# Improving Automatic BPMN Layouting by Experimentally Evaluating User Preferences

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# Improving Automatic BPMN Layouting by Experimentally Evaluating User Preferences

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**Abstract.** BPMN Process Models are the basis for implementing and optimizing business processes in the era of digitization. Good layouts of BPMN diagrams help readers to better understand them. In order to improve the quality of automatic layouting, we need to identify subjective and objective characteristics of diagram layouts. While research into objective criteria has been ongoing, we want to evaluate subjective layout preferences by model readers. Therefore, we conducted an experiment, which let participants select the preferred layout out of two layout variants. The experiment yields significant findings for subjective layout preferences, e.g., with regards to spacing of elements, layout options after gateways, and the routing of message flows. The findings help modelers to produce better process models and we incorporated them in an automatic layout tool.

**Keywords:** BPMN, Automatic Layout, Experiment, Element Size, Element Placement, Edge Routing, Boundary Event Placement

## 1 Motivation

Business processes are continuously evolving. Especially in digitization projects, processes are analyzed, optimized and implemented in software.in order to improve their efficiency. Processes have to be presented in a unified and consistent manner to allow for easier analysis and optimization. BPMN was created to tackle these problems and allows the modeling and presentation of business processes with a standardized notation. Syntactical rules are defined to guarantee the correct usage of the notation elements; each for itself and within the context of the model. The layout of the associated diagram, however, has to be created manually by the modeler. Rules considering the position and order of the elements have been defined to a certain extent but are mainly focused on the semantics of the corresponding elements and the definitions of the BPMN specification [11].

Layout principles helping to create BPMN diagrams, which are easily comprehensible and visually pleasing, have not been researched as much. However, it has been examined that the layout can improve the intelligibility of a diagram [9]. Specified layout principles are thus necessary to develop an automatic layout algorithm. Part of our research project was to find out which layout principles are preferred by model readers. The resulting experiment, its results and their interpretation are described in this paper.

This paper is structured as follows: Related work is discussed in the next section. Section 3.1 presents the experiment design. The results are presented in Section 4 and are interpreted in Section 5. Section 6 presents the take-aways for automatic BPMN layouting before we finally conclude and give ideas for future research.

## 2 Related Work

Kitzman et al. developed a grid-based layout algorithm for BPMN models [5]. The generator specifies the ordering of BPMN elements relative to each other (e.g., next to, below, ...). The grid needs to be transformed into absolute coordinates. The describing paper does not give the values used by the generator nor does it justifies any absolute positions empirically.

Specific layout criteria for BPMN diagrams have already been defined in the works of Effinger et al. [4] which were mostly covered by Kitzmann et al.'s algorithm. Criteria like keeping the workflow direction or minimizing overlapping elements, for example, were already fulfilled through the grid-based approach. Furthermore, Effinger et al. developed an algorithm, which globally optimizes the placement of BPMN elements. However, elements are placed without a strict relation to each other. Therefore, the example diagrams do not have an as clear layout direction as the diagrams layouted by the Kitzmann et al.'s algorithm.

Most of the aforementioned layout criteria were researched in-depth by Purchase et al. and refined into specific metrics to measure the presence of those criteria in graph drawing algorithms [8]. For example, this includes the minimization of edge bends. Furthermore, it has been examined which of those criteria are actually preferred for domain-specific graphs like UML diagrams [7]. Siebenhaller & Kaufmann used those criteria to develop a new layout approach for activity diagrams [10]. Their work is based on a combination of the TSM approach of Tamassian et al. [14] and the Sugiyama approach [13].

Störrle conducted several experiments in his series "On the Impact of Layout Quality to Understanding UML Diagrams" [12]. Most notably he found that diagrams are profiting more of a good layout in their early lifecycles. He also hypothesizes that layout is benefiting more from the simultaneous use of many different principles; every single one in isolation, however, has not as much impact on the end result.

## 3 Experimental Design

### 3.1 Goals, Hypothesis & Variables

Nick & Tautz [6] demonstrated that the extended use of the Goal-Question-Metric (GQM) approach [1] in guiding research can be very helpful. We follow it and started by defining our goal as

| |
|---|
| *Understand* the *User Preferences*<br>with regard to the *Layout of BPMN 2.0 Diagrams*<br>from the viewpoint of a *Model Reader*. |

From this goal we derived our research questions numbered RQ1 to RQ7:

**RQ1: Which horizontal spacing, i.e., the distance between two BPMN elements, is preferred?** Automatic layout tools need to place elements not only relatively to each other but also calculate absolute positions. Therefore, we need to evaluate which horizontal spacing between elements is preferred. We created three diagrams with small, medium and large spacings, which correspond to 25%, 50% and 70% of an activity's width.

**RQ2: Which vertical spacing, i.e., the distance between two BPMN elements, is preferred?** Similarly, we evaluate the vertical spacing with three options small, medium, and large, which correspond to 12.5%, 25%, and 50% of an activity's height.

**RQ3: What relative size for subprocess contents compared to main process elements is preferred?** The activities within a subprocess can have the same size and spacing as the rest of the diagram. In order to highlight the hierarchical structure, activites could be made smaller. The freed space can be used to make the diagram more compact. Therefore, want to evaluate preferences for these three diagram options (same sizes and spacings as rest of process, smaller-sized activities, and totally smaller-sized subprocesses).

**RQ4: What placements of BPMN elements after gateways are preferred?** A BPMN gateway represents a decision point. Multiple sequence flows start from the gateway and form different branches in the diagram. The branches can be symmetrical, i.e., one branch is higher than the gateway and the other is lower, or one branch could extend on the level of the gateway while the other branch is offset above or below. In addition, branches can contain the same number of activities or have different sizes. We want to evaluate preferences of branch placement after gateways for these cases.

**RQ5: What placements of pools are preferred?** BPMN diagrams can use collapsed and uncollapsed pools. Collapsed pools hide the control flow with the modeled party. Collapsed pools usually exchange messages represented with message flows with other pools. We want to evaluate whether there are preferences on placing collapsed pools above all other pools or whether they can be distributed on top and below an uncollapsed pool.

**RQ6: What routing strategy of message flows is preferred?** Message flows represent messages between different pools. Because the process in the pools is usually differently complex, message flows require more sophisticated routing, i.e., they need to be bent or the process models need ot be changed in order to make space for them. We want to evaluate preferences for different options on routing message flows.

**RQ7: What placements of boundary events are preferred by model readers?** BPMN defines boundary events, which are placed on the edge of an activity. The standard allows to attach events at all places on the border. We want to evaluate, whether there is a preference for the bottom border, which is often used in examples and books (e.g., [11]) or whether the placement can occur on the top and bottom, especially when many boundary events are attached.

The metrics for all questions is the subjective preference between diagrams exposing the different layout options as shown in Figure 1.

### 3.2 Objects & Participants

The experiment was conducted as an online test. Participants could test themselves for their "BPMN Modeler Type" by choosing the diagrams, which they liked best. For this they had to choose the best out of two model layouts: Diagrams were syntactically the same but differed in one aesthetic characteristic. All diagrams are shown in Figure 1. The concrete pairs of diagrams the participants had to choose between are listed in Table 1. After a participant had answered all questions a summary of his/her layout preferences was shown, i.e., the BPMN Modeler Type was described.

We advertised the BPMN quiz on various social media platforms (Facebook & Xing) and at the university's student forums. Furthermore, we sent out invitations to personal contacts and asked for snowballing the invitation to colleagues.

The quiz is programmed to log every user choice to one CSV file per user. Each choice consists of a unique session ID, the question to be answered, and the user's answer. This means that a trace of user decisions is available for statistical analysis. Because the data is collected in parallel to the quiz no further instrumentation is required.

### 3.3 Analysis Procedure

The data will be aggregated and the number for each of the two answers for every question will be counted. This means that $x_q <= n$ out of $n$ participants will have opted for answer $x$ for a given question $q$ and in turn $y_q = n - x_q$ participants will have opted for answer $y$.

If we code all participants, who chose answer $x$, as 0 and the others as 1 and sum up their answers, we will get a mean value of $m_q = y_q/n$ for a given question $q$.

If the difference in layout is insignificant, i.e, the users randomly choose one of the answers, the null hypothesis is $x_q = y_q$. In this case $m_q = 0.5$ holds. The expected standard deviation for the null hypothesis is 0.5. We will use a z-test with a 5% alpha-level to test whether the actual measurements for each question differ significantly from this null hypothesis. The effect size is calculated using Cohen's d.

### 3.4 Evaluation of Validity

In order to eliminate learning effects the order of all questions was randomized. In addition, to avoid bias due to the order of the presented options, the order of the two answers was randomized for every question as well.

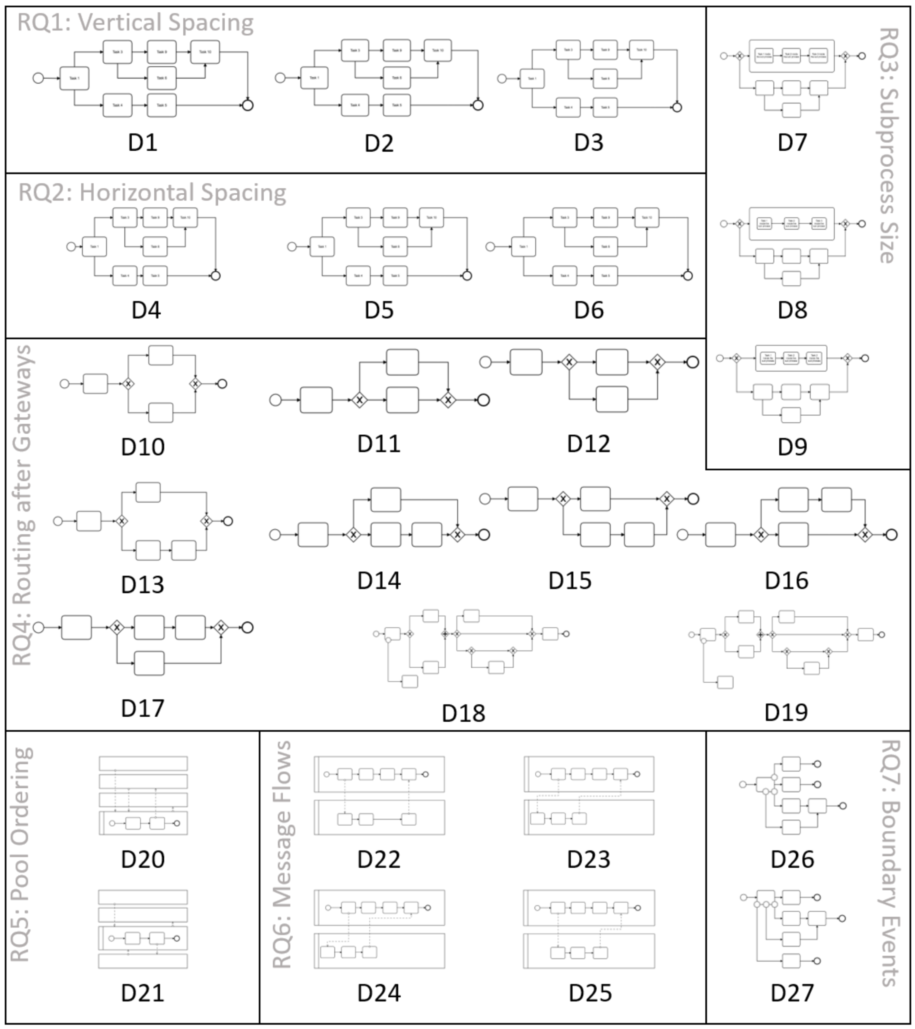


**Fig. 1.** Diagrams used in Experiment

However, our control over both the experiment participants is limited. This applies to both the sampling of the participants as well as the way how seriously they conduct the quiz. The sample might be not representative of BPMN modelers and participants might just click through the quiz out of curiosity.

## 4 Analysis

121 people participated in our experiment. We excluded the data for a) duplicate IP addresses (which seemed to come from bots) and b) incomplete data sets. This left us with 70 records.

**Table 1.** Statistics Summary for Experiment Questions

| | Option A | Option B | Count A | Count B | p-value | Eff/d |
|---|---|---|---|---|---|---|
| Q1 | D1 | D2 | 35 | 35 | 1.00000 | 0.00 |
| Q2 | D1 | D3 | 25 | 45 | 0.01683 (*) | 0.29 (+) |
| Q3 | D2 | D3 | 31 | 39 | 0.33898 | 0.11 |
| Q4 | D4 | D5 | 21 | 49 | 0.00082 (***) | 0.40 (+) |
| Q5 | D4 | D6 | 28 | 42 | 0.09426 | 0.20 |
| Q6 | D5 | D6 | 37 | 33 | 0.63259 | 0.06 |
| Q7 | D7 | D8 | 48 | 22 | 0.00189 (**) | 0.37 (+) |
| Q8 | D7 | D9 | 37 | 33 | 0.63259 | 0.06 |
| Q9 | D8 | D9 | 31 | 39 | 0.33898 | 0.11 |
| Q10 | D10 | D11 | 51 | 19 | 0.00013 (***) | 0.46 (+) |
| Q11 | D10 | D12 | 46 | 24 | 0.00855 (**) | 0.31 (+) |
| Q12 | D11 | D12 | 31 | 39 | 0.33898 | 0.11 |
| Q13 | D13 | D14 | 37 | 33 | 0.63259 | 0.06 |
| Q14 | D13 | D15 | 27 | 43 | 0.05583 | 0.23 (+) |
| Q15 | D14 | D16 | 46 | 24 | 0.00855 (**) | 0.31 (+) |
| Q16 | D15 | D17 | 52 | 18 | 0.00005 (***) | 0.49 (+) |
| Q17 | D18 | D19 | 19 | 51 | 0.00013 (***) | 0.46 (+) |
| Q18 | D20 | D21 | 40 | 30 | 0.23200 | 0.14 |
| Q19 | D22 | D23 | 57 | 13 | 0.00000 (***) | 0.63 (++) |
| Q20 | D23 | D24 | 45 | 25 | 0.01683 (*) | 0.29 (+) |
| Q21 | D22 | D25 | 50 | 20 | 0.00034 (***) | 0.43 (+) |
| Q22 | D23 | D25 | 17 | 53 | 0.00002 (***) | 0.51 (++) |
| Q23 | D26 | D27 | 27 | 43 | 0.05583 | 0.23 (+) |

We used the z-test for statistically determining whether we could reject the null hypothesis that no differences in user preferences exist for each pair of diagrams. All gathered counts, as well as p-values and the effect sizes are shown in Table 1. p-values below 0.05 are deemed a significant finding (*). p-values below 0.01 are marked with (**), and below 0.001 are marked with (***). Effects above 0.8 are deemed a large effect size (+++), above 0.5 a medium effect size (++), and above 0.2 a small effect size (+).

In total we found 2 *-significant differences (Q2 & Q20) below 0.05, 3 **-significant differences (Q7, Q11, Q15) , and 7 ***-differences (Q4, Q10, Q16+Q17, Q19, Q21+Q22). For all these significant differences, 2 had a medium effect size (Q19, Q22) and the rest had a small effect size. Two differences had a small effect size (Q14 & Q23) but gained only a nearly significant p-value.

In addition to our measurements one participant emailed us feedback and told us that his/her preference for positioning of elements after a split is context-dependent: if the probability of the branches is the same, he/she prefers the symmetric split. Otherwise, the most probable branch should extend on the same level as the gateway.

## 5 Interpretation

### 5.1 Evaluation of Results & Implications

Overall the number of usable data points (n=70) is relatively small. However, due to the experiment design, many of the significant findings have a very low p-value. Overall, we were positively surprised by the high number of significant findings of subjective layout preferences. The findings are explained in more detail in the following.

**RQ1: Which vertical spacing, i.e., the distance between two BPMN elements is preferred?** Considering the results for diagrams with varied vertical spacings, not all cross comparisons yield significant results. However, all in all, large vertical spacings are overall preferred by readers. They are significantly preferred over small spacings (Q2) and are non-significantly preferred over medium spacings (Q3).

**RQ2: Which horizontal spacing, i.e., the distance between two BPMN elements is preferred?** As with vertical spacings not all cross comparisons yield significant results, medium horizontal spacings are overall preferred by readers. They are significantly preferred over small spacings (Q4) and are non-significantly preferred over diagrams with large spacings (Q6).

**RQ3: What relative size for subprocess contents compared to main process elements is preferred?** Experiment participants favored that the subprocess has the same layout (size and spacings of activities) as the embedding process. Significant differences were found compared to adjusting the activity sizes (Q7), although the preference compared to subprocesses that are smaller altogether is only minimal (Q8).

**RQ4: What placements of BPMN elements after gateways are preferred?** The preference of element placements after a gateway seems to be dependent on the characteristics of the branches: In questions Q10 to Q12 only one activity was in each branch. In this case the symmetrical split, i.e., one branch continues above the gateway and one below the gateway, is significantly preferred over the other variants. However, when one branch consists of two activities and the other one only of one activity, preferences change: Depending on whether the second branch is above or below the gateway, it is preferred that the longer

branch is on the level of the gateway (Q15) or below the gateway (Q16). Comparing symmetric splits to non-symmetric splits yielded no significant results (Q13/14). Space after gateways should be minimized and not tried to be made consistent with other gateways (Q17).
**RQ5: What placements of pools are preferred?** No significant difference was found between the two offered layout variants by placing all collapsed pools on top or distributed on top and on the bottom (Q18). Therefore, no subjective preference can be evaluated.
**RQ6: What routing of message flows is preferred?** All questions regarding preferences for routing the message flows yielded significant results. In general participants preferred less bends in the message flows. The variants in which activities in all pools were distributed so that message flows ran straight were preferred (Q19 & Q21). If not given this option, it is preferred that the left-most message flow is not bent (Q20 & Q22). All in all, existing literature, which says that edge bends are to be avoided, was fully confirmed.
**RQ8: What placements of boundary events are preferred by model readers?** The result of question Q23 is nearly significant ($p = 0.056 > 0.05$) in favor of using only the bottom edge of an activity to place boundary events but it has a small effect size ($d = 0.23$). Further research is required in order to judge whether this layout is significantly better or not, although our results indicate that this is probable. For choosing an option for automatic layouts, it is therefore currently sensible to place boundary events only at the bottom.

### 5.2 Limitations of Study

This experiment exclusively focused on the layout of BPMN diagrams. This also means that no business context was given for the BPMN models and users simply voted for the best aesthetics but not necessarily for the most understandable model. However, "[i]n general, researchers associate aesthetics with readability, and readability with understanding" [2].

Because no business context is present, some results may be refined. One angle is the suggestion by one practitioner for layouting gateways differently based on the probability of branches. Context could also influence placing of pools, e.g., importance or time of involvement in process orchestration might be a context factor for layouting different pools.

All diagrams were layouted left to right, i.e., horizontally. Some results – especially vertical and horizontal gaps – are therefore probably not generalizable to vertical layouts.

## 6 Improvements for BPMN Layout Algorithms

Our goal was to improve the current state of automatic BPMN layouting. As such, we wanted to incorporate our findings into a generator tool. As the basis we chose the algorithm of Kitzmann et al. [5] because it generates diagrams that look more like human-modeled BPMN. The algorithm by Effinger [3] tries to excel on objective metrics but does not necessarily place consequitive activities in a row in order to avoid edge crossings.

Kitzmann et al.'s BPMN layout algorithm follows a local strategy: Activities are first sorted and then placed activity by activity into a grid. The grid is expanded as required during this process. Finally, the grid is optimized by removing cells, which are not required.

The grid and the containing BPMN elements are then written back as a valid BPMN model following the OMG's standardized BPMN XML format. This grid-structure allows easy implementation of the findings: When calculating absolute positions from the relative grid, the horizontal and verticals spacings can be easily considered.

We also added support for the layout of boundary events. Although there was only a near-significant finding for the placements along the bottom of the activity, this was the most preferred option. Consequently, the layout tool is implemented to support the layout boundary events at the bottom edge of an activity. The Java implementation of the BPMN layouter is freely available on GitHub[1].

## 7 Conclusions & Outlook

Within this paper we described an experiment, which aims for evaluating subjective layout diagram choices. The preferred constructs have been implemented in an automatic BPMN layout tool, which is freely available. However, the findings can also guide modelers to create better process diagrams, who manually layout their models.

The findings were that a) medium horizontal spacing and large vertical spacing were preferred by the participants, b) sub-processes should be layouted with the same sizes and spacings as the rest of the process, c) splits after gateways should be symmetric if the number of activities are the same in both branches and should otherwise contain the branch with the most activities in the same level as the gateway, and d) message flows should have no bends even if this means to add additional spacings between the activities in the pools.

However, while we could find many significant preferences, more research questions emerged: Especially the influence of the semantics of the modeled process could have an influence on the layout being used. Also we found a nearly significant finding for placing boundary events, which should be explored further in future research. Our experiment did not dive deeply enough into the placement and order of pools. Positioning those is a further research possiblity worth pursuing. Furthermore, our experiment used small, simple diagrams in order to control for layout choices better. However, the experiment could be extended to cover larger diagrams and see what preference patterns emerge.

We encourage everyone to use our BPMN layouter tool and explore more improvements for automatic layouts of BPMN processes!

[1] https://github.com/t0b1z/BPMNLayouter

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