The Role of Semantic Annotations in Business Process Modelling

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Abstract—Semantically annotating business processes is about enriching the elements of a process description (e.g., activities, events) with annotations taken from an ontology defining the domain semantics of the elements of the process. Semantic annotations enable to provide business analysts with tools and services that, by exploiting automated reasoning and inference engines, facilitate the analysis, search and validation of business processes. However, besides the benefits deriving from these automated services, semantic annotations have further unexplored implications on the modelling of business processes. In this paper we present a principled experimental user evaluation showing, as main outcomes, that semantic annotations also directly impact (i) on the modelling process, suggesting that they favour a more accurate and careful design of the models, and (ii) on the resulting process models, as the models obtained using semantic annotations are qualitatively better than those obtained without using them.

I. INTRODUCTION

Semantic Business Process Management [1], [2] aims at improving the level of automation in the specification, implementation, execution, and monitoring of business processes by extending business process management tools with the most significant results from the area of Semantic Web.

When the focus is on process modelling, i.e. the activity of specification of business processes at an abstract (descriptive and non executable) level, annotating process descriptions with labels taken from domain ontologies (aka semantic annotation of business processes) enables to provide business analysts with additional tools and services that, by exploiting automated reasoning and inference engines, facilitate the analysis, search and validation of business processes (see e.g., [3], [4], [5], [6], [7], [8]). For instance, semantically annotating the elements of a business process favours checking the compliance of the process with domain-specific constraints [7], [8] (e.g., in an on-line shop process, the analyst may want to ensure that “the activity of providing personal data is always preceded by an activity of reading the policy of the organization”), or to effectively and automatically implement exception flows handling mechanisms [8] (e.g., “the activity of reserving products in the On-line Shop pool has always to catch a product unavailability error event, which has to be handled by executing in parallel two activities, one for warning the buyer, and one for ordering the unavailable products”).

However, besides the benefits deriving from the automated services that can be offered on top of semantically annotated business processes, in this paper we show, by means of a principled experimental evaluation, that semantic annotations have further advantages at business process design time: they directly impact on the modelling process and the resulting process models.

In detail, we ran an experiment with several modelling teams, each composed of two modellers. Each team was asked to (collaboratively) design the business processes of one of two quite diverse modelling scenarios that were presented to them, one about the publishing processes of a publishing house and the other about nurses activities performed in a hospital ward. Roughly half of the teams semantically annotated, with concepts taken from a preliminary basic ontology that they substantially revised and extended, their process models while designing them, whereas the remaining teams modelled the processes without using semantic annotations. The results of the experiment show that the usage of semantic annotations while designing business processes have an impact on:

the process of business process modelling: semantic annotations encourage designers to refine more frequently the process models, thus suggesting that semantic annotations favour a more accurate and careful design of the models.

the business process model: the models obtained using semantic annotations are better in quality than those obtained without their use.

Furthermore, semantic annotations also have an impact on the perception of the team modellers on several aspects related to (i) the modelling process, (ii) the collaboration with team members, as well as (iii) the resulting process models.

The paper is organized as follows. In Section [II], we recall the purpose and advantages of semantically annotating business processes. In Section [III] we describe how the experiment was designed, clarifying the research questions that we investigated. In Section [IV] we report the results and findings of the experiment, commenting also cofactors and possible threats to its validity. In Section [V] we recall some recent contributions related to our work, concluding with some final remarks in Section [VI].

1Semantically annotating business processes is a multifaceted activity, as a good quality semantic annotation requires a clear understanding and analysis of the process domain, to which the consultation, revision and construction of a domain ontology definitely contributes.

2Although the experiment was conducted in a collaborative setting, most of the results (all except those related to collaborative aspects) also hold for process modelling in general.
II. SEMANTIC ANNOTATION

Semantically annotating business processes is about enriching the elements of the process description (e.g., activities, events) with annotations taken from an ontology, either already available or built/revised for the specific process domain. Semantic annotations can be used to augment business processes with different information. In [9], semantic annotations are used to capture the semantics of task execution, where task preconditions (input) and effects (output) are formulated in the terms of an ontology that axiomatizes the underlying business domain. In [6], semantic annotations are used to define the domain semantics of the elements of the process diagram, i.e., to characterize the nature of each process element according to a domain ontology. In the experiments that we present in this paper the latter approach is considered. Figure 1 depicts an excerpt of a semantically annotated business process, where a business process encoded using the BPMN language [10] is enriched with semantic annotations.

It has been argued that annotating process descriptions with a set of tags taken from a set of domain ontologies would provide an additional support to business analysts in process modelling (see e.g., [3]), i.e., the activity of specification of business processes at an abstract (descriptive and non executable) level. Indeed, in a previous work [6], we presented an ontological framework that formally describes semantically annotated business processes. This framework, by integrating together the process model and the domain ontology used for the annotation, enables modellers to semantically query an annotated business process, submitting requests that combine both domain and process knowledge (e.g., “retrieve all the BPMN events following activities annotated by concept to buy (or its subconcepts) of the domain ontology”). In addition to this feature, that may be particularly useful especially when dealing with large models, several automated services exploiting ontological reasoning can be implemented and offered to business analysts to support the modelling phase:

• checking the correctness of the semantic annotations added to the business process [6] (i.e., verifying that the annotations are compliant with respect to some defined constraints, like for instance that “BPMN activities can be annotated only with domain ontology concepts representing actions”);
• checking the compliance of business processes with respect to some domain specific structural requirements [7] (e.g., in an on-line shop process, the analyst may want to ensure that “the activity of providing personal data is always preceded by an activity of reading the policy of the organization”); and
• verifying constraints on the management of exceptional flows (e.g., “the activity of reserving products in the Online Shop pool has always to catch a product unavailability error event”), and semi-automatic aspects-based building of exception handling mechanisms [8] (e.g., “the product unavailability error event has to be handled by executing in parallel two activities, one for warning the buyer, and one for ordering the unavailable products”).

However, as we will show in the following, the usage of semantic annotations while modelling business processes have further unexplored implications that go beyond the aforementioned automated services.

III. EXPERIMENT DESIGN

This section presents the design of the empirical study carried out to evaluate the impact of semantic annotations on (collaborative) process modelling. The study is conducted and reported according to the methodology proposed by Wohlin [11] for the evaluation of software engineering experimentations.

A. Goal and Research Questions

In the study we are interested to investigate whether the usage of semantic annotations has a role in modelling business processes. The goal of the study is considering two process modelling approaches (one based on traditional process modelling and a second one exploiting the enrichment of process models with semantic knowledge) with the purpose of evaluating the resulting process modelling. The quality focus of the experiment is on the impact of the use of semantic annotations on: (i) the process of modelling; (ii) the modelled processes. In detail, we are interested to answer the two following research questions:

RQ1 Do semantic annotations impact on the process of (collaborative) process modelling?

RQ2 Do semantic annotations impact on the modelled business processes?

RQ1 aims at investigating the role of semantic knowledge in the sequence of activities carried out by process designers when modelling processes. RQ2 focuses on the impact of semantic annotations on the resulting process models.
Following the approach presented in [11], for each of the above research questions, RQx, we formulate a null hypothesis \(H_0\) and an alternative one \(H_1\). The rejection of the null hypothesis determines the acceptance of the alternative one and the positive answer to the corresponding research question. In detail, we investigate the research questions both from an objective and a subjective perspective. We can hence decompose the corresponding alternative hypotheses in a subjective and an objective one. For what concerns \(H_1\):

(\(H_{1a}A\)) Semantic annotations have an (objective) impact on the process of (collaborative) process modelling.

(\(H_{1a}B\)) Semantic annotations have an impact on subjects’ perception about the process of (collaborative) process modelling.

In case of \(H_{2a}\), we have:

(\(H_{2a}A\)) Semantic annotations have an (objective) impact on the modelled business processes.

(\(H_{2a}B\)) Semantic annotations have an impact on subjects’ perception about the modelled business processes.

B. Context

The study involved 22 subjects, organized in 11 teams (\(T_1\), \(T_2\), . . . and \(T_{11}\)) of 2 subjects each. In detail, the subjects are the students of the Master Degree in Economics and Management of the University of Trento, attending a course on Information Technologies and Organization Efficiency, focused on the techniques and methods for the analysis and redesign of organizational processes with the use of new information technologies (Business Process Reengineering).

Two use cases (objects) were considered in the experiment, and each team was assigned the task of designing the business processes taking place in one of the two. One use case consists in the book publishing process of a publishing house\(^3\) specialized in educational books. In particular, the presentation of the use was focused on the editorial, design, and production phases implemented by the publishing house: the editorial phase, in which the author and the editors iteratively revise the content of the original manuscript; the design phase, which consists of the activities needed to transform a manuscript to a prepress release (e.g. typesetting, page layouting, negatives production); and, finally, the production phase which consists in the printing and binding of the copies of the book. The other use case consists of the nurses activities taking place in ward of a hospital\(^4\). Examples of activities include triage, patient record search, taking of blood samples. The use cases were presented to the subjects by domain experts. The material (slides) used by the experts during the presentation, as well as the audio recordings of the presentations, were provided to the teams.

C. Procedure and Material

Each team developed the process models of one of the two use cases presented (publishing house, hospital ward) over a three months period. The experiment was designed so that some teams modelled the processes exploiting semantic annotations, while others designed processes without using them, as reported in Table I.

<table>
<thead>
<tr>
<th>Without semantic annotations</th>
<th>Hospital Ward</th>
<th>Publishing House</th>
</tr>
</thead>
<tbody>
<tr>
<td>With semantic annotations</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

**TABLE I: Experiment design**

To design the business process models, the subjects were provided with MoKi\(^5\), a collaborative wiki-based modelling tool to design (semantically annotated) BPMN business process models. In details, MoKi enables users to develop domain ontologies as well as BPMN business processes within the same modelling environment, and allows users to annotate the elements of a business process diagram with the concepts defined in the domain ontologies. MoKi is a collaborative modelling environment: a team of users can work together on the development of the same (semantically annotated) business process model, supported by several collaborative functionalities like discussion and notification mechanisms, track changes, and more. In the experiment here considered, each team was provided with a dedicated MoKi installation, accessible only by team-members. Furthermore, each subject in the team was provided with a personal account to access the team MoKi installation, so that each member was able to contribute to the process models of her team.

The teams that modelled the processes exploiting semantic annotations were also provided with a very basic ontology (describing high level concepts like role, action, and object) that they were encouraged to extend and refine with domain knowledge relevant for the use case they were modelling, in order to use the ontology concepts for annotating the elements of the business process model they were developing.

Before starting the experiment, subjects were trained with an introduction to BPMN\(^6\) ontology modelling and semantic annotation of business processes. Furthermore, the subjects were also introduced to MoKi and its functionalities. After the end of the training session, subjects were asked to fill a pre-questionnaire, collecting information about their background and high-level competencies.

To follow, both use cases considered in the experiment were presented to the subjects. The use case presentations were performed by domain experts, and lasted approximately 1 hour and a half each (including a question and answer session). All the materials (e.g., slides and audio recording of the presentations used by the experts during their use case introduction, as well as training session material) were provided to the subjects. During the running of the experiment, an intermediate check was performed approximately at midterm of the three months period, to ensure the correct execution of the experiment.

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\(^3\)Edizioni Centro Studi Erickson [http://www.erickson.it/].

\(^4\)The Day-Hospital Oncology ward of the Santa Chiara Hospital, Trento, Italy.

\(^5\)Users were already familiar with business process modelling, due to their study plans. However, a short summary of BPMN elements and their usage was also presented.
Finally, at the conclusion of the experiment, subjects were asked to fill a final questionnaire\(^6\) to collect their subjective perception about the modelling process.

**D. Variables**

In order to accept (or reject) the alternative hypotheses listed in Subsection \(\text{III-A}\) (and hence answer the corresponding research questions), we evaluated the impact of the semantic annotations on the investigated factors. For example, for accepting (or rejecting) the alternative hypothesis related to the modelled process perception (\(H2_{\text{a}}\)), we investigated the subjects’ perception about the quality of the designed process models.

The independent variable (i.e., the controlled variable that is supposed to affect the factors analysed in the research questions) is the use of semantic annotations for the (collaborative) modelling process. The independent variable can therefore assume only two values, i.e., the two treatments: SA (with semantic annotations) and NSA (without semantic annotations).

The dependent variables (i.e., the variables associated to the factors that potentially “depend” upon the treatment) considered in the study to evaluate the effect of the semantic annotation on the factors, are listed in Table II. In detail, for each research question, the table reports (i) the alternative hypotheses we are interested to accept in order to positively answer the research question; (ii) the factor investigated by the sub-hypotheses; (iii) the specific variable(s) used to measure the factor; (iv) the unit/scale used for measuring each variable; and, (v) a short textual description of the variable.

In detail, to have an objective evaluation of the impact of semantic annotations on the activities carried out in the (collaborative) modelling process, we computed the number of operations performed by the team members during the process of business process modelling: creation (CON), editing (EON), renaming (RON), deletion (DON), visualization (VON), navigation (NON) and system access (AON). Differences in the number of each of these operations, indeed, provide an objective measure of the differences existing in the main typologies of activity carried out during the modelling process. For the evaluation of the subjects’ perception about the process of collaborative modelling, we separately considered the modelling and the collaborative dimensions. For both of them we looked at the difficulty and at the required effort perceived by subjects. In detail, for the modelling dimension of the design process we measured the subjective perception of users about the difficulty of (MPD) and the time required for (MPTS) the modelling process. With respect to the collaborative dimension of the modelling process, we investigated the collaboration aspects that have been identified as levels of social interaction by Malone et al. \(^1\) and further investigated in the field of CSCW (Computer-Supported Cooperative Work): awareness, communication, coordination, group decision making\(^1\). Indeed, collaborative modelling can be conceived as a form of social interaction among people \(^1\). For each of the collaboration aspects, we investigated the perception of the subjects about difficulty (AwD, CommD, CoordD and DMD) and time spent (AwTS, CommTS, CoordTS and DMTS). These two sets of metrics, indeed, provide a reasonable measure of the perceived benefits or disadvantages of using semantic annotations in the collaborative work. All the subjective evaluations of the process designers have been expressed in terms of 5-point Likert scale ranging from 1=very easy/very fast to 5=very difficult/very time-consuming.

To measure the differences occurring in the produced output we also considered the objective and the subjective dimension. In detail, for measuring the objective differences in the quality of the modelled processes, we: (i) quantitatively evaluated the models through the overall number of process graphical elements (PMGEN) and connections among them (PMCN); (ii) relied on a more qualitative assessment, asking an expert business process designer (the evaluator), aware of both the modelled domains, to assess his rate about the quality of the produced models (PMEE). The evaluator expressed his rate on the whole set of models produced by each team only looking at the modelled processes, i.e., without taking into account semantic annotations (in the semantically enriched models). The evaluator’s rate is a value on a 5-point scale, being 1 the lowest evaluation (representing a poor quality of the models) and 5 the highest one (representing a good quality set of models). We believe that these metrics, considering both the size and the connection degree among process model elements, as well as the “quality” of the produced output, represent a reasonable evaluation of the produced models. Finally, for evaluating the perceived quality of the models, we collected the evaluation of the subjects with respect to the modelled process completeness (PComp) and correctness (PCorr).

Also in this case, indeed, the proposed pair of metrics seems to provide a meaningful quantitative and qualitative picture of the subjects’ perception/satisfaction about the quality of the produced models. The process designer subjective evaluation has been expressed on a 5-point Likert scale ranging from 1=models are absolutely incomplete/incorrect to 5=models are absolutely complete/correct.

**IV. Experiment Results**

In this section we describe the statistical analysis performed on the data collected in the experiment to evaluate the impact of the two treatments (with and without semantic annotations) on each of the variables described in Table II

The type of collected data, preventing the applicability of parametric tests, suggested the usage of non-parametric tests, while the design of the experiment, lacking the adoption of the two treatments by the same subject (i.e., no paired values for the two treatments were available), implied the choice of an unpaired test. We hence resorted to the non-parametric unpaired Mann-Whitney test \(\text{[11]}\). Moreover, due to the exploratory nature of the hypotheses we are interested to investigate, we applied two-tailed Mann Whitney tests, i.e., we did not fix any direction of the impact of treatments on the variables.

All the analyses are performed with a level of confidence of 95% (\(p\)-value < 0.05), i.e., there is only a probability of 5%
that the results are obtained by chance. In the following tables, rows containing variables in bold indicate that the obtained results are statistically significant.

\textit{a) Research Question 1 (RQ1):} Table [III] reports the descriptive statistics and the statistical significance related to the variables used in the first research question\(^5\).

The upper part of the table provides details about the H\(_{1A}\) alternative hypothesis, showing data related to the number of creation, editing, renaming, deletion, visualization, navigation and access operations carried out by the team members during the process of collaborative modelling with and without the use of semantic annotations. The table reveals that, except for the number of creation operations, the number of operations carried out by teams that used semantic annotations was overall greater than the number of operations of teams that designed processes without using semantic annotations. This difference, in case of renaming, deletion, navigation and access operations is also statistically confirmed. No renaming operation at all has been performed by NSA teams, while for the other three types of operations a substantial difference in terms of number exists (the NSA teams carried out on average half of the SA teams). This result (for 4 out of 7 types of operations) allows us to overall reject the H\(_{0A}\) null hypothesis and accept the alternative one: the use of semantic annotations has an impact on the (collaborative) process of business process modelling carried out by process designers; indeed, the use of semantic annotations, seems to encourage designers to refine more frequently the process models.

\textit{b) Research Question 2 (RQ2):} Table [III] reports the descriptive statistics and the statistical significance related to the variables used in the second research question\(^6\).

The lower part of the table describes the subjects’ perceived evaluations about difficulty and time spent in the modelling process and in the collaboration activities. In relation to the perceived difficulty, a difference seems to exist for the modelling process: SA teams perceive the modelling process easier than teams not using semantic information and the result is also statistically confirmed. On the other hand, the use of semantic annotations makes slightly more difficult some of the collaboration activities, as for example being aware of what other members of the teams are doing (AwD). This seems to be reasonable, given the further dimension added by the semantic knowledge to the procedural one. However, overall, no big differences exist in the perception of the difficulty of collaboration activities between the two groups of teams. Indeed, none of these differences is statistically significant. Concerning the time required to model processes (MPTS), subjects exploiting semantic annotations seem to perceive it lower than NSA subjects. The same trend also occurs for awareness, communication and coordination collaborative activities, as well as in awareness, collaboration and coordination activities, and more time in making decisions. Nevertheless, the results are statistically confirmed only for the perception about the time spent in communication and coordination, while no statistically significant differences exist in the other cases. Summarizing, with respect to H\(_{1A}\) we can confirm that the use of semantic annotations impacts on the subjects’ perception about the difficulty of the modelling process as well as on the time spent for communication and coordination activities.

\(^{5}\)Descriptive statistics and statistical significance related to RQ1 variables have been all computed on data related to subjects.

\(^{6}\)Descriptive statistics and statistical significance related to RQ2 variables have been all computed on data related to subjects.

<table>
<thead>
<tr>
<th>RQ</th>
<th>Alt. hp</th>
<th>Factor</th>
<th>Variable</th>
<th>Unit/Scale</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ1</td>
<td>H(_{1A})</td>
<td>(collaborative) modelling process activity</td>
<td>CON, EON, RON, DON, VON, NON and AON</td>
<td>integer</td>
<td>number of creation, editing, renaming, deletion, visualization, navigation and access operations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(collaborative) modelling process difficulty perception</td>
<td>MPD, AwD, CoordD, CoordTS, DM, DMTS</td>
<td>[1, 5]</td>
<td>perceived modelling process difficulty of collaborative aspects (namely awareness, communication, coordination, decision making)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(collaborative) modelling process effort perception</td>
<td>MPTS, AwTS, CoordTS, DMTS</td>
<td>[1, 5]</td>
<td>perceived time spent in the modelling process of collaborative aspects (namely awareness, communication, coordination, decision making)</td>
</tr>
<tr>
<td></td>
<td>H(_{2A})</td>
<td>modelled process quality</td>
<td>PMGEN</td>
<td>integer</td>
<td>total number of process model graphical elements</td>
</tr>
<tr>
<td></td>
<td></td>
<td>modelled process quality subjective perception</td>
<td>PMCN, PME</td>
<td>integer</td>
<td>total no. process element connections; process model expert’s evaluation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PMC, PME</td>
<td>[1, 5]</td>
<td>process model expert’s evaluation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PC</td>
<td>[1, 5]</td>
<td>perceived process completeness</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PCorr</td>
<td>[1, 5]</td>
<td>perceived process correctness</td>
</tr>
</tbody>
</table>

TABLE II: Summary of the dependent variables.
investigated in the research questions, it seems that, overall, semantic annotations enable a more critical and careful approach to the analysis of the domain to be modelled. Indeed, the results show that: (i) the quality of the models produced by SA teams is higher than the quality of NSA ones; (ii) the number of renaming and deletion operations carried out by the SA modellers is higher than the corresponding NSA ones, thus showing a more careful revision of processes by SA process designers; (iii) despite the larger size of SA models, the SA designers perception of model completeness is lower, thus suggesting they had a more critical approach towards the domain to be modelled. A qualitative analysis of the process construction, further confirms this impression. The impact of the usage of semantic annotations, indeed, can be observed also on the lifecycle of the modelled processes, i.e., on the activities carried out by the team members to model processes. Figure 2 shows the process lifecycles mined from the MoKi log files. The model lifecycles, depicted as Heuristic Nets (oriented graphs that can be easily converted into Petri Nets) in which the process textual description can be refined (DU) or with the refinement of its flow (U). After the creation, the process textual description can be refined (DU) one or more times, as the process control flow (U). Moreover, the process/activities can be renamed (RE) or deleted (D). The two nets in Figure 2 suggest that a greater attention is given to the model understanding in the modelled processes.

A. Discussion and Further Findings

Looking more closely at the direction of the impact of treatments on the variables (i.e., of the semantic annotations on the modelling process and on the modelled processes) investigated in the research questions, it seems that, overall, semantic annotations enable a more critical and careful approach to the analysis of the domain to be modelled. Indeed, the results show that: (i) the quality of the models produced by SA teams is higher than the quality of NSA ones; (ii) the number of renaming and deletion operations carried out by the SA modellers is higher than the corresponding NSA ones, thus showing a more careful revision of processes by SA process designers; (iii) despite the larger size of SA models, the SA designers perception of model completeness is lower, thus suggesting they had a more critical approach towards the domain to be modelled. A qualitative analysis of the process construction, further confirms this impression. The impact of the usage of semantic annotations, indeed, can be observed also on the lifecycle of the modelled processes, i.e., on the activities carried out by the team members to model processes. Figure 2 shows the process lifecycles mined from the MoKi log files. The model lifecycles, depicted as Heuristic Nets (oriented graphs that can be easily converted into Petri Nets) in which the process textual description can be refined (DU) or with the refinement of its flow (U). After the creation, the process textual description can be refined (DU) one or more times, as the process control flow (U). Moreover, the process/activities can be renamed (RE) or deleted (D). The two nets in Figure 2 suggest that a greater attention is given to the model understanding in the modelled processes.

<table>
<thead>
<tr>
<th>Alternative hypothesis</th>
<th>Variable</th>
<th>NSA</th>
<th>SA</th>
<th>NSA</th>
<th>SA</th>
<th>NSA</th>
<th>SA</th>
<th>NSA</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1a,A</td>
<td>CON</td>
<td>37.14</td>
<td>35.75</td>
<td>31</td>
<td>27</td>
<td>29.13</td>
<td>30.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EON</td>
<td>74.64</td>
<td>110.71</td>
<td>72.5</td>
<td>105</td>
<td>64.25</td>
<td>75.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RON</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DON</td>
<td>6.14</td>
<td>19</td>
<td>0.5</td>
<td>9</td>
<td>10.57</td>
<td>19.17</td>
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<td></td>
<td>VON</td>
<td>179</td>
<td>371.29</td>
<td>166.5</td>
<td>340</td>
<td>106.4</td>
<td>275</td>
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<tr>
<td></td>
<td>NON</td>
<td>73.86</td>
<td>197</td>
<td>61</td>
<td>138</td>
<td>53.39</td>
<td>139.08</td>
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<td></td>
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<tr>
<td></td>
<td>AON</td>
<td>6</td>
<td>13.5</td>
<td>4</td>
<td>15</td>
<td>5.14</td>
<td>7.4</td>
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<td></td>
<td>MDP</td>
<td>3.25</td>
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<td>3</td>
<td>2.5</td>
<td>0.62</td>
<td>0.55</td>
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<tr>
<td></td>
<td>AwD</td>
<td>1.42</td>
<td>1.67</td>
<td>1</td>
<td>2</td>
<td>0.51</td>
<td>0.52</td>
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</tr>
<tr>
<td></td>
<td>CommD</td>
<td>1.6</td>
<td>1.67</td>
<td>2</td>
<td>2</td>
<td>0.65</td>
<td>0.52</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>CoordD</td>
<td>1.6</td>
<td>1.83</td>
<td>2</td>
<td>2</td>
<td>0.65</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DMD</td>
<td>2.58</td>
<td>2.53</td>
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TABLE III: Descriptive statistics and p-values related to RQ1

b) Research Question 2 (RQ2): Table [V] reports the descriptive statistics and the statistical significance of the variables used for investigating the second research question. In the upper part of the table, the objective measures, i.e., those related to the hypothesis $H_{2a,A}$, are reported. The results show that the models produced using semantic annotations are overall composed of a higher number of process graphical elements, as well as connections among them. Moreover, according to the rate of the evaluator, also the quality of the former models is higher than the one of the latter ones. All these trends are also statistically confirmed, thus permitting to accept the alternative hypothesis $H_{2a,B}$, i.e. to assess that differences exist in the quality of the processes modelled using or not semantic annotations: in detail, the use of semantic annotations favours the development of higher quality process models.

The lower part of the table reports, instead, the evaluation of the subjects about the modelled processes and, in particular, about their completeness and correctness. Contrarily to what expected, given the results about size and connection degree of the processes modelled with and without the use of semantic annotations, the subjects working with semantic annotations perceived the completeness of their models, on average, lower than the perception of the NSA subjects. While such a difference is also statistically confirmed, no difference exists in the subjective evaluations provided by process designers about models’ correctness. We can hence confirm the impact of semantic annotations only with respect to the perception of the completeness of the designed process models ($H_{2a,B}$).

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Footnotes:

10The process models have been mined by applying the Heuristic miner plugin of the ProM 6.1 tool (http://www.promtools.org/prom6/) with the default values. The Heuristic miner plugin mines Heuristic Nets by retrieving frequent patterns, thus focusing on the main behaviours in the event logs.

11MoKi is equipped with a functionality for tracing user activities and storing them in log files.

12Note that, since our purpose was investigating the impact of semantic annotations on the process modelling, we omitted in the SA net the activities related to the process semantic annotation, thus enabling a fair comparison.

13MoKi indeed makes it possible not only to design the (semantically annotated) process control flow but also to associate it a textual description of the process.
The greater attention to the domain analysis and modelling by the SA modellers with respect to the NSA process designers is also suggested by the subjects’ impression about the clarity of the domain presentation they attended. SA subjects, indeed, evaluated the clarity of the presented domain lower than their NSA colleagues (the median value for NSA subjects was 4 versus 3 on a Likert scale from 1=absolutely unclear to 5=absolutely clear).

Of course, despite the number of advantages provided by semantic annotations, their use has a cost, both in terms of time required to model further knowledge and of difficulty encountered during the modelling process. To better investigate drawbacks and limits of semantic annotations, we asked SA subjects their perception about the difficulty and the time spent in enriching the model with semantic information. Their evaluations reveal that using semantic annotations is on average almost difficult (avg = 3.38 on a Likert scale from 1=very easy to 5=very difficult) and time-consuming (avg =2.3 on a Likert scale from 1=very time-consuming to 5=very fast). Such a result is also statistically confirmed applying a Mann-Whitney test \[^{11}\], verifying the hypothesis that \(SP_x \leq 3\), where \(SP_x\) stands for \(SP_s\) and \(SP_a\), which respectively represent the subjective perception about the difficulty of and the time spent in using the semantic annotations, \(SP_s\) is its median and 3 the intermediate value of the scale. However, despite an extra-effort is undoubtedly required when using semantic annotations, as also objectively confirmed by the more time spent by SA teams in the use of MoKi for modelling the processes than the NSA teams, the overload imposed by their use is not extremely high. Indeed, comparing the time spent in the use of MoKi by SA and NSA teams, we found that no statistically significant difference exists between the time spent in the two treatments.

Finally, the post-questionnaire also revealed other useful and interesting information about the strategy adopted by teams in the modelling process. In detail, all the teams declared to follow a modelling process which proceeds for further refinements from more abstract process definitions towards more concrete and detailed ones and, in almost all cases, no specific roles for the work organization have been defined within the team.

### B. Cofactors and Threats

Besides the effect of the use of semantic annotations, we also investigated the impact of other possible factors. In particular, we focused on the influence of the objects and of the process designers’ background expertise (in terms of ontology modelling experience and related tool use). In order to discover the effect of the cofactors on the results, we applied the two-way ANOVA statistical test \[^{11}\] to all the dependent variables, taking into account both the direct effect of the possible cofactors, as well as the effect of their interaction with the use of semantic annotations. We found that interaction effects of the use of semantic annotations and objects exist on the size of the produced model, although no direct effect of the use cases on the variable occurs. Such a result can be justified considering the difference between the two considered use cases; however, we evenly distributed the use cases between the two treatments, which should limit such a use case impact on the results. Moreover, it seems that the interaction of the semantic annotations and the ontology modeling competencies in ontology modelling impacts on the number of renaming operations carried out by process designers. This result confirms our intuition about the effect of ontological analysis on the greater attention to the choice of meaningful names and labels. Previous experience in ontology tool use seems, instead, not to impact on the dependent variables.

Some threats affect the validity of the experiment: they mainly relates to the internal and external validity. As described above we measured the impact of possible cofactors on the dependent variables and we found an interaction effect of semantic annotation and objects on the size, as well as of the treatment and ontology experience on the renaming operations. However, the first effect is mitigated by the symmetric distribution of the objects with respect to the treatments, while the second by the random distribution of the subjects in the teams. Moreover, the lack of supervision during the experiment could have somehow influenced the way in which the subjects carried out the work. However, we believe that this is a good compromise between control and real modelling situations. Indeed, a completely controlled experiment would have imposed limitations e.g., on time or communication means, thus undermining the simulation of real modelling scenarios. External validity is related to the generalization of the findings. The number of subjects, as well as of teams (and hence the number of points considered) in the analyses, was not high (22 people in 11 teams). Nevertheless, all the involved subjects have a process designer background and process modelling experience. This makes our results closer to a real and generalizable scenarios.
(a) Modelling process carried on by subjects without the usage of semantic annotations (NSA).

(b) Modelling process carried on by subjects with the usage of semantic annotations (SA).

Fig. 2: Process model lifecycles: Modelling process carried on by subjects without (NSA) and with (SA) the usage of semantic annotations.

V. RELATED WORKS

The work presented in this paper contributes to a recent and lively research stream that investigates the process of process modelling (PPM) and how it impacts on (the quality of) the business process model that emerges from it [15], in order to understand how to support modellers in creating better models. For instance, [16] examined how modelling behaviour (e.g., modelling style, frequency of moving objects, modelling speed) relates to the quality of the resulting process model. [17] analyzed the modeller’s interactions with the modelling environment, while [18] proposed a comprehensive framework (i.e., a tool and some metrics) to study collaborative business process modelling.

Concerning semantic annotations, several works have claimed the benefits and advantages of exploiting them to support business process modelling (e.g. [3], [4], [5], [6], [7], [8]). Within the context of the EU project SUPER14, ontology concepts were used to annotate pre/post-conditions of process elements [3]. With respect to this approach, proposals of methodology for semantic business process modelling [4] and user-friendly semantic annotation of business process [5] were presented. Other works adopt semantic annotations to specify the domain semantics of business process elements [6], and show their added value in supporting the business process modelling phase by means of semantic query-based services: from checking the correctness of the semantic annotations [6], to verifying the compliance of business processes with respect to some domain specific structural requirements [7], and, to semi-automatically aspects-based building of exception handling mechanisms [8]. However, none of these works empirically assessed, by involving users, the added value of semantic annotations for modellers.

To the best of our knowledge, the work presented in this paper is the first contribution that investigates, by means of a rigorous empirical study, how semantic annotation impacts on the modelling process and the resulting business process models. A preliminary exploratory investigation to validate the practical relevance of semantic business process management (and, thus, covering also modelling aspects) was presented in [19]. Actually, we believe that to a certain extent our work

14http://www.ip-super.org
empirically confirms a claim of that paper, that “having a domain ontology is useful even if no other semantic technologies are used”. In our experimental study, the domain ontology is used “just” to annotate the elements of the process, describing their semantics in terms of domain concepts, but no semantic services that exploit semantic annotations (e.g., semantic query, constraint verification) were offered to the modellers: nevertheless, the business process models obtained by annotating process elements with concepts from a domain ontology show higher quality than those designed without using the domain ontology at all.

VI. Conclusion

The paper reports an empirical investigation of the effect of using semantic annotations in (collaborative) process modelling. We found that, in addition to the several advantages of semantic annotations from a practical perspective, i.e., the automated services that can be provided on top of semantically annotated processes, semantic annotations also have an impact on the process design itself. In detail, they increase the refinement and revision steps in the process of business process modelling and improve the quality of the modelled processes, without however strongly affecting the required time (i.e., modelling cost).

In the future, we plan to replicate the experiment with more subjects to further confirm the results here presented. Moreover, inspired by the outcomes of this work, we would like to run new experiments involving teams composed of both ontology and process modellers, to better investigate the ontology and process modelling background and experience needed to effectively construct good quality process models.

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REFERENCES


