# Pro2Screen – High-Fidelity-Prototyping of Mobile Enterprise Applications using Process Models

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***Abstract*—Mobile Enterprise Applications are becoming more and more relevant to enterprises as the dissemination of smartphones has risen over the last decade. However, developing these applications is a very challenging and resource-intensive task. In this context, prototyping can lead to several benefits, including a better app usability. While Mobile Enterprise Applications are often used to support or carry out business processes, no low-code mobile prototyping approach exists that is based on business process models and is adapted to the needs of non-developers. In this paper, we present the tool Pro2Screen that fills this gap. The tool uses a Business Process Model and Notation (BPMN) model annotated with screen designs as a source for generating a prototype. The prototype is integrated with a business process execution engine that runs the business process. To demonstrate the effectiveness of Pro2Screen, we present a user study with experts from the field of Mobile Enterprise application development. The user study shows that the approach is able to tackle important aspects of prototyping in Mobile Enterprise Application development and enables practitioners with little or no coding experiences to develop prototypes that closely resemble functional aspects of a final product.**

***Keywords–Mobile Enterprise Application; BPMN; Process Model; Prototyping.***

## I. INTRODUCTION

Since the beginning of the decade, mobile applications have become more and more ubiquitous. This trend also reached enterprises, where employees expect to use smartphone apps for their daily work with the high usability they are accustomed to from using consumer apps. These expectations and the continuously and fast changing ecosystem of mobile app development pose a significant difficulty for the development of Mobile Enterprise Applications (MEA). In our previous work, we proposed the prototyping approach Pro2Screen for MEAs [1] that is extended in this paper.

MEAs differ from regular consumer apps in several ways, e.g., they are often used to support some kind of business process, have only few potential users in comparison to consumer apps and need to adhere to enterprise specific guidelines [2]. Integrating business processes into mobile applications means implementing new interfaces to process engines and adhering to process guidelines are some of the challenges for MEA development that are caused by MEA-specific aspects. Since other aspects of mobile application development also need to be taken care of, these factors contribute to developing MEAs being a time consuming and expensive process.

To reduce the effort required to develop mobile applications in general, prototyping can be used. A good prototyping process can prevent misunderstandings and make the conceptual phase of the development process prior to coding significantly easier to handle and therefore reduce costs [3][4]. More important, this can also allow a better usability of the final product which will improve the willingness of employees to use the final MEA. However, no prototyping tool that supports all of the aforementioned aspects of MEAs exists. To our knowledge, there is no prototyping approach that caters to the business process aspect of this type of application and does not require coding.

This paper is an extension of [1], which presented the prototyping approach Pro2Screen. Pro2Screen focuses on using business process models [5] as the primary source for MEA prototypes. Our approach enables designers and business engineers to create prototypes with several user roles and process steps that connect these roles. For the creation of the prototype, no coding experience or background in formal modeling is required. This is accomplished by annotating visual representations of business process models with screen designs and creating a prototype using code generation and business process execution engines that can interpret and automatically execute business processes.

The description of the approach is extended by a discussion of an evaluation with MEA development experts and a discussion of the results of the approach. The evaluation consists of a user study, where users were given a task to fulfill using Pro2Screen and answer a survey. This work is embedded into the scope of the Prototyping Framework for Mobile App Design in Large Enterprises (PROFRAME) [6]. The presented work will lay the foundation for the implementation of PROFRAME.

The remainder of this paper is structured as follows: Section II gives a brief overview on related work and identifies the research gap. The general approach of this paper is presented in Section III. Details on the behavioural modeling of the prototypes are given in Section III-A, designing screens is discussed in Section III-B and code generation and prototype execution are presented in Section III-C. The implementation is described in Section III-D. A user study and its results are presented in Section IV. The methodology of the evaluation is discussed in Section IV-A. Section IV-B presents the questionnaire. Results of the questionnaire are discussed in Section IV-C. Section V discusses advantages

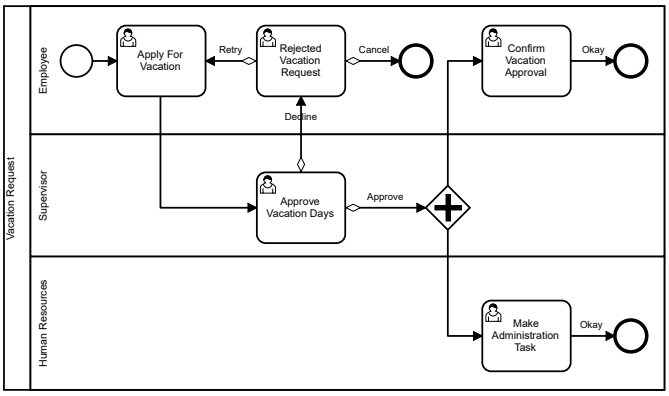


Figure 1. Example Process

and disadvantages of Pro2Screen including findings from the evaluation. A conclusion is given in Section VI.

## II. Related Work

According to [2], a huge gap between the development of MEAs and standard non-mobile enterprise applications can be observed. However, the demand for MEA development in the next few years will be much higher than the supply [7]. Hence, it is important to support a very efficient way of implementing MEAs.

One way to improve the development of MEAs is improving the prototyping process. Several models for classifying prototypes have been proposed in the literature. Nielsen [4] proposed a distinction between vertical and horizontal prototyping fidelity. A horizontal prototype supports most functionalities of a product, whereas a vertical prototype allows only a few functionalities but is technically more similar to the final product. The filter fidelity model [8] adds more dimensions to this view, e.g., regarding interactivity, data model, weight and many other dimensions. Breadth and depth of functionality are also included in this model.

For prototyping mobile applications in general, many products and approaches can be found in the literature. However, regarding prototyping for MEAs, only a few tools can be found (e.g., Kony, Verivo Akula and SAP Mobile) [9]. These tools are often focused on a specific use case or bound to a specific platform. None of them take business process modeling into account, so the depth of functionality according to the filter fidelity model is low.

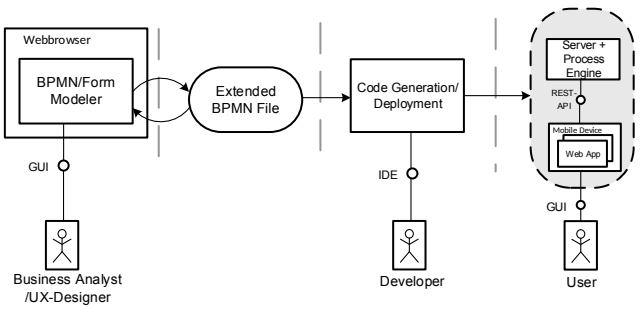


Figure 2. Pro2Screen Architecture

Integrating process models into application development has been discussed in the area of process-driven development. AgilePDD [10] proposes an agile approach to implementing business processes. In the prototyping phase of this process, business process models are used to define the behaviour of the prototype. While this approach seems promising, it does not define how a prototype should be generated from the process model or how process steps should be represented as screens. The approach is in general focused on modeling use cases with business process models, whereas generating code from these models is only mentioned as an option to be considered [11].

Similar work has been conducted in the area of model-driven development using models formulated in the Business Process Model and Notation (BPMN). BPMN [12] is the most popular language for modeling business processes [13][14]. This area focusses on supporting the coding of applications by generating parts of applications from BPMN models. A platform used in this context is WebRatio [15]. WebRatio allows the implementation of mobile applications by modeling them in BPMN. While WebRatio can be used for prototyping, the platform tries to help developers with a background in coding and formal modeling and can not be used by users not experienced with these techniques. Other approaches like Axon.ivy [16] is a similar approach that is even more tailored at coders.

From the presented literature, we can conclude that no prototyping approach or tool for MEAs exists that facilitate a high fidelity regarding the representation and integration of business process models into the prototype and cater to the needs of UX designers and Business Engineers that do not have a background in coding. Also, there should be no requirement for a deep understanding of formal modeling approaches prior to using the tool. This issue is at the core of our research, since a prototype that better resembles the final product can help improve its usability.

## III. Approach

We consider three major requirements for our work: the tool needs to support (1) modeling a business process, (2) designing a user interface and (3) generating a platform-independent prototype that can be executed on mobile devices. The basic idea of our approach is to use business process models as the primary source for the prototype. The process model defines the behaviour of the app. To add a graphical user interface, the process model is annotated with screen designs for specific parts of the business process. With this information, a prototype for the app is generated.

In practice, several implementations of process engines exist. They are able to interpret and execute BPMN models and integrate business processes with several backend systems. Therefore, BPMN is used as the process model language in the presented prototyping tool.

An overview of the prototyping process is given in Figure 2. A Business Analyst/UX Designer uses the *BPMN/Form Modeler* to create a model of the process that shall be implemented with an app including a user interface design. To model the process itself, one can simply use an existing process modeling tool that supports BPMN. This can be done in close coordination with the customer, e.g., at a kick-off-meeting for a project. The result of this process is an *extended BPMN file*. Internally, this file can then be used to generate a

*Web App* that cooperates with a business *process engine*. The customer can then use this app as a prototype, which allows a clear separation of the code generation and the prototype modeling. For customization, a developer that modifies the code generation can be included in the process.

To support the described process, answers to the following questions are required: What aspects of a process should be represented as screens (Section III-A)? How can screens be designed and how can data be reused over several screens (Section III-B)? How are prototypes generated (Section III-C)?

### A. Process Model

BPMN in general is well-known for its graphical representation of business processes. An example model is shown in Figure 1. The most important element of BPMN is the *task* (e.g., *Apply for Vacation*). Tasks represent any kind of activity. Several kinds of tasks exist, the kind of task is represented by a icon at the top of a task. *Apply for vacation* is a user task and *Check Vacation request* is a script task. User tasks require user interaction whereas script tasks are automatically executed by the business process engine.

To connect tasks, so called *Sequence Flows* that are represented by arrows are used. Gateways (represented by rhombuses) are used to model situations where the flow is split, either because of decisions (x) or parallel execution (+). The swimming pool element (*Vacation Request*) is used to structure the control flow. A swimming pool can contain multiple swimlanes (e.g., *Employee*) that distinguish different domains of activity.

Our approach proposes a representation of tasks as screens: when the model is executed, each user task corresponds to one screen on the mobile device. A swimming pool corresponds to an app and a swimlane corresponds to a user role. For the example shown in Figure 1, users with role *Employee* would be shown at most three different screens (*Apply for Vacation, Vacation Request Rejected* and *Confirm Vacation Approval*) and users with role *Supervisor* or *HR* one (*Approve Vacation Days* and *Start Administrative Task*). Sequence flows determine the control flow of the business process.

### B. Form Modeler

To design the forms that correspond to user tasks, a form modeler is used that is able to store screen designs as annotations in BPMN files. The form modeler needs to add a screen design to each user task and store the design as an annotation in the BPMN model. A screenshot of the form modeler that implements this idea is shown in Figure 3. The user of the form modeler can drag and drop user interface components (1), e.g., *Plain Text*, *Text Inputs* and *Radio Buttons*, into the screen layout (2). Properties of components can be modified using controls on the right (3).

Our approach uses a grid layout to model the screen design. By using a grid layout, the prototype is not bound to a specific screen size or orientation. The grid is shown as dashed lines in the screenshot. Users can add and remove rows and columns. Each cell in this grid can only hold one widget. To improve the design, the user can modify row height and column width.

By modifying a component's properties using the box on the right (3), the user can edit several aspects regarding its behaviour and appearance, e.g., inputs can be set as editable and required and their label can be defined. The property *parameter* (4) is used to specify parameter IDs that are used to identify data throughout the complete business process. When a screen is used to input data into a field with a certain parameter ID and another screen shown later in the process has a component with a matching parameter ID, the second screen will show the data entered in the first screen. The parameter IDs are identifiers in a global data space bound to a workflow.

The screen shown in the example corresponds to the task *Apply for Vacation* from Figure 1. To view the data entered in this screen, e.g., in the task *Approve Vacation Days*, it is only required to add an UI component to that task and set its parameter ID to `request_reason`, similar to the example shown in Figure 3 (4).

### C. Code Generation and Process Execution

The previously described steps allow the creation of an annotated BPMN model that contains information about the behaviour of the application, as well as the UI design. Based on this information, code generation can be used to create a prototype.

Besides generating app prototypes, using BPMN as a foundation for the prototype allows execution of the process model on a business process execution engine. To exploit this circumstance, the generated prototype is separated into two parts: (1) A business process engine that is given the business process model and executes it and (2) a Web App that interacts with the business process execution engine. The engine controls the process and data related to it. This allows the synchronization between prototypes for different user roles involved in the process, which are all created in the generation process. Also, the business process engine can be integrated with other enterprise systems, which allows accessing real-world data from the prototype.

### D. Implementation

As a component for modeling business processes, Camunda Modeler [17] is used. Camunda Modeler needed to be extended to provide an interface to the form modeler. Angular [18] is used to implement the form modeler from scratch to allow a seamless integration with the process modeler. These components write their data into the shared extended BPMN file.

Prototype generation form the shared BPMN document is implemented using XSLT [19]. To support multiple mobile platforms, the generated code uses the Ionic framework [20], a HTML and Javascript-based Framework, as SDK. Ionic allows the visual design of the app to be easily changed using CSS. This supports the integration of enterprise corporate design guidelines into the product. To execute the business process, the Camunda Core Engine [21] is used. To interact with the engine, the Web App uses the Camunda REST API.

## IV. Evaluation

The core of the Pro2Screen idea is to support Business Analysts and UX Designers to develop prototypes in close coordination with the customers. We want to evaluate the suitability of this concept in a user study with the help of a group of practitioners who handle these tasks in their daily work. This evaluation shall answer the following research questions:

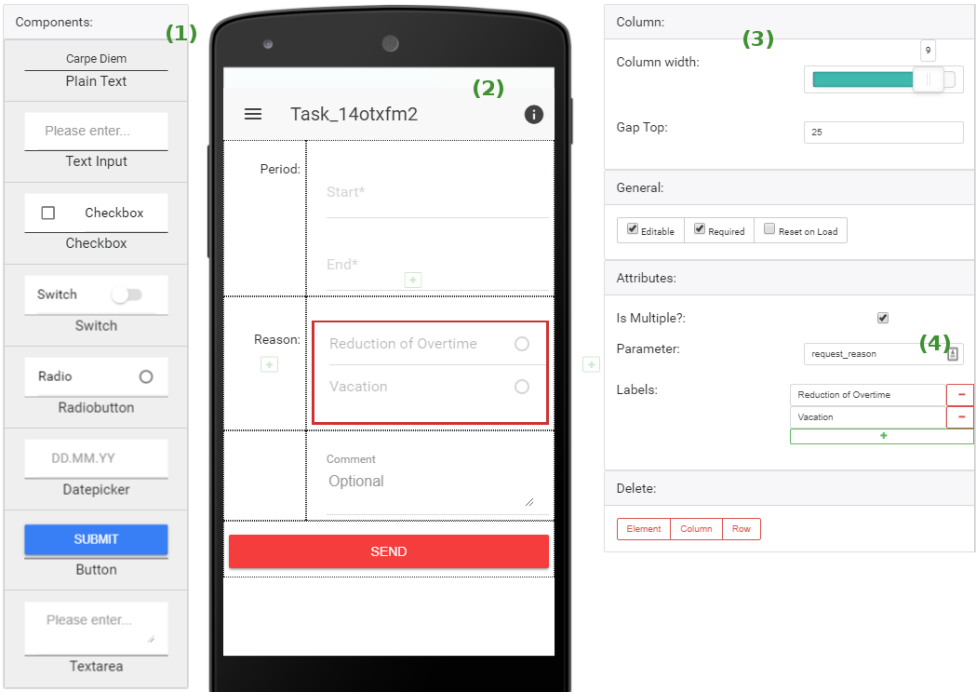


Figure 3. Form Modeler Screenshot

- Can Business Analysts and UX Designers that have no experience in coding mobile apps develop prototypes using Pro2Screen?
- Do practitioners see a benefit in working with the tool?
- Is experience with BPMN-based modeling tools required to work with Pro2Screen?

As described in Section III Pro2Screen consists of two parts, the BPMN-modeler and the form modeler. In our experiment, the group of practitioners worked on two subtasks: First, model a business process using the BPMN-modeler and second, model the corresponding interactive screens for the app using the form modeler. Test participants filled out questionnaires before and after completing the two subtasks. In the following subsections the methodology, the questionnaire and the results are described.

### A. *Methodology*

The evaluation is carried out on two days with a total of seven test persons. The test persons are employees of a leading German ICT solution provider and bring along experiences from their daily work in the process of Mobile Enterprise Application Development from requirement analysis (Business Engineers) or User Experience Design (UX Designers and Consultants).

In total, a test run takes 90 minutes. Each test run is conducted in a separate room and monitored by two test supervisors. The test runs are carried out sequentially under the same conditions. First, the concept of Pro2Screen is presented by the supervisors. The aim of the testing is explained, too. Subsequently, the test persons receive a questionnaire about their personal experiences in the field of MEA development. The experience with prototyping tools as well as the modeling of a business process in BPMN are also part of this questionnaire.

Next, the test persons watch a three-part video tutorial as an introduction to the functionality and modeling capabilities of Pro2Screen. In this tutorial, the business process for a vacation request from Section III-A is described in more detail. In the first part of the tutorial the final BPMN process model with the corresponding screens is shown. How the BPMN process can be modeled in Pro2Screen is shown in the second part of the tutorial. The last part of the video shows how to model the corresponding screens in the form modeler.

Afterwards, the test persons fill out a pre-test questionnaire with seven questions before they could use the tool independently on the basis of two tasks: First, sketch a business process in the BPMN modeler and second, model the screens with the help of the form modeler. As an input for the task to be completed, the following use case description is given to the test participants: *A procurement process involves the roles of employee, manager and a member of the purchasing department. The need for procurement is recognized and initiated by the employee himself. An employee can choose between a laptop, PC, or monitor. After successful selection, this process is transmitted to the manager. The manager can reject or approve the acquisition request of the employee. If rejected, the process is sent back to the employee without explanation. He takes note of this and ends the process. If the acquisition request is approved by the manager, once the employee receives a positive response regarding his application and on the other hand, the purchasing department on the acquisition request are informed. Both roles end the assigned subprocess.* The participants have 10 minutes to sketch this process using the BPMN-modeler and 20 minutes to add forms to the process using the screen modeler. After solving the

two tasks, the post-test questionnaire is distributed. The same questions are asked on the post-test questionnaire as on the pre-test questionnaire.

### B. Questionnaire/Survey

In this Section, the contents of the questionnaires are presented in detail. During the evaluation three questionnaires are distributed. The user questionnaire is used to gather information regarding the user and experiences with BPMN and prototyping and opinions on MEA prototyping in general. A pre-test concept evaluation questionnaire and a post-test questionnaire try to capture the users opinions and proficiency of Pro2Screen before and after the users execute the task.

The experience values in the user questionnaire relate to the methods used in this tool. Each question can be answered on a scale of 1 (very low or never) to 5 (very high or always). The questions are the following:

1) *UX proficiency*: How do you rate your skills in UX Design?
2) *Prototyping tool usage*: How many times have you worked with a mobile app prototyping tool?
3) *BPMN proficiency*: How do you assess your business process modeling skills?
4) *BPMN tool usage*: How many times have you worked with a BPMN modeling tool?

Additionally, each user rated the following statements on a scale of 1 (do not agree at all) to 5 (completely agree).

1) *Existing tools sufficiency*: Existing app development tools are sufficient.
2) *Enjoy experimenting with tools*: I enjoy experimenting with tools that support app development.
3) *Large enterprise adaption*: Existing tools are well adapted to being used in large enterprises.
4) *Collaboration support*: Existing tools support collaboration in interdisciplinary teams.
5) *Reuse support*: Existing tools support the reuse of existing results.

The questions asked in the pre- and post-test regarding Pro2Screen are identical. Each question can be answered on a scale of 1 (very bad) to 5 (very good).

1) *Conceptual comprehension*: How much do you think you have understood the concept of the new tool so far?
2) *Concept rating*: How do you rate the concept of this new tool so far?
3) *Enterprise-wide applicability*: How do you rate the usability of this tool in your company so far?
4) *Local applicability*: How do you rate the applicability of this tool in your personal workspace?
5) *Self-assessed proficiency*: How do you think so far, will you be able to cope with this tool?
6) *Personal job ease*: How do you rate the chances that this novel tool could make your job easier?
7) *App quality improvement*: How do you rate the chances that this tool will improve the quality of app development?

### C. Results

We executed the aforementioned test plan with seven users from a large enterprise that work on mobile enterprise applications. The created solutions of the test persons were compared with the model solution. These results are presented in Table I. In the first task they should create the BPMN process diagram for the described task from Section IV-A. At this task a maximum of 18 points could be achieved. In each case, one point was awarded for creating one of the three roles in the swimming lane, setting the correct task for the corresponding roles and setting the associated connections between the tasks. On average, each test person scored 12.86 points, which corresponds to 71.43% of the possible points.

In the second task the test persons should model the screens of the BPMN process diagram described in Section IV-A. Due to the comparison of the results, they start with the same BPMN process diagram. This diagram is the model solution of the first task. In the second task a maximum of 24 points could be achieved. They could receive one point for setting the correct fields. Further points could be reached if the necessary fields were linked to global variables and the buttons on the screens were linked to the corresponding outgoing transitions. The test persons achieved an average of 19.5 points in this task. This corresponds to 78% of total points. In sum, for both tasks, the test persons reached an average of 32.36 points out of 42 possible points. In other words, 75.25% of all possible points were achieved by the test persons on average.

TABLE I. Completion Rate

| | Task 1 | Task 2 | Total |
|---|---|---|---|
| Average number of achieved points | 12.86 | 19.50 | 32.36 |
| Percentage of achieved points | 71.43% | 78.00% | 75.25% |

An overview of their answers to the user questionnaire are shown in Table II. In these results, we can see that the majority of the test persons are experienced in UX Design. But on the other hand, the majority has low experience (the median is one, meaning no experience using BPMN-based tools) modeling business processes with a BPMN modeling tool. While the capability of modeling business processes in general is rated a little higher than working with BPMN tools, the values are quite spread out. The answers to this question is quite similar to the regular usage of prototyping tools, while test persons seem to use these tools a lot more than business process modeling tools. Nearly all test persons enjoy experimenting with tools.

Regarding the experts opinions on existing MEA development tools, the majority thinks that prototyping tools are not well adapted to large enterprises. The users did not express that existing tools are sufficient for MEA development, while they are not completely unusable for this task. Similar answers were given regarding the support for collaboration or reuse.

An overview of the pre- and post-test evaluation of these users is shown in Table III. In nearly all questions, the scores slightly improve from pre-test to post-test. The results for *conceptual comprehension* are at least four in pre- and post-test. This means that after watching the video tutorial (pre-test) and after doing the tasks (post-test), the test persons understand the concept of the tool well. In the post-tests, these values are even higher. Results for *concept rating* are similar. The

TABLE II. Results of User Questionnaire

| | Minimum | Median | Maximum |
|---|---|---|---|
| UX proficiency | 2 | 4 | 5 |
| Prototyping tool usage | 1 | 3 | 4 |
| BPMN proficiency | 1 | 2 | 4 |
| BPMN tool usage | 1 | 1 | 4 |
| Existing tools sufficiency | 2 | 3 | 4 |
| Enjoy experimenting with tools | 3 | 4 | 4 |
| Large enterprise adaption | 2 | 2 | 4 |
| Collaboration support | 2 | 3 | 4 |
| Reuse support | 2 | 3 | 4 |

results for *enterprise-wide applicability* show that it is not clear whether the tool can be used enterprise-wide. Regarding the *local applicability*, we can see disagreement in the results. While the majority of the responses to this question in the post-test where four or higher, the results are spread out. Post-test answers to *personal job ease* show that a majority of test persons believe that Pro2Screen can benefit their personal job, with a slight increase from the pre-test. Results for a possible improvement in app quality are similar.

## V. Discussion

In comparison to prototyping approaches mentioned in Section II, we see several benefits. One important advantage of using BPMN as the foundation for prototyping is that it supports reusing existing process models to create a prototype. Even an automated transformation from existing files is supported. This is not possible for prototyping approaches based on other models. Another important aspect of this approach is the option to build applications using more than one user role easily. Supporting a business process execution engine allows the integration of existing enterprise systems in the prototype, since these systems can be integrated into the process engine. This can allow the prototype to access real-world data, which give the user of the prototype a better understanding of the functionality.

A drawback of our approach is the limitation regarding visual design choices of the form modeler caused by the grid layout and the limited set of standard components. While inexperienced users might see the simplicity as an advantage, especially designers might need more freedom in positioning components and a broader collection of usable widgets.

Regarding the prototype's fidelity according to the filter fidelity model [8], our approach allows building prototypes that have a high breadth and depth of functionality and a close relation to data and appearance of the final product. This can make it easier to demonstrate to customers how an app can support their business processes and help manage expectations. This can lead to reduced costs for reworking requirements and app concepts during the MEA development process and improve the usability of the final product.

From our user study, we can see that there is room for improvement in the area of MEA-Prototyping in general. Users in our evaluation stated that existing tools are not well adapted to the needs of MEA development and did not state that existing tools are sufficient for this process. Since the majority of test persons see an applicability of Pro2Screen in their personal work area, this can indicate that this tool can make a contribution in MEA development. This effect intensified after the test users worked with the tool. Users did also see that MEA quality could be improved by working with the tool.

Our evaluation also shows that the tool is well adapted to the needs of UX Designers and Business Engineers. While the majority of test users were not familiar with prototyping tools or BPMN modeling, after the test most users believed that they can work with the tool. Even before the test, the users were confident that they can work with it. This shows that the tool can be used by users with little experience in BPMN modeling or even prototyping tools, which is especially important when prototypes are created by users that are not as "tech-savvy" as coders.

The presented evaluation has some limitations: While the size of seven participants is in general considered suitable for usability testing [22], the ample size is small, and thus the generalizability of our results to MEA development experts is questionable. Besides, our evaluation was performed with test users from only one company. The situation in other large enterprises might be fundamentally different and thus needs to be further evaluated.

In general, the presented approach allows creating prototypes by directly mapping screens and process steps. This supports non-developers in creating high-fidelity prototypes without the need for learning to code or a background in formal modeling. Our evaluation indicates that the approach is adapted to the needs of this group, which makes the approach an interesting candidate for further research.

## VI. Conclusion and Future Work

In this paper, we have presented the prototyping tool Pro2Screen for MEAs that is based on the usage of business process models written in BPMN. Prototypes are created using a business process annotated with screen designs. The annotated process is then used to generate a prototype that consists of an app and a business process execution engine that executes the process.

Pro2Screen allows fast prototyping of MEAs, since it is possible to reuse existing BPMN models for prototyping and integration with other enterprise applications through the business process execution engine. Generated prototypes can achieve a high level of fidelity regarding several aspects, especially the depth of functionality and the visual quality of the prototype is high.

To evaluate the feasibility of this approach, we have presented a user study conducted with practitioners from the field of MEA development with a background in user experience and business engineering. The evaluation shows that users from our test group where able to work with Pro2Screen and indicates that Pro2Screen can make a significant contribution in the area of MEA development.

As future work, we plan to further evaluate the benefits of this prototyping approach regarding the ability to develop MEAs. Especially financial aspects of the approach and possible improvements of MEA quality need to be examined. As shown in the discussion, to obtain generalizable results, a repetition of our evaluation with a larger and more diverse user group will also be considered. Another next step could be integrating existing screens from a standard screen library into the prototyping tool.

TABLE III. Comparison Pre-Test versus Post-Test

| | Pre-Test | | | Post-Test | | |
|---|---|---|---|---|---|---|
| | Minimum | Median | Maximum | Minimum | Median | Maximum |
| Conceptual comprehension | 4 | 4 | 5 | 4 | 5 | 5 |
| Concept rating | 3 | 4 | 5 | 4 | 4 | 5 |
| Enterprise-wide applicability | 3 | 3 | 5 | 3 | 3 | 4 |
| Local applicability | 2 | 3 | 5 | 2 | 4 | 5 |
| Self-assessed proficiency | 3 | 4 | 4 | 3 | 5 | 5 |
| Personal job ease | 3 | 3 | 5 | 3 | 4 | 4 |
| App quality improvement | 3 | 3 | 4 | 2 | 4 | 4 |

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