Progress Determination of a BPM Tool with Ad-Hoc Changes: An Empirical Study

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Abstract. One aspect of monitoring business processes in real-time is to determine their current progress. For any real-time progress determination it is of utmost importance to accurately predict the remaining share still to be executed in relation to the total process. At run-time, however, this constitutes a particular challenge, as unexpected ad-hoc changes of the ongoing business processes may occur at any time. To properly consider such changes in the context of progress determination, different progress variants may be suitable. In this paper, an empirical study with 194 participants is presented that investigates user acceptance of different progress variants in various scenarios. The study aims to identify which progress variant, each visualised by a progress bar, is accepted best by users in case of dynamic process changes, which usually effect the current progress of the respective progress instance. The results of this study allow for an implementation of the most suitable variant in business process monitoring systems. In addition, the study provides deeper insights into the general acceptance of different progress measurements. As a key observation for most scenarios, the majority of the participants give similar answers, e.g., progress jumps within a progress bar are rejected by most participants. Consequently, it can be assumed that a general understanding of progress exists. This underlines the importance of comprehending the users' intuitive understanding of progress to implement the latter in the most suitable fashion.

Keywords: Business process monitoring, empirical study, progress determination, progress visualisation, real-time monitoring

1 Introduction

The quest to monitor business processes is very much in demand. Monitoring processes allows us to identify and address problems and errors at an early stage of process execution. A crucial task of business process monitoring is to determine the progress of running process. This is particularly challenging when facing ad-hoc changes during run-time, which might affect progress.

The unexpected addition or deletion of process instances as well as direct changes of the underlying process model itself are examples of such ad-hoc changes, which have a direct impact on progress determination. As a result of this process flexibility, further investigation of how to determine and visualise the progress of a running business process is needed, and to understand which variants exist to cope with unexpected progress.

In this paper, we investigate how to cope with dynamic progress changes of flexible processes during run-time. In particular, we want to know whether there exists a generally accepted notation of progress and which type of visualising progress are accepted best by users. For this purpose, an empirical study to investigate the acceptance of different progress variants for business processes is conducted. Its aim is to determine which type of progress is accepted by the users of a business process monitoring system when facing process changes during run-time. The results of the study shall allow us to implement the most suitable variants of progress changes.

The remainder of this paper is structured as follows. Section 2 gives backgrounds on the process paradigm presumed by this paper, of object-aware business processes. In Section 3, the applied research methodology, and the design of the empirical study are described. Section 4 analyses, evaluates, and discusses the answers of the 194 participants of the study. Related work is discusses in Section 5, whereas Section 6 concludes the paper.

2 Backgrounds

The framework PHILharmonicFlows, which we have developed in recent years, enables implementing object-aware business processes, which allow for a high user flexibility as well allows ad-hoc process changes during run-time [1]. In object-aware processes the collection of process data is accomplished with data-driven form sheets. The latter are auto-generated from the process specification. Forms usually have to be designed manually for each activity while form generation is a built-in feature of PHILharmonicFlows due to its data-centric approach. Thereby, forms logic and enactment utilises the operational semantics of the dynamic aspects of the form, such as the next value that is required. The latter also allows for a high degree of flexibility, for example, a user is not forced to fill out the fields of a form in-order. User may choose their preferred order, e.g., by filling out the form from bottom to the top. Additionally, jumping back within a form allows users to check or correct previously filled fields [2].

Basic to our approach are business *objects*. Each object is defined by its *attributes* as well as its *lifecycle*, which describes object behaviour (i.e., the processing of object-related forms) during run-time [3]. Moreover, the relations between the various objects of a business process are manifested by a *relational process structure*. Possible cardinality constraints on these object relations are 1:n or n:m [4]. An object lifecycle is defined in terms of *states*. Each lifecycle has one start state and at least one end state, and an arbitrary number of intermediate states. Each state is represented by a *form sheet* and maybe refined by *steps*, which correspond to object attributes and hence represent the data input fields of the respective form. Finally, a *coordination process* controls the interactions between these multiple lifecycle processes making use the relation process structure [5].

In [6], we have defined four research questions to be investigated in the context of determining the progress of an object-aware business process. Moreover, in [7], we presented an approach that addresses Research Question 1 and 2. To answer Research Question 3, the challenges of determining the progress of large, dynamically evolving process structures, which consist of interacting loosely coupled, smaller processes that may be also subject to ad-hoc process changes must be investigated first. Regarding these challenges, a solution for progress determination with empirical evidence is provided.

Research Question 1	How can the progress of a single lifecycle process with its state-based view form be determined?
Research Question 2	How can the progress of the processing of a single state within a lifecycle process be measured?
Research Question 3	How can the progress of multiple, interacting (i.e., interrelated) lifecycles be determined?
Research Question 4	How does a coordination process affect the progress of an object-aware business process?

3 Research Methodology and Study Design

This section presents our research methods and the design of the empirical study. We combine the methodologies from [8], [9], and [10] to investigate a real-world scenario for a process monitoring tool. Section 3.1 introduces the research questions addressed by this paper. Section 3.2 defines the data collection method. Section 3.3 presents the study design and Section 3.4 describes the used data analysis method.

3.1 Research Questions

For each business entity, a separate instance (with its own lifecycle instance) of an object type is created at run-time. In addition, changes of a lifecycle instance may be defined at run-time by adding new attributes, which are considered in the dynamically generated form sheets, i.e, new form sheets or input fields may be created at run-time. Moreover, form sheets and input fields may be deleted at run-time. In the context of such dynamic lifecycle and form changes as well needs to investigated how the progress of the overall process be adapted and what adaptations are accepted by different users or user groups. This leads us to the following research question:

Main Research Question:	Does a generally suitable accepted understanding of progress exist?

This includes the following sub-research questions:

Sub-Research Question 1	Which variants of determining progress are rejected by most users?
Sub-Research Question 2	Are progress jumps or progress speed adjustments better accepted by users in the context of run-time changes?
Sub-Research Question 3	Which progress variant is most suitable?

3.2 Data Collection Method

The study is performed with an anonymous online questionnaire[1] leveraging the web-based tool `Google Forms` for data collection. Further, the study is available in German and English. The language options do not differ with respect to content or structure. The participants can choose their preferred language in the first step of the questionnaire. The questionnaire was available for the participants over a period of more than eight months.

3.3 Study Design

Demographic questions: In the first section of the online questionnaire, demographic data of the participants are collected. The latter shall provide us with information about the participants. In addition, these data allow us to compare the results of the remaining study for different groups. In detail, the demographic questions refer to the participants' gender, age group, highest school or university degree, professional field, experience with reading or creation process models, experiences with process monitoring, and satisfaction with existing process monitoring tools (on a 5 point Likert-scale, from 1 *not at all satisfied* to 3 (*neutral*) to 5 *very satisfied*), if the participant has worked with any monitoring tools before.

Intuitive view of progress: Following the demographic questions, each participant is presented an introductory video of a linear, continuous progress bar course of a lifecycle process i.e., sequentially passing the states of the lifecycle process without any deviations. However, such a progress course is generally not feasible due to unpredictable changes during lifecycle process execution. Therefore, alternatives need to be developed that reflect process changes in the progress bar of this process best. For this purpose, to each participant additional eight videos of progress bar courses are presented, which should be rated in terms of whether progress determination is properly presented to users and intuitively perceived by them. For these ratings, a 5 point Likert-scale ranging from 1 (*not at all true*) to 3 (*neutral*) to 5 (*completely true*) is used. The aim of this section of the questionnaire is to investigate whether there are progress variants which are rejected by users and therefore should be not used in the context of process monitoring.

[1] The questionnaire and the responses of the 194 participants are available via the following Researchgate link: `https://www.researchgate.net/publication/358140443_Study_Results`

Scenario view of progress: In this section of the study, five intralogistic scenarios are described. Along these scenarios different challenges of determining the progress of a running business process are covered, e.g., when creating or deleting business object instances. The results shall help us to find the most suitable progress measurement for a business process monitoring system. Additionally, we want to evaluate our hypothesis that a generally accepted understanding of progress exists.

The following introduction is given before presenting the different intralogistic scenarios to the users: *Robots can support the intralogistic processes in an industrial environment, receiving goods. Robots can support human interactions when unloading, recognising and aligning packages. During the enactment of the process, its progress is displayed in an optimised way. Unexpected (i.e., dynamic) changes may occur during process execution e.g., the technical failure of a robot or the commissioning of a replacement robot. When a robot fails, the remaining robots must compensate this failure and perform additional work. In turn, this might lead to a delay of the total process. The situation is similar to the ad-hoc emergence of additional work.*

For each scenario, the participants are confronted with two videos describing different options for courses of the progress. In all five scenarios, Option A describes the progress with no jumps by speeding up or slowing down the progress depending on the respective ad-hoc changes. In turn, Option B enables progress with the same speed. If progress adjustments become necessary corresponding backward or forward jumps are made in the progress bar. In the following, the five scenarios are described.

Creation of business object instances. During run-time an unexpected workload may occur. For example, the unexpected absence of staff (illness) or robots requires the redistribution of the workload among fewer staff or robots respectively. In this case, progress adjustments can be made by either jumping back in the progress bar or slowing down the remaining progress. Scenario 1 shall help us to find the most suitable solution when creating instances of a business object.

Scenario 1: Reordering packages

Before the start of each working day, the total amount of work is determined. Due to unexpected hoarding of toilet paper, as much toilet paper as possible is reordered and delivered during the working day. The ordered toilet paper is delivered by an unknown number of trucks throughout the afternoon. The current progress of the goods' delivery is determined each time a truck arrives by considering the additional work.

In Figure 1, the progress determination according to Option A and B are shown. Both progress determinations are identical until 60%. Then the progress according to Option A grows slower until 80%, due to the unexpected delivery of toilet paper from the trucks. For Option B, with this delivery the progress determination drops immediately to 50% and is growing up to 80% with the same speed as before. When the progress reaches 80%, another unexpected truck load arrives in the intralogistic centre. Again, for Option A the progress grows slower until 100%, whereas for Option B the progress drops immediately to 60% and is growing up to 100% with the same speed as before.

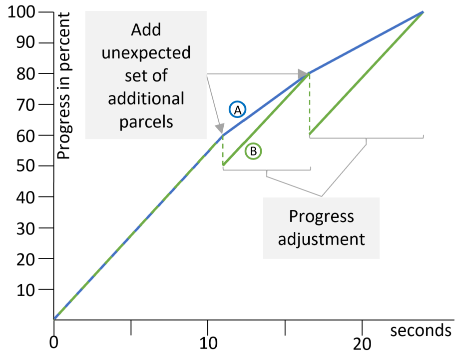

Fig. 1. Progress adjustments in Option A and B after the unexpected delivery of additional parcels (cf. Scenario 1).

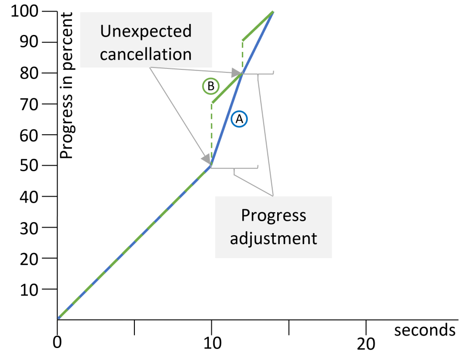

Fig. 2. Progress adjustments in Option A and B after the cancellation of parcels (cf. Scenario 2).

Deletion of business object instances. Besides the unexpected increase of the total workload, an unexpected decrease of the latter may occur as well, e.g., after cancelling orders or work assignments. Scenario 2 shall help us to find the most suitable solution for adjusting progress measures in such cases.

Scenario 2: Order cancellation

Due to a more favourable price development of a competitor's product, unexpected cancellations are made throughout the working day. Consequently, the overall workload is reduced.

In Figure 2, for Option A and B the respective progress with respect to Scenario 2 is depicted. For both options the progress determination evolves the same way until reaching 50%. Then, for A it grows significantly faster up to 80%, due to a first unexpected order cancellation. For Option B, with the order cancellation the progress jumps immediately from 50% to 70%, and is then growing up to 80% with the same speed as before. When reaching 80%, another unexpected cancellation occurs. For Option A the progress determination is then growing even faster up to 100%, whereas for Option B with the cancellation the progress immediately jumps from 80% to 90%, and is growing up to 100% with the same speed as before.

Replacement of business object instances. During process execution, multiple unexpected events might occur, which affect the overall progress determination.

Scenario 3: Robot failure and replacement by another robot

Assume that a robot fails when reaching 60% of the calculated progress due to technical reasons. Adding a replacement robot takes some time as the failed robot has to be removed and the new one needs some time to be ready for use. Assume further that is not possible to predict whether the replacement robot will be ready for use before completing the entire process.

In Figure 3, for both options the respective progress determination is shown. The latter are the same until reaching 60%. Then, for Option A the progress is growing slower due to of the unexpected robot failure, whereas for Option B the progress drops immediately to 45%. Afterwards, for Option B the progress is growing from 45% to 70%, whereas for Option A the progress is growing from 60% to 70% in the same time. When activating the backup robot, the progress determination readopted adapts again. For Option A, the progress is growing significantly faster, whereas for Option B it jumps from 70% to 85% with the same speed as before.

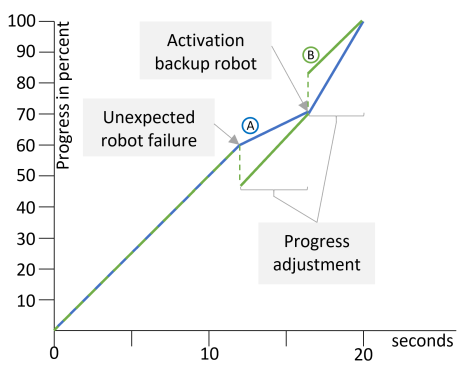

Fig. 3. Progress adjustments in Option A and B after the unexpected robot failure and provision of a backup robot (cf. Scenario 3).

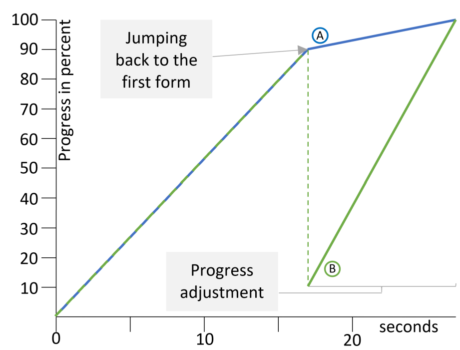

Fig. 4. Progress adjustments in Option A and B when jumping back to a previous form (cf. Scenario 4).

Progress jumps within a form. As shown in Section 2, in the PHILharmonicFlows approach the end-users interact with forms to collect data. After filling out the current form, it is possible to activate the next one. However, it is also possible to jump back to a previous form to review and update the input added previously with the respective form. The input data of all forms is preserved.

Scenario 4: Jumping back to a previous form

This scenario switches to the customer's perspective. During an order process, multiple forms are displayed to the customer one following the other. These forms and their order are as follows: *Shopping cart* → *Enter address* → *Payment method* → *Confirm* → *Done* (end of order process). Assume that before confirming the customer jumps back to the *Shopping cart* and re-checks it. In this context note that the input data of the previously filled forms *Enter address* and *Payment method* persists.

In Figure 4, for both options the progress determination is shown. Both progresses evolve the same way until 90%. For Option A the progress is growing slower due to the backward jump in the form, whereas for Option B the progress immediately drops to 10%. After the backward jump, for Option B the progress is growing from 10% to 100% in the same time as it is growing from 90% to 100% in Option A.

Time- or work-based. In general, there are two metrics that can be used to determine the progress of a business process. First, the progress calculation can be based on the total execution time. Assume, for example, that a business process needs from its start five days upon completion. Accordingly, on the second day at 6am the progress reaches 25% (presuming a duration of 5 days with 24 hours). Alternatively, progress calculation can be based on the completion of work packages, which results in progress of 20% on the second day at 6am as only the work of the first day has been completed so far (assuming working hours from 8am to 5 pm).

Scenario 5: Time- or work-based

If there are planned breaks during process execution in which no active work is done, this affects the progress determination of the process. Assuming that the following sequence of work packages and breaks, together with the time required for them, is given.
Work package A: 3 hours + 15 minutes break
Work package B: 1 hour + 15 minutes break
Work package C: 4 hours + 30 minutes break
Work package D: 2 hours

Figure 5 depicts the determination for progress time- and worked-based scenario. For Option A, there is no progress growth in the three breaks, whereas for Option B the progress is growing continuously from 0% to 100%.

Outlook Section of the Questionnaire: The last section of the questionnaire concludes the study by asking general questions about progress determination and presentation. The aim is to get insights into the accepted duration for progress determination and further fundamental monitoring components.

Ideally, progress determination is accomplished in real-time. However, the calculations take time, and the more comprehensive the process is, the greater

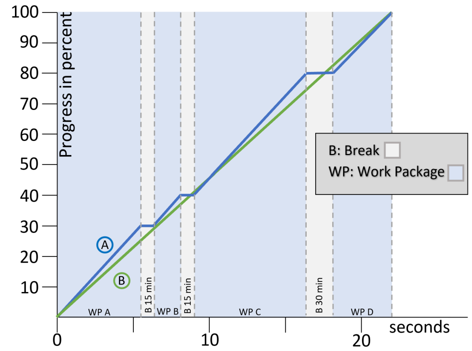

Fig. 5. Progress adjustments in Option *A* based on work and *B* based on time (cf. Scenario 5).

the delay due to the continuous progress calculation will be. For this reason, we investigated what delay in progress determination is acceptable for the users of a process monitoring tool. For this investigation, we defined four process duration: *one hour*, *one day*, *one week*, and *one month*. For each process duration, the participants gave the maximal acceptable delay of progress determination.

Besides the progress determination, many more monitoring components exist, e.g., *Risk Management*, *Resource Management*, *Process Performance Measurement*, *Alarm Trigger and Error Warnings*, and *Numbers of running processes*. Therefore, the participants were asked which components shall be part of a process monitoring tool and which of them is the most important.

3.4 Data Analysis Method

All collected data are analysed and evaluated in a structured way to answer the research question defined in Section 3.1. For this purpose, the methodology from [8] is used. In a first step, the answers of all participants are analysed. In a second step, an expert group among the participants is defined based on the answers given in the demographic section of the questionnaire, e.g., experience in modelling processes. The answers of these experts are then compared with the ones of the first step. `Pearson` and `Spearman Correlation` are used to evaluate the correlation between the data of the questionnaire.

4 Evaluation

Demographic questions: Overall, more male (110 | 56.7%) than female (84 | 43.3%) participants took part in the study. The majority of the participants are between 18 and 25 years old (152 | 78.4%); 36 participants are between 26 and 35 years old (36 | 18.6%). The number of participants with an age between 36 and 65 (6 | 3.0%) is negligible. Most participants work in economy and administration (89 | 45.9%) or information technology (76 | 39.2%). More than two third (133

| 68.6%) of the participants have experiences with process models or process modelling. Much fewer participants (28 | 14.4%) use process monitoring tools in the context of their professional activities. Participants with both modelling experience and professional familiarity with monitoring tools (24 | 12.8%) are considered as the experts in our study. In the following, the study results of the experts (E) are compared with the ones of the non-experts (NE) to enable a profound analysis. The non-experts are composed of all participants expect the experts. Finally, the satisfaction score of 3.3/5 rated by the experts is slightly above a neutral rating, which indicates that existing monitoring tools are not perceived as satisfaction by users.

Intuitive view of progress: This section of the study deals with the intuitive view users have on the progress determination of a process. For this purpose, they are confronted with eight different progress variants, which they shall evaluate with respect to suitability and usability. Table 4 describes the considered progress determinations of Videos 1-8 as well as the average rating received from experts and non-experts, respectively. For Videos 1, 3, and 6 the scores of the non-experts and experts are almost the same (≤ 0.10). For Videos 2, 5, 7, and 8, the scores are slightly different (≤ 0.38). The biggest difference (0.50) occurs for Video 4.

In a nutshell, adjustments (cf. Videos 2 and 7) are perceived as more suitable and usable compared to progress jumps (cf. Video 1 and 3). Concerning the latter, forward progress jumps (cf. Video 1) are considered being more intuitive compared to backward progress jumps (cf. Video 3). The non-experts and experts rate slow and fast progress speed adjustments differently. Non-experts prefer progress that, from a certain point during process execution, is growing faster (cf. Video 2) as more intuitive than progress growing slower (cf. Video 7). The experts evaluate this the other way round. Note that the same observations can be made for the permanently increased (Video 6) and decreased (Video 4) progress. In practice, an unexpected more workload is more common, e.g., due to staff absence (illness) or defect tools. This might be one reason why experts perceive this as more intuitive, as they are used to such scenarios. Unexpectedly, the 90% problem is rated slightly above neutral (cf. Video 8). With the experts rating it even better than the non-experts. This might be related to the aforementioned habitual practice. Finally, the progress variant considered being the least usable by both groups is illustrated by Video 5, where the progress finished at 80%. Consequently, progress representations should utilise the full progress spectrum between 0% and 100%.

Scenario view of progress: Due to the additional information provided (cf. Section 3.3), participants get a better understanding of when and for what reason process changes become necessary. In the following analysis, first of all, Scenarios 1 to 3 are considered together, followed by an individual analysis of Scenarios 4 and 5.

Scenarios 1 to 3. In a nutshell, in the context of Scenario 1 (creation of instances), Scenario 2 (deletion of instances), and Scenario 3 (replacement of instances) we investigated whether progress speed adjustments (Option *A*) or

Table 4. Average evaluation of intuitive progress view for each video (#) by non-experts (NE) and experts (E).

#	**Description**	$\O_{NE}$	$\O_E$
1	Recalculation of progress at 60% and forward jump in progress.	3.02	3.04
2	Adjustment of progress speed at 60% and faster growing progress.	4.05	3.79
3	Recalculation of progress at 60% and backward jump in progress.	2.14	2.21
4	Progress becoming slower and slower over the entire process duration.	3.21	3.71
5	Progress growing equally, but finishing at 80%.	1.92	2.30
6	Progress becomes faster and faster over the entire duration.	3.52	3.42
7	Adjustment of progress speed at 60% and slower growing progress.	3.53	3.88
8	Progress growing uniformly up to 90% and then becoming slower and slower.	3.13	3.33

progress jumps (Option B) are preferred by users. In all three scenarios progress speed adjustments without jumps are preferred more than progress jumps:
Scenario 1: overall (140 | 72.2%), experts (17 | 70.8%), non-experts (123 | 72.4%);
Scenario 2: overall (124 | 63.9%), experts (14 | 58.3%), non-experts (110 | 64.7%);
Scenario 3: overall (158 | 81.4%), experts (20 | 83.3%), non-experts (138 | 81.2%).
Moreover, for all three scenarios the answers are analysed in detail. Table 5 gives an overview of the eight possible answer sequences for Scenarios 1 to 3. The sequences constitute all possible combinations of preferences regarding progress jumps and are grouped by their number: none, 1, 2, and 3. Half of the experts (12 | 50.0%) and almost half of the non-experts (78 | 45.9%) vote for Option A in all three scenarios, i.e., they prefer progress speed adjustments (without jumps). Furthermore, one third of the non-experts (57 | 33.5%) preferred Option B (i.e., progress jumps) in one of the three scenarios as opposed to only 4 experts (16.7%). Additionally, only 23 non-experts (13.5%) and 7 experts (29.1%) choose Option B in two of the three scenarios. Finally, 12 non-experts (7.1%) and 1 expert (4.2%) prefer progress jumps instead of progress speed adjustments for all scenarios. Figure 6 depicts the distribution of the preferred options for both non-experts and experts. In summary, progress speed adjustments (without jumps) are significantly more preferred than progress jumps even thought there are some opposing opinions.

Moreover, Scenario 3 reflects the real world most accurately. Usually, more than one unexpected event happens during run-time. In this case, Option A (no progress jumps) is preferred by 138 (81.8%) non-experts. The experts, in turn, show similar results (20 | 83.3%). The latter can be further divided into two subgroups: computer scientists who are developing process monitoring tools and professionals from economy, administration, transport, or logistics who use these tools in their daily business. Of the latter, 100% agreed that avoiding progress jumps is the better option for Scenario 3. This confirms the previous result.

Table 5. Percentage of possible answer sequences for Scenario 1-3 (S1-S3) are given by non-experts and experts.

S 1	S 2	S 3	$\%_{NE}$	$\%_{E}$
A	A	A	45.9	50
A	A	B	5.3	0
A	B	A	17.0	16.7
B	A	A	11.2	0
A	B	B	4.1	4.2
B	A	B	2.3	8.3
B	B	A	7.1	16.6
B	B	B	7.1	4.2

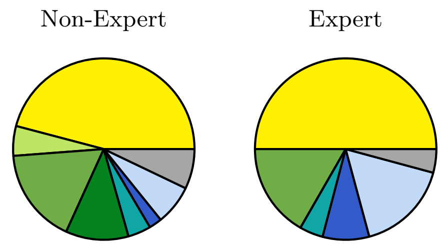

Fig. 6. Associated pie diagram for percentage distribution of Table 5.

Scenario 4. Previously entered data are still available when jumping back to an already completed form. For Option A, progress is determined on the basis of the already entered data. Therefore, a backward jump to a previous form sheet does not affect the progress of the process. For Option B, however, the progress is correlated with the currently edited form. Consequently, progress drops when jumping back to an already completed form. The non-experts (102 | 60.0%) and experts (14 | 58.3%) rate this scenario similarly and prefer the first progress determination without dropping progress.

Scenario 5. Progress is determined based on the calculated time (Option A) or work-based (Option B). Non-experts (101 | 59.4%) and experts (13 | 54.2%) preferred the work-based approach for this scenario. Especially the results of the experts, however, have revealed no clear preference. This scenario will therefore be re-considered in a more detailed study in future.

Outlook Section of the Questionnaire: This part of the study helps us to define the accepted delay due to the progress determination of process monitoring tool and gives an overview of other possible monitoring components. In the following, the maximum accepted delay due to progress determination is investigated. In the **first step**, outlier detection is conducted. When a participant specifies a maximum accepted delay of the progress determination, which is larger than total the process duration, all for possible answers of this participant related to delay of the monitoring tool (i.e., hour, day week and month accepted delays) are omitted. Additionally, if the accepted delay for a process lasting an hour is bigger than for a process lasting a day (the same applies to: hour > day > week > month) from one participant, it can be assumed that this participant has misunderstood the given format for this question. For this reason, answers from such participants are omitted as well. This results in a total of 186 participants (164 non-experts and 22 experts) for the following analysis.

In the **second step**, a `Pearson Correlation` is performed, due to the expected linear dependency. Table 6 shows the results of this analysis. Note that the result correlation may be between -1 and $+1$. The larger the absolute value of the coefficient is, the stronger the relationships between the variables are. However, in all relations there is only a `moderate correlation` $(0.40 - 0.69)$ or `strong correlation` $(0.70 - 0.89)$ and not, as expected, a `very strong correlation` $(0.90 - 1.00)$ [10].

Table 6. Analysis of `Pearson` and `Spearman` correlation with $N = 186$. Moderate, Strong, and Very strong.

	Pearson				Spearman			
Relation	NE		E		NE		E	
Hour & Day	0.748	S	0.637	M	0.816	S	0.835	S
Hour & Week	0.631	M	0.621	M	0.708	S	0.644	M
Hour & Month	0.646	M	0.499	M	0.687	M	0.520	M
Day & Week	0.807	S	0.622	M	0.859	S	0.846	S
Day & Month	0.729	S	0.429	M	0.835	S	0.729	S
Week & Month	0.809	S	0.849	S	0.891	S	0.890	S

Using the results of the `Pearson Correlation`, the following hypothesis can be established and investigated in a **third step**: *The longer the total duration of a process is, the smaller the percentage share of accepted delay from the total process duration is.* Having a closer look at the average accepted delay due to progress determination we perceive the hypothesis backed up with 9.1% for the one-hour process, about 5% for both a one-day-process and a one-week-process, and 0.6% for a one-month-process. Furthermore, for some participants it can be observed that the longer the process duration is, the more similar the accepted delays become. These results indicate the existence of an absolute upper limit for the accepted delay caused by the determination of the progress. This assumption is further supported by the different delays accepted by the experts and non-experts. For this reason, an additional `Spearman Correlation` is performed (cf. Table 6), which is suitable for monotonic functions. As opposed to the `Pearson Correlation`, the `Spearman Correlation` results in significantly more strong correlations as expected.

In the **fourth step**, the maximum accepted delay caused by progress determination is visualised with the boxplot diagrams as shown in Figure 7. For each of the four given total process duration's (hour, day, week, and month) a boxplot, which represents the accepted delay by the quartiles and the average of the experts and non-experts are depicted. All values are given in seconds (for better visibility, the scale of time (y-axis) is individual for each process duration). In summary, the smaller quartiles of the experts indicate that they have a very similar understanding of progress delays. In contrast, the results of the non-experts show significantly more outlier points and a larger span of the boxplot. Except

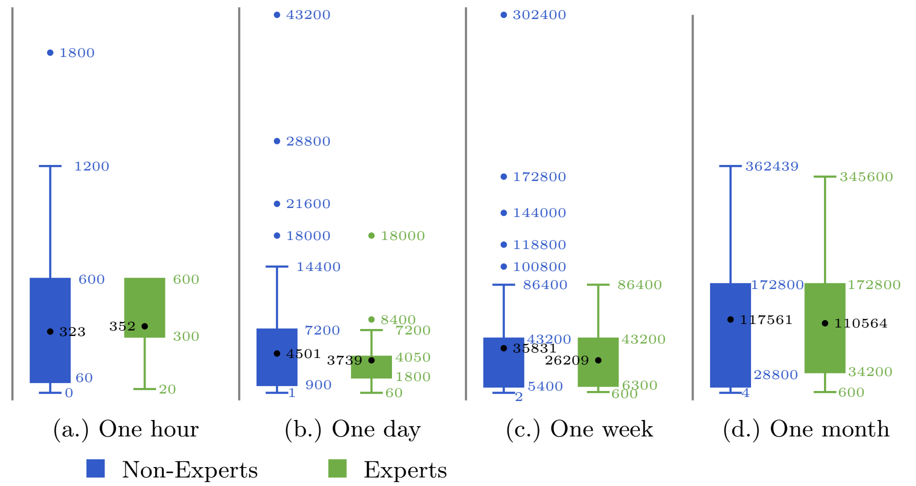

Fig. 7. Boxplot diagram showing the accepted delay caused by progress calculation for the different process duration's in *seconds* for non-experts and experts.

for the one-hour process, the average of the accepted delays are smaller for the experts in comparison to the non-experts.

The last question investigates which monitoring component should be covered by a process monitoring tool (Question A) and which should be implemented next (Question B). No distinction is made between experts and non-experts. For Question A, five possible additional components are given and multiple answers are allowed. Figure 8 (a) shows the answers to this question. Note that all five options are equally distributed (about 20%). To conclude all components seem to be relevant. Moreover, participants may name further components of a process monitoring tool. Proposed components include *Completed sub-processes*, *Early warning through pattern recognition based on machine learning*, and *Heat and failed tasks*.

For Question B, the most important monitoring component besides progress determination should be chosen. The distribution is shown in Figure 8 (b). This indicates, that *Alarm Trigger and Error Warnings* is preferred by the majority (38,7%) of the participants.

5 Related Work

To the best of our knowledge there exist no works dealing with progress determination in process monitoring tools. In participant, this applies to *object-aware BPM*, as there exists no comparable approach that offers the same flexibility as PHILharmonicFlows does (e.g. ad-hoc changes of running process instances) [11]. Consequently, no monitoring rules for processes being subject to ad-hoc changes in *object-aware BPM* approaches exist.

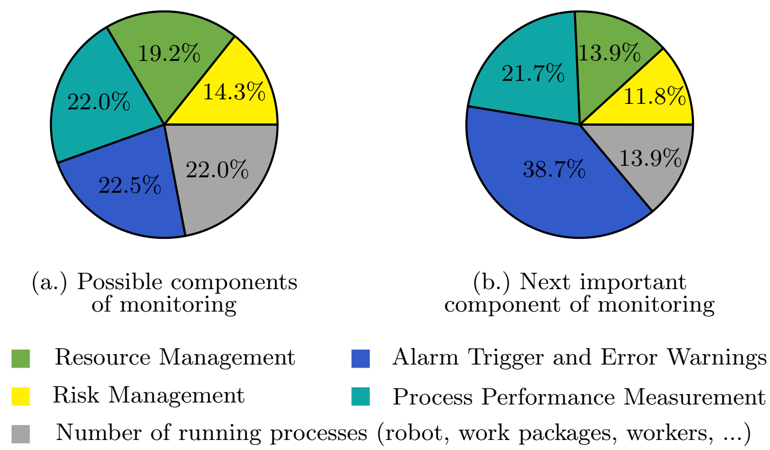

Fig. 8. Evaluation of which components of a monitoring shall be part of a process monitoring tool (a) and realised next (b).

Concerning *data-centric BPM*, only few approaches offer this flexibility during process execution. In *artifact-centric BPM*, for example, process executions are driven by business data [12]. Moreover, a tool for designing and modelling *artifact-centric* processes exists. There is no intuitive tool support for executing and monitoring corresponding instances in the large scale (as in the case of our PHILharmonicFlows engine) [13].

A second approach for *data-centric BPM* is *case handling*, which is based on the idea what can be done to achieve a business goal [14]. With Flowers a tool exists, which supports the design, implementation, and execution of data-centric processes, but does not provide comprehensive monitoring support [13]. Note that other data-centric approaches to BPM are available. However, all of them are limited compared to the *artifact-centric BPM* and *case handling* paradigms [13]. In summary, no related works of dynamic process changes exist.

Furthermore, there exists research emphasising the importance of progress indicators. The study presented in [15] shows that progress representation can influence perception of a user concerning the duration of a task. This progress representation influences the decision whether a task (e.g., in form of a online questionnaire) is abandoned or continued. Thereby, progress representation is displayed with different progress speed throughout the total questionnaire. As a result, this study shows that the slower the progress is in an early stage of the questionnaire the higher abandonment rates are [15]. Furthermore, the experiment presented in [16] shows that progress representations are important and useful for user-interaction tools. Additionally, [16] underlines that users prefer tools with progress visualisation.

6 Summary and Outlook

All the defined research questions could be addressed. Progress determination and visualisation should always end up with 100% progress upon process termination (SR1). When ad-hoc changes occur, progress speed adjustments without jumps are considered being more suitable and usable by the majority of the users (SR2). 100% of the experts with a profession in economy, administration, transport, or logistics agreed that no progress jumps are the best option, particularity when facing more than one ad-hoc change (SR3). The well-known 90%-problem (i.e., progress needs significant more time for the last 10% of the work than for the first 90%) is evaluated slightly more suitable than neutral. Previously entered data are still available when jumping back to an already completed form the majority of the participants preferred progress speed adjustments without jumps (SR2). Additionally, work-based progress calculation is favoured compared to time-based one by a small majority (SR3). Furthermore, the study evaluation indicates, which components are essential for monitoring tools and should therefore be considered in further tool releases.

The conducted study confirms a generally accepted understanding of process progress (Main Research Question). However, further research is needed to gain a deeper understanding of progress in data-driven processes aware information systems and its perception by end-users. For example, a *Delphie* study with a focus on experts might provide additional insight into prediction needs.

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