated in the context of time constraints. All comments on the generalized topic "Time constraints" are displayed in Figure 2.
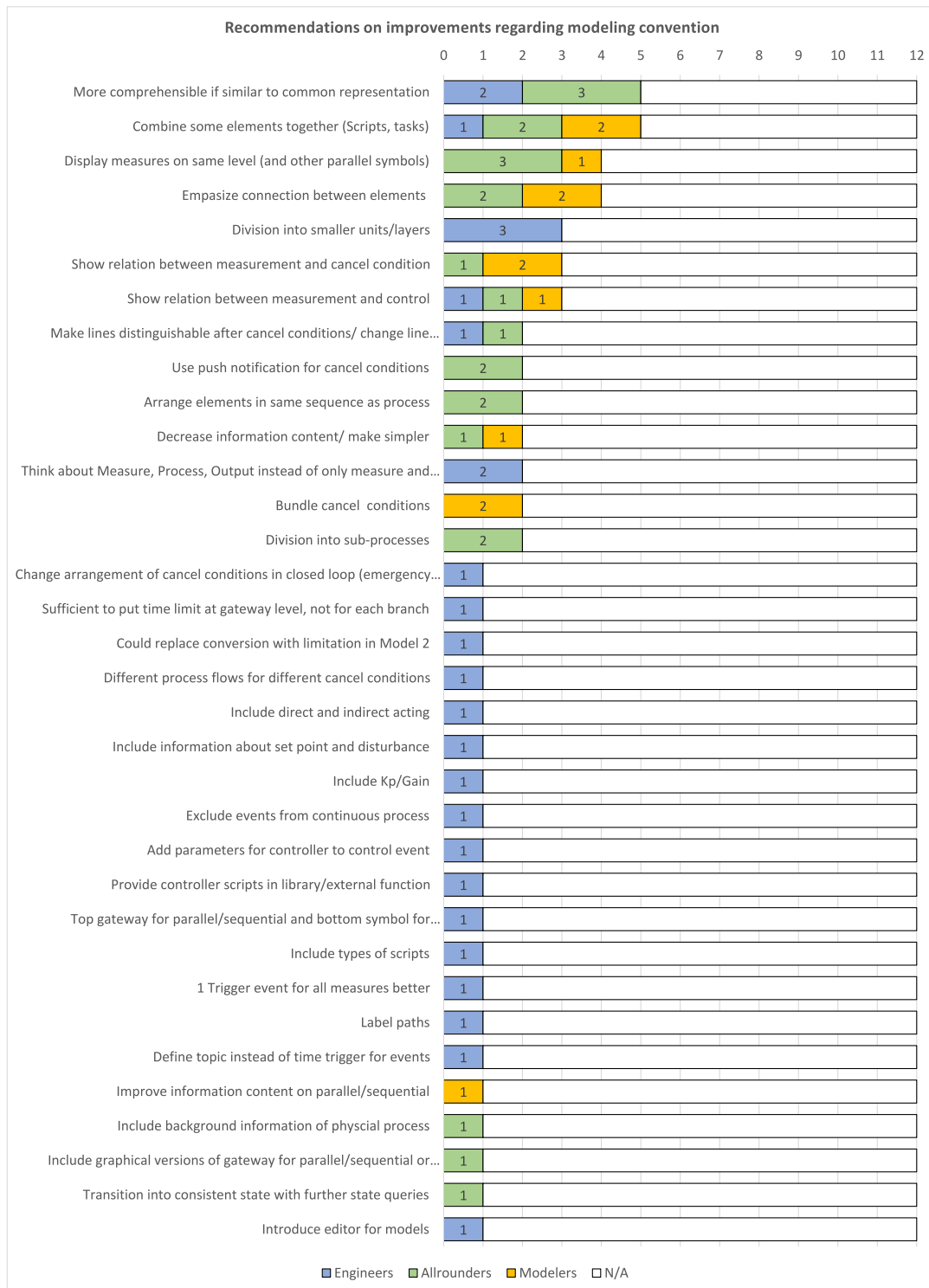
Recommendations on improvements regarding modeling convention

Recommendation	Engineers	Allrounders	Modelers
More comprehensible if similar to common representation	2	3	
Combine some elements together (Scripts, tasks)	1	2	2
Display measures on same level (and other parallel symbols)		3	1
Empasize connection between elements		2	2
Division into smaller units/layers	3		
Show relation between measurement and cancel condition		1	2
Show relation between measurement and control	1	1	1
Make lines distinguishable after cancel conditions/ change line…	1	1	
Use push notification for cancel conditions		2	
Arrange elements in same sequence as process		2	
Decrease information content/ make simpler		1	1
Think about Measure, Process, Output instead of only measure and…	2		
Bundle cancel conditions			2
Division into sub-processes		2	
Change arrangement of cancel conditions in closed loop (emergency…	1		
Sufficient to put time limit at gateway level, not for each branch	1		
Could replace conversion with limitation in Model 2	1		
Different process flows for different cancel conditions	1		
Include direct and indirect acting	1		
Include information about set point and disturbance	1		
Include Kp/Gain	1		
Exclude events from continuous process	1		
Add parameters for controller to control event	1		
Provide controller scripts in library/external function	1		
Top gateway for parallel/sequential and bottom symbol for…	1		
Include types of scripts	1		
1 Trigger event for all measures better	1		
Label paths	1		
Define topic instead of time trigger for events	1		
Improve information content on parallel/sequential			1
Include background information of physcial process		1	
Include graphical versions of gateway for parallel/sequential or…		1	
Transition into consistent state with further state queries		1	
Introduce editor for models	1		

■ Engineers ■ Allrounders ■ Modelers □ N/A

Figure 1: Recommendations

Comments on time constraints

Recommendations regarding time constraints include the following statements: "Sufficient to put time limit at gateway level, not for each branch" and "1 Trigger for all measures would be better" (see Figure 2). Engineer 4 states that it would be sufficient to put the time limit at the Closed Loop Sub-System Gate-

way level while Allrounder 2 rates the definition of time constraints for each branch of the Closed-Loop Sub-System Gateway positively. Therefore the first recommendation has a counterargument. The second recommendation is a more specific version of the first recommendation. The first one would include time constraints in form of timer events for the complete closed loop system, the second recommendation refers specifically to measure events.
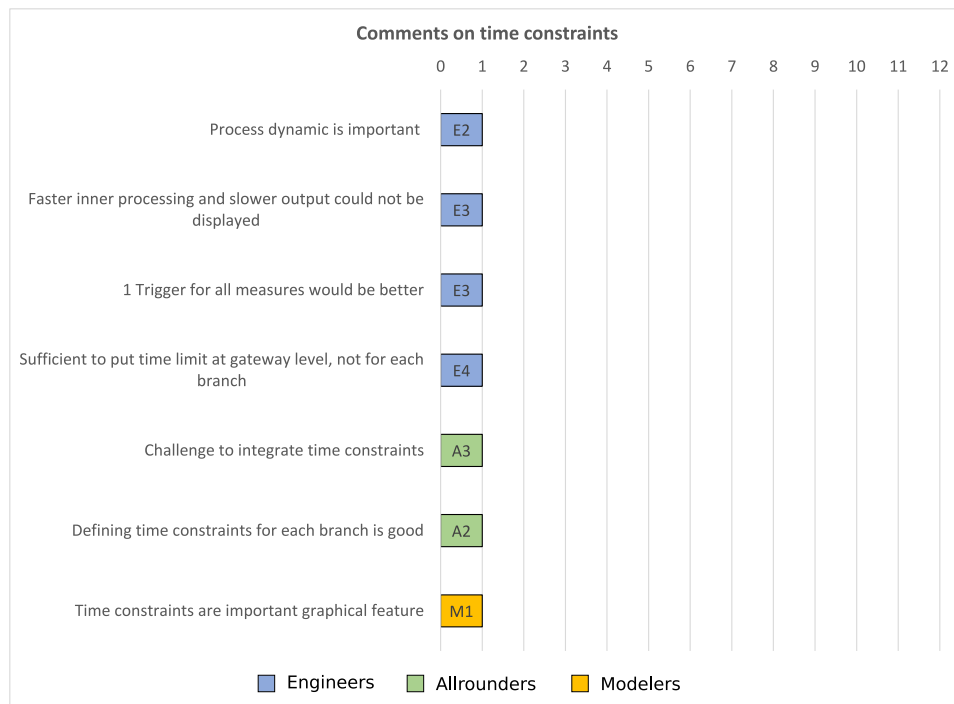

Figure 2: Comments on time constraints

As a compromise, following the statements from Group 1 and 2 and for more clarity regarding time conditions, elements of the same type (Measure or Control) and with the same time limits are grouped together. To increase comprehensibility the attribute "Interval frequency in Hz" of Measure and Control events will be renamed to "Maximum duration in s".

Comments on process sequence

In Figure 3 among other statements, three recommendations are listed regarding the process sequence. The first recommendation comes from Engineer 4 and refers solely to the arrangement of the Cancel event in the event of an emergency stop. From Group 2, Allrounder 2 and 4 share the opinion that the elements in the process model should be arranged in the same way as the real physical process. Modeler 4 strengthens the importance of the arrangement of the elements in a process model with their statement.

Comments on process sequence

	0	1	2	3	4	5	6	7	8	9	10	11	12
Change arrangement of cancel events in closed loop (emergency stop)	E4												
Arrange elements in same sequence as process	A2	A4											
Order to read the model is an important graphical feature	M4												

■ Engineers ■ Allrounders ■ Modelers
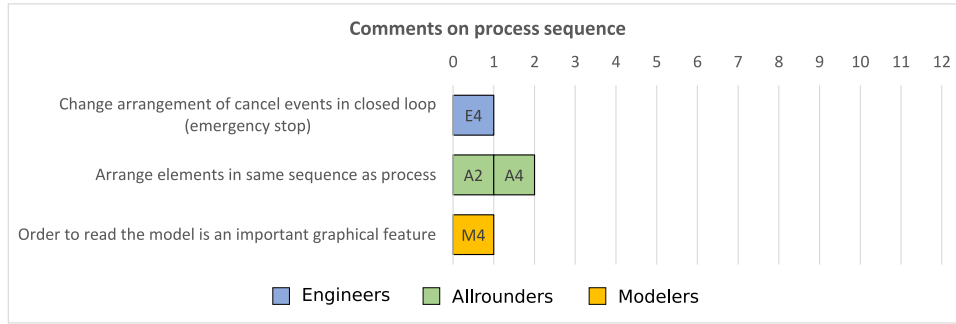
Figure 3: Comments on process sequence

As the depiction of the elements in a closed-loop sub-system has been derived from the functionality of a PLC, the position of the state queries remains the same. However, following the recommendation to use push notifications for cancel conditions, state queries for such events are no longer integrated in the model if the value is not needed for the control task sequence. The further arrangement of elements in each lane after the events depends on the modeler.

Comments on physical process

An overview of comments on the physical process behind the process model is given in Figure 4. The recommendation to include more background information on the physical process in the model comes only from Allrounder 4, but is reinforced by two other statements from Engineer 3 and Modeler 2. On the one hand Engineer 3 agrees with physical values being important graphical features, and on the other hand Engineer 3 and Modeler 2 agree that the physical process behind the models is not apparent.

Comments on physical process

	0	1	2	3	4	5	6	7	8	9	10	11	12
Physical values are important graphical features	E3	A4											
Physical process behind model not apparent	E3	A4	M2										
Include background information of physical process	A4												

■ Engineers ■ Allrounders ■ Modelers
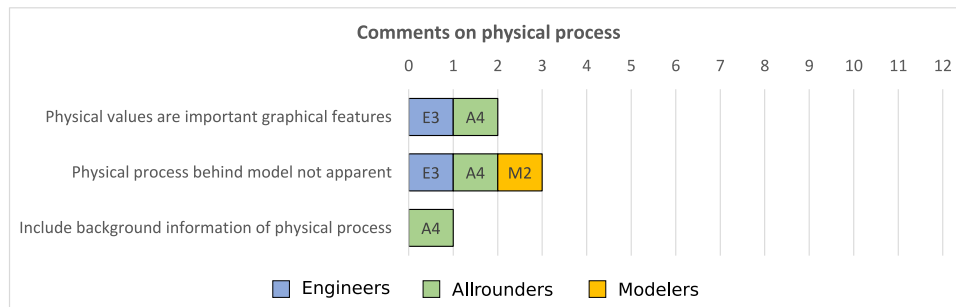
Figure 4: Comments on physical process

Following the discussion regarding weaknesses, the integration of another notation to make the physical process visible depends on the final purpose of the models. There needs to be a discussion prior to the modeling process whether the models should only depict the logic behind the real process or should also represent the physical characteristics. More background information on the physical process can already be included in the model by applying clear and consistent modeling conventions (e.g. defining

4

variable names).

Comments on gateway attributes

The recommendations in Figure 5 include separating the gateway symbol into a top symbol for parallel/sequential and a bottom symbol for wait/cancel suggested by Engineer 3, including graphical gateway versions for parallel/sequential and wait/cancel suggested by Allrounder 4 and improving information content on parallel/sequential suggested by Modeler 3. While the third recommendation is generically formulated, the first and second recommendation are more specific. Both speak for a change in the symbolic representation of the gateway with respect to the configurable attributes. This is contradicted by the statement of Allrounder 2, for whom the representation of the attributes in the form of a string next to the symbol is enough. Figure 5 shows that the graphical representation of the attributes is criticized by one representative member from each of the Groups 1 and 2. The difficult comprehensibility of the attributes, on the other hand, is emphasized by Group 3, by Modelers 2 and 3 together with Allrounder 2.
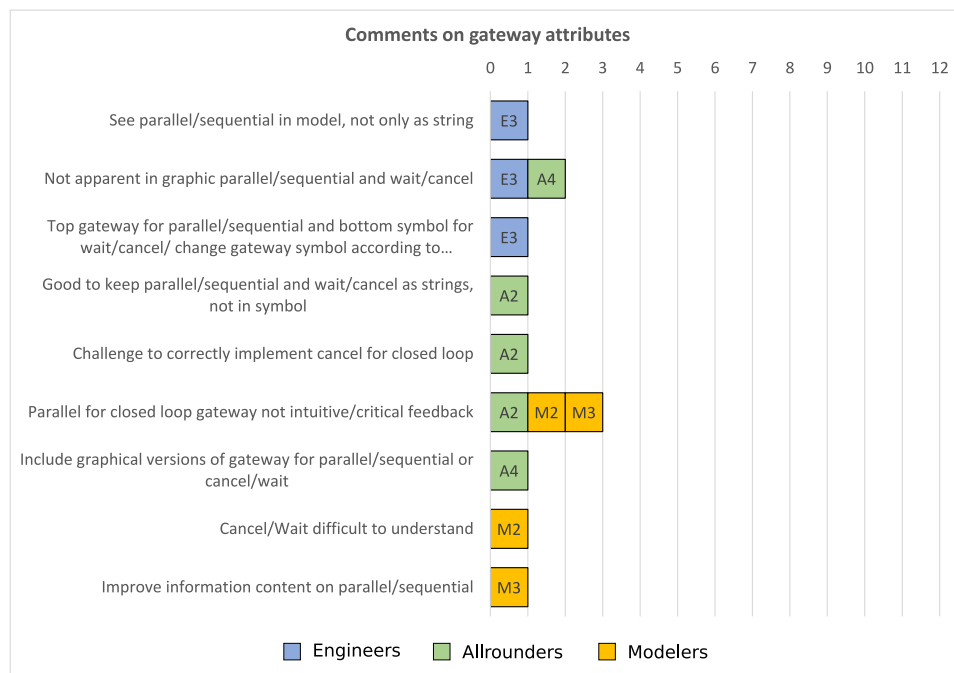
Figure 5: Comments on gateway attributes

The statements about the graphical representation of parallel/sequential and wait/cancel show that the visibility of those attributes in the process model is a desired feature. The dependency of gateway symbols on variable attributes and not on the processing of a token is not provided in standard BPMN so far. Therefore, an option will be to implement the differences between the opposing attributes recognizably

in the representation of the individual elements inside the closed-loop system.

Comments on controller functionality and parameters

As expected, comments on controller functionality and parameters come from Group 1 (see Figure 6). It is also noticeable that all comments come from one person at a time and are not shared by several persons. The recommendations in Figure 6 come from Engineer 3 and 4. While Engineer 4 suggests to include technically relevant parameters such as an indicator for direct or indirect acting of the controller, set point and disturbance as well as the gain parameter in the model examples, Engineer 3 only recommends to add parameters relevant for the controller to the Control event in the model. Engineer 1 would read from the model examples, that the focus lies on the operation of the respective process plant. For Engineer 1 signal names are missing, but not every detail needs to be included in the process models. For Engineer 2 it is hidden in the process models how the controller works. In addition to the recommendations, Engineer 4 identifies the functionality of the controller as important graphical feature and modeling independently from a PLC/PCS as a challenge. Following the recommendations, members of Group 1 miss the process variable and disturbance, controller modes, indicators for direct or indirect acting of the controller and information about the set point.
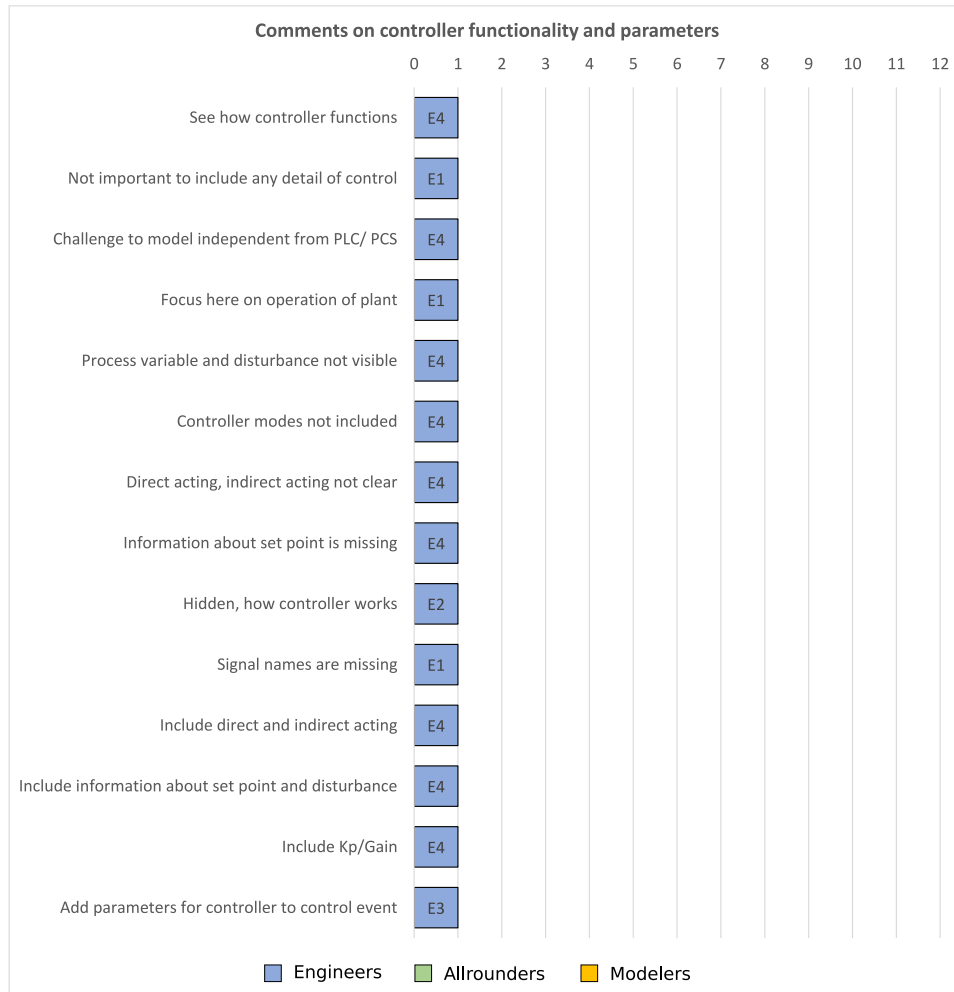
Figure 6: Comments on controller functionality and parameters

The recommendations to include direct and indirect acting, information about the set point and gain can be realized by introducing best practices in modeling and implementing the controller scripts. The recommendation to add the parameters to the Control event by Engineer 3 can be realized by adding the respective parameters in the form of attributes to the Control event.

Comments on bringing system into consistent state

The recommendation of Allrounder 4 that transitioning to a consistent state should be done with further state queries contrasts with the discussion of whether this element should be integrated into a process model (see Figure 7). While Engineer 1 and Allrounder 1 and 3 state that bringing system into a consistent state is relevant for safety, Engineers 3 and 4 question whether it should be integrated in process models. In figures, one representative from Group 1 and two from Group 2 face two representatives from Group 1.
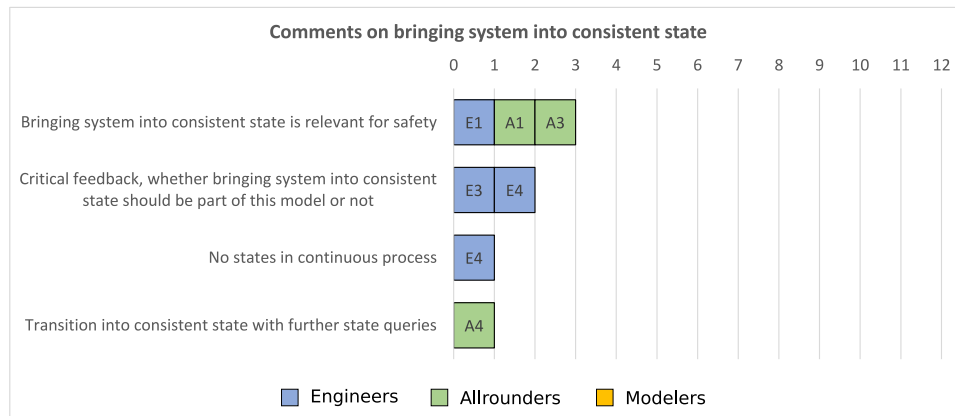
Figure 7: Comments on bringing system into consistent state

The recommendation to include further state queries for the transition of the system to a consistent state by Allrounder 4 can be realized by simply defining and applying respective modeling conventions.

Comments on alarms, events, conditions and states in cont. processes

The recommendations represented in Figure 8 are and "Define topic instead of time trigger for events" by Engineer 3 and "Exclude events from continuous process" by Engineer 4. With regard to alarms, events, conditions and states, representatives from Groups 2 and 3 have the opinion that certain values or conditions for corresponding process flows are not sufficiently represented in the model, or they see it as difficult to represent causes and reasons for certain process flows. Engineer 4 also highlights that limits are missing for the controller, but also notes that alarms and events as well as limits and shutdown conditions do not belong in a model for a continuous process. Regarding shutdown conditions, Engineer 1 also has a critical view of shutdown conditions in continuous processes. Engineer 3 sees it as a challenge to combine a continuous process model with a corresponding state model and switching between them. The first recommendation on integrating topics instead of time triggers for events is not supported by other similar statements.
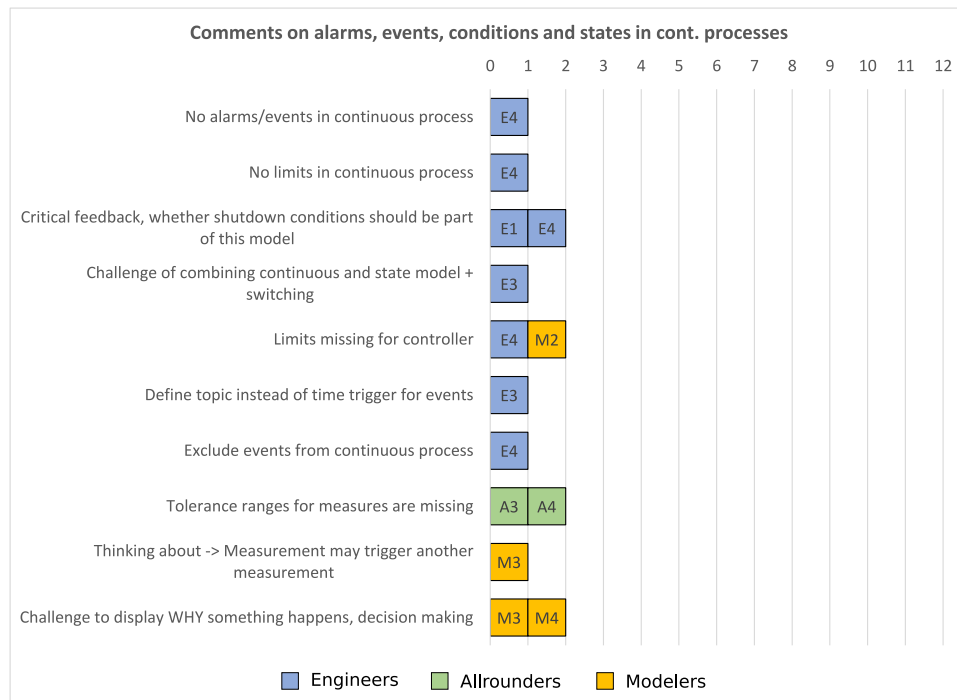
Figure 8: Comments on alarms, events, conditions and states in cont. processes

The recommendation to exclude events from continuous processes cannot be followed here, as events are an elementary component of BPMN. Without events represented in the process models, the procedures of real processes could not be modeled and processed.

Comments on cancel conditions in model

The recommendation represented in Figure 9 is introducing "Different process flows for different cancel conditions" by Engineer 4. Depending on the consequences of different cancel conditions Engineer 4 suggests to model the process flow after each cancel condition according to its effects on the process. This is in accordance with the suggestion of Engineer 4 and Allrounder 3 to display the lines in the model differently for cancel conditions. The statement by Engineer 3 indicating no difference between cancel conditions and other lines going back to the gateway supports this approach.
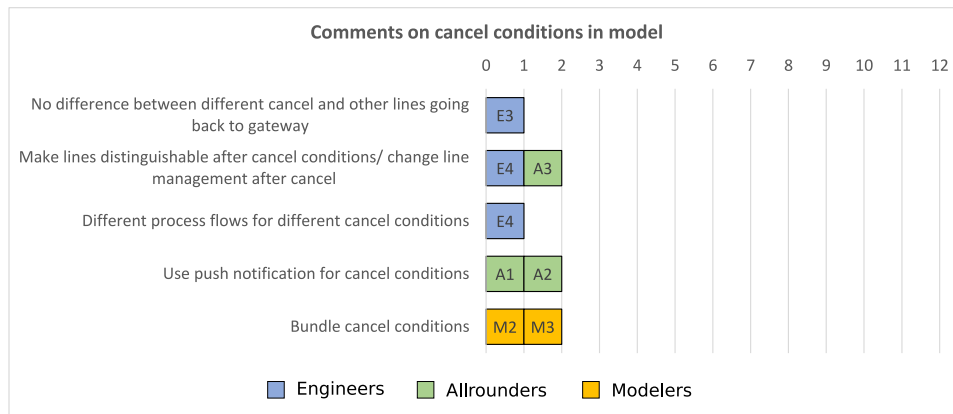
Figure 9: Comments on cancel conditions in model

To a certain extent, this recommendation can be met again by introducing and applying a suitable modeling convention.

The remaining statements, which have not been dealt with so far, are statements made by one person at a time and are not explicitly related to further statements made by other persons. Due to the quantitative representation of these statements, they are not discussed in detail, but only commented in Table 1.

Table 1: Assessment of remaining recommendations

Statement	Comment
Could replace conversion with limitation in Model 2	User can remodel process example
Provide controller scripts in library/ external function	Already intended
Include types of scripts	Already intended as of library functions/ sub-processes
Label paths	Elements are labeled, symbols are distinctive
Introduce editor for models	CPEE is an editor