UTILIZING CHANGE EFFORT PREDICTION TO ANALYZE MODIFIABILITY OF BUSINESS RULE ARCHITECTURES AT THE NHS

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Abstract

Business rules (BR’s) play a critical role in an organization’s daily activities. With the increased use of BR (solutions) and ever increasing change frequency of BR’s the interest in modifiability guidelines that address the manageability of BR’s has increased as well. A method of approach to improve manageability and modifiability is to utilize architectures to structure BR’s. In current literature three different methods to structure business rules can be identified: 1) the rule family-oriented approach, 2) the fact-oriented approach and, 3) the decision-oriented approach. Scientific research comparing the ability to modify business rules in each of the three architectural candidates is limited. The goal of this research is to evaluate which architectural candidate and underlying architectural structures allow for the best modifiability. We sought to do so by applying design science research for the creation of the architectural candidates and by conducting semi-structured interviews to identify the case-specific productivity scores. By applying an Architecture-Level Modifiability Analysis using eight years of historical data from the British National Health Service each architectural candidate is evaluated with regards to its modifiability. Results of the analysis reveal that the rule family-oriented architecture scores best on modifiability, followed by the fact-oriented architecture, and lastly the decision-oriented architecture. The results of this study provide a foundation for further research on the application and evaluation of business rule architectures.

Keywords: Business Rules, Business Rule Architecture (BRA), Modifiability
1 INTRODUCTION

Laws, regulations, policies, protocols, and standards are all examples of rules that organizations are forced to act in accordance with (Bajec & Krisper, 2005; Shao & Pound, 1999; Tarantino, 2008). Each of the previously mentioned forms of rules are applied to guide entities, such as individuals, teams, and organizations to act in accordance with internal or externally provided criteria. Take, for example, a general practice. From a regulatory and legislative point of view, rules are used to restrict access to patient information, force general practitioners to be more transparent in their decision-making and constrain the incentive system general practices can apply (Blomgren & Sundén, 2008; King & Green, 2012). In addition to externally provided criteria, organizations themselves also create additional rules, which they want teams and individuals to comply with. For example, a general practitioner states rules on how a specific decision must be made. To prevent individuals and teams in an organization deviating from desired behavior, laws, regulations, policies, protocols and standards are translated into business rules. According to Morgan (2002) a business rule (BR) is defined as: “a statement that defines or constrains some aspect of the business intending to assert business structure or to control the behavior of the business.” As the amount of BR’s utilized in products and/or services increases, the need for efficient maintenance increases as well. It is common for practitioners to scope the product and/or service which is being designed before the BR’s themselves are added as part of the decision logic (Zoet, de Haan, & Smit, 2014). As no uniform definition of a scope of BR’s exists in the current body of knowledge we propose the following definition: “A business rule architecture is a formal description of a cohesive set of business rules and related relationships with the goal to provide knowledge about the structure, dependencies, and design principles.” Currently, these business rule architectures (BRA’s) are often built without adherence to well-known and proven design principles which should be taken into account to ensure, amongst other quality attributes, modifiability to support the future evolution of the product and/or service (Smit, 2015). Although earlier research by van Thienen (1993) focused on the modifiability of one single architectural candidate we want to evaluate multiple architectural candidates.

In this study, we evaluate three business rule architectures regarding their modifiability. To be able to do so we explored the application of architectural structures in neighboring fields to be applied in the context of the design of large sets of BR’s, which are further elaborated in the next section. For this, we utilized the design science approach, featuring eight validation cycles with BR-experts. This resulted in the inclusion of the rule family-oriented architecture, fact-oriented architecture, and decision-oriented architecture. To conduct our evaluation we used data from the NHS. The NHS published business rules documents since 2004, which served as input on which the architectural candidates are based. To be able to evaluate the included architectural candidates regarding modifiability we address the following research question: "Which business rule architecture design copes best with most common business rules modifications?"

The remainder of this paper proceeds as follows. The next section provides this research’s context by describing business rules, separation of concerns, and theory on modifications that can occur to business rules. The third section describes the research methods utilized for this study. This is followed by the data collection in section four. The fifth section presents the data analysis and results. Lastly, section six comprises a summarization of this study’s core findings, contributions as well as its limitations.

2 BACKGROUND AND RELATED WORK

The primary goals of software engineering are to improve software quality, reduce software production costs, and facilitate maintenance and evolution. To achieve these goals, organizations constantly seek for technologies and methodologies that add value in terms of complexity reduction,
increase comprehensibility, promote reuse, and facilitate the evolution of software systems (Tarr, Ossher, Harrison, & Sutton Jr, 1999). As these goals are all contributing to the overall perceived quality of software systems, mechanisms utilized for these goals are often conflicting of nature. In their work, Ossher & Tarr (2001) indicate that these problems are related to the separation of concerns, as coined by Dijkstra (1974). The ability to achieve the goals that represent different concerns depends on the ability to keep and manage separately all concerns of the importance of software engineering. Based on the further advance of separation of concerns in software engineering in the previous decades, van der Aalst presented a literature overview, as further visualized by Zoet (2014), depicted in Figure 1.

According to Zoet (2014), separating BR’s is the next step in the evolution of separating concerns from application development, which is in line with earlier work of Boyer & Mili (2011) and Graham (2007). The independent treatment of BR’s by organizations also implies a different approach than process and data management (Hohwiller, Schlegel, Grieser, & Hoekstra, 2011). As much research effort is currently spent on the implementation-dependent development of BR’s (Boyer & Mili, 2011; Zoet, 2014) we specifically analyze the design process of implementation-independent business BR’s. The process of designing implantation-independent BR’s is part of the Business Rules Management (BRM) research field. BRM can be defined as the systematic and controlled approach to support the elicitation, design, specification, verification, validation, deployment, execution, governance and evaluation of business rules (Zoet, 2014).

Our goal is to analyze modifiability of different architectural candidates utilizing an Architecture Evaluation Method (AEM). To be able to do so we need to 1) select multiple architectural candidates, 2) select case material to ground our architectural candidates and, 3) select an appropriate AEM. As the current body of knowledge only features two formal architectural standards: 1) CogNIAM and 2) TDM. Additionally, we reviewed the literature of neighboring fields like enterprise architectures, software architectures, and data(warehouse) architectures. According to Van Thienen (1993) and Zoet (2011), the theoretical underpinnings of the database and data warehouse methods are most similar to that of the rule-oriented approach. Literature regarding the data warehouse domain contains many standards, but three widely-used schools exist: 1) the relational model adhering to the normalization principles proposed by Inmon (2005), 2) the star-and snowflake-schemes, focusing on dimensions of data proposed by Kimball (2002), and 3) the relational data vault principle, based on hubs, satellites, and links proposed by Linstedt (2009).

A detailed explanation with case specific examples can be found in Smit (2015). However, to ground our research, a summary of the data warehouse-related architectural candidates and their business rules management-related counterparts are summarized. The comparison of the business rules management domain and the data warehouse domain reveals that The Decision Model (TDM) is similar to the
architectural structure utilized by Inmon (2005). The TDM architecture structure could best be labeled as a rule family-oriented architecture as it utilizes rule families in which the underlying BR’s and fact types are centrally stored. Secondly, the Cognition enhanced Natural language Information Analysis Method (CogNIAM) approach (Nijssen & Le Cat, 2010) is similar to the theoretical underpinnings of the architectural structure utilized by Kimball (2002). The CogNIAM architectural structure could be best labeled as a fact-oriented architecture as it utilizes fact types as central concepts which are derived from other facts and applying BR’s that are stored separately. Lastly, since no other alternative architectural structure could be identified in the BRM-domain, we selected the widely utilized concepts used for BR’s described by Ross (2003) and Zoet (2014) for the construction of the decision-oriented architecture based on the theoretical underpinnings as presented in the work of Linstedt et al., (2009), which is a hybrid architectural structure comprising both principles from Inmon’s (2005) and Kimball’s (2002) approach. This architectural candidate is referred to as decision-oriented due to the fact that the decision itself is applied as the central concept which derives BR’s and fact types that are stored separately, and additionally, relationships are registered with separate elements.

Regarding the architecture discipline, authors agree that architectures are utilized to cope with change, and, therefore, should evolve constantly. Change as part of evolution is necessary and inevitable, as products and/or services are influenced by: 1) the ever-changing operating environment, 2) changes in implementation technology, and 3) stakeholder needs which are either functional or quality requirements (Rowe, Leaney, & Lowe, 1998). BR’s, amongst the other concerns, are characterized by the highest change frequency (Chapin, Hale, Khan, Ramil, & Tan, 2001). This demands an architecture design that takes into account quality attributes like evolvability, and as an important sub-aspect of that, modifiability of BR’s. Modifiability concerning architectures can be interpreted as the ability of an architecture to be modified after it has been deployed (Bass, Klein, & Bachmann, 2000). To be able to control evolution, thus, modifiability of architectures, Mannaert and Verelst (2009) propose the concept of stability. Stability with regards to the evolution of architectures can be achieved by utilizing a set of anticipated modifications. In a recent study, Zoet et al. (2015) defined a set of eleven possible modifications on a BRA: 1) Create Decision, 2) Delete Decision, 3) Update Decision, 4) Create Business Rule, 5) Delete Business Rule, 6) Create Condition, 7) Delete Condition, 8) Update Condition, 9) Create Fact-Value, 10) Update Fact-Value, and 11) Delete Fact-Value. For a detailed explanation of the possible modifications, we refer to the original article. The identified modifications provide the possibility to standardize the design of BRA’s to manage the processing of upcoming modifications in a more efficient and effective manner. Additionally, anticipated modifications provide room for more detailed impact assessment regarding existing products and/or services which embed BR’s. The current body of knowledge features several methods to evaluate architectures regarding different quality attributes, including modifiability of software architectures. Such evaluation methods are referred to as Architecture Evaluation Methods (AEM) (Babar & Gorton, 2004; Griman, Perez, Mendoza & Losavio, 2006).

Multiple AEM’s are available to evaluate architectural candidates (Babar & Gorton, 2004; Mattsson, Grahn, & Mårtensson, 2006). For the selection of the most appropriate AEM, we employed two rounds of selection. The first round of selection solely stated that 1) the included AEM’s focused on modifiability. However, as the first round of selection resulted in six possibilities, two more criteria were employed in the second round of selection, which were: 2) the AEM received at least 100 citations, and 3) the AEM is utilized in follow-up research studies which evaluated its usefulness in practice.

In literature, six AEM’s are identified which focus on modifiability: Empirically-Based Architecture Evaluation (BAE) (Lindvall, Tvrdt, & Costa, 2003), Scenario-based Architecture Analysis Method (SAAM) (Kazman, Bass, Abowd, & Webb, 1994), Architecture Tradeoff Analysis Method (ATAM) (Kazman, Bass, Klein, Lattanze, & Northrop, 2005), Architecture-Level Modifiability Analysis (ALMA) (Bengtsson, Lassing, Bosch, & Van Vliet, 2004), QUASAR (Bosch, 2000), and ABAS
ALMA comprises five main steps, 1) Goal formulation, 2) Creation of architecture descriptions, 3) Elicitation of scenarios, 4) Evaluation of scenarios, and 5) Interpretation of the results (Bengtsson et al., 2004). First, the goal of the analysis is to compare three architectural candidates on modifiability utilizing effort prediction. Furthermore, the architectural candidates are created based on the case at hand, while the same holds for the elicitation of scenarios. In their work, Bengtsson et al. (2004) propose an equation to calculate the effort required to process the included scenarios, depicted in Equation 1. The equation includes a summation of the products per type of change in the numerator, which is divided by the total amount of scenarios included (maintenance profile), as represented by C(MP). The products are determined by multiplying the size of the scenario, as represented by S, by the weight of the scenario, as represented by j. Furthermore, the product is multiplied by its corresponding productivity level, as represented by Pcc. Lastly, the result of dividing the numerator by the denominator is multiplied by the total amount of modifications expected.

\[ E_M = \frac{\sum_{i} \left( \sum_{j} s_{ij} \cdot P_{cc} + \sum_{j} s_{ij} \cdot P_{p} + \sum_{j} s_{ij} \cdot P_{nc} \right)}{C(MP)} \cdot CT \]

The formula as proposed in the work of Bengtsson et al. (2004) is adopted and slightly adapted to accommodate the eleven modification types as presented in earlier research (Zoet et al., 2015). The results of the conversion of the equation are presented in Equation 2.

\[ E_M = \frac{\sum_{i} \left( \sum_{j} s_{ij} \cdot P_{cd} + \sum_{j} s_{ij} \cdot P_{p} + \sum_{j} s_{ij} \cdot P_{nc} \right)}{C(MP)} \cdot CT \]

For example, in Equation 2 the modification types included are Change Code (Pcc), New Parameter (Pp), and New Code (Pnc). We adapted the formula in such a way that the earlier mentioned modification types regarding BR’s are included, for example, Create Decision (Pcd). This process is depicted in Figure 2.

![Figure 2. Example adaptation of (a part of) the equation of Bengtsson et al (2004)](image-url)
3 RESEARCH METHOD

The goal of this research is to evaluate the rule family-oriented, fact-oriented, and decision-oriented architectures regarding modifiability. To accomplish our research goal, a research approach is needed in which 1) different architectural candidates have to be adopted and/or constructed, 2) an appropriate method to analyse modifiability of architectural candidates is selected, and 3) the analysis is performed and its results interpreted and reported in order to contribute to the incomplete body of knowledge. The measurement of modifiability is conducted utilizing the ALMA method in a quantitative manner. Furthermore, to ground the construction of the architectural candidates we utilized the design science framework of Hevner et al. (2004) in which we conducted eight validation cycles. Lastly, we conducted two semi-structured interviews to obtain case-specific productivity metrics of the NHS.

3.1 Construction of the architectural candidates

The first stage of this study comprised the actual construction of the architectural candidates based on NHS case data. This was executed by one researcher in order to guard consistency. The construction process was planned to run for two months. In this period, the researcher who constructed the architectural candidates planned a meeting each week with two BR experts to validate the progress. Expert one had eight years of experience with modeling of BR’s while expert two had three years of experience.

![Diagram](image-url) **Figure 3.** Example of a small part of the RFO architectural candidate in the context of the NHS
The validation focused specifically on whether the contents of the case material was properly applied in the RFO, FO, and DO architectural candidates and that the architectural principles and properties were maintained. While nine cycles were planned, eight validation cycles with the BR experts were needed, after which saturation occurred and the architectural candidates were found valid on its contents as well as syntactically correct. The entire process is elaborated in more detail with examples in the work of Smit (2015). However, to ground this process, we provide an example of a small part of the RFO architectural candidate in Figure 3.

3.2 Quantitative evaluation of modifiability

To be able to apply ALMA, several input variables need to be collected: 1) scenario size, 2) scenario weight, 3) amount of expected modifications, and 4) case specific productivity scores. The scenario size was determined utilizing function points as the unit of analysis. The weight of the modification scenario was determined utilizing a normalized weight for each scenario based on historic data as reported upon in the work of Zoet, Smit & Leewis (2015). Furthermore, the third variable comprises the amount of modifications estimated for a given period. Again, based on the work of Zoet, Smit & Leewis (2015), the total amount of modifications identified are included to estimate the number of modifications for the following eight years. Lastly, the productivity scores concerning the scenarios included determine how much time is needed to process the modifications as part of the scenarios. Literature states that productivity should be measured in the case organization due to the many context-specific influences that should be taken into account (Bengtsson et al., 2004). To be able to do so we conducted semi-structured interviews with subject matter experts at the NHS.

3.3 Semi-structured interviews

To be able to derive context-specific productivity metrics in a structured manner an interview protocol was created. The interview protocol consists of a set of fifteen questions from which questions 3 – 13 focus on quantifying how much time is needed to perform a single modification per modification type. For example, the time needed to Create a Decision or the time needed to Delete a Fact-Value. To ground our interviews we based our interview protocol on earlier research on the identification and classification of modification types regarding the same ‘organization’, i.e. the NHS. For a detailed description of the modifications see Zoet et al. (2015). Furthermore, a case specific example was created to guide the interviewees with identifying the elements on which modifications could occur.

4 DATA COLLECTION

Our main criterion for data collection in a real life case setting was: “the case site should deal with business rules, regulations, laws or policies that change frequently.” Our pragmatic criterion was: “the case site should have kept different versions of the documentation of their business rules, regulations, laws or policies” Based on these criteria the National Health Service (England) (NHS) was selected. The NHS is built up from four different health care systems, England, Northern Ireland, Scotland, and Wales. These regions combined provide healthcare services for over 64.1 million UK residents. The NHS employs more than 1.6 million people, which makes it one of the top five workforces in the world in terms of scale. Over one million patients every 36 hours make use of NHS services. A significant part of healthcare management in the UK by the NHS focuses on the management of chronic diseases. In April 2004, the NHS introduced the Quality and Outcomes Framework (QOF) as part of the new General Medical Services (GMS) contract. The QOF is a Pay-for-Performance-scheme covering a range of clinical, organizational, and patient areas in primary care. It is established to reward practices for the provision of high-quality care and helps fund further improvements in the delivery of clinical care. The QOF includes the measurement of different domains, however, due to the scope of this study only the clinical and public health domains are considered. The NHS manages the QOF which is a Pay-for-Performance-scheme that comprises 25 clinical conditions. For each
individual clinical condition, BR’s are created to decide whether a clinic must be remunerated for the treatment of the patient (Gillam & Siriwardena, 2011).

The business rule sets are updated twice a year to accommodate the introduction of new insights revealed by empirical research and/or changes in law and regulations. At the time of writing, the combination of these domains contains 25 clinical conditions, with 70+ underlying indicators, which make up for 80 percent of the commonly encountered health issues in primary care (Lester & Campbell, 2010). Examples of clinical conditions as part of the QOF are: Heart Failure (HF), Diabetes Mellitus (DM), and Chronic Obstructive Pulmonary Disease (COPD). Furthermore, other documents, for example, the guidance documents concerning the QOF specifically designed for NHS employees were extracted to support the creation of the architectural candidates.

Lastly, the interviews were conducted with all the department members working at the Health and Social Case Information Centre (HSCIC, as a department of the NHS) which are responsible for the translation of requirements, resulting from new laws and regulations, policies, changing healthcare need, and/or research outcomes, into BR’s. Due to practical reasons, the interviews are conducted utilizing telephone interviews and are recorded by an audio recorder via a secondary device.

5 DATA ANALYSIS

Data analysis followed the ALMA method and, therefore, consisted of five main activities, 1) determination of the modification scenario’s, 2) analysis of the size of each included modification scenario, 3) analysis of the standardized weights of each modification scenario, 4) analysis of the collected data concerning the interviews to derive productivity levels, and 5) the analysis of the modification occurrences to be able to calculate the total amount of modifications. First, we determined the structure for each scenario. The scenarios were structured according to the eleven modification types. The modification types as well as the impact of each of the modification types on the different architectural candidates is presented in the work of Smit (2015). For the COPD case, we included five modifications per modification type, whereas for the DM case we included twenty modifications per modification type, as this case is four times as large in size compared to the COPD case. The size for each modification scenario is analyzed using function points as the unit of analysis, based on the work of Felfernig & Salbrechter (2004). To be able to do so we classified each individual element in the architectural candidates as one logical function.

For each logical function the size in function, points are calculated by multiplying the amount of logical functions affected by the modification in the scenario, by the amount of function points per modification type. The amount of function points per modification type is calculated by dividing the total amount of minutes needed to process one modification by the total amount of minutes per function point, which we derived from earlier research on project delivery rates in software engineering, averagely 755 minutes per function point (Bundschuh & Dekkers, 2008; Shepperd, Mair, & Forselius, 2006). The standardized weights are analyzed by utilizing the results of modifications per modification types as presented in the work of Zoet, Smit & Leewis (2015). The calculation of the normalized weights is performed by dividing the amount of modifications observed of a given modification type by the total amount of modifications observed.

The interview data was analyzed using arithmetic calculations, which for this initial study regarding modifiability is an adequate way to approximate productivity levels. The productivity levels are expressed as an average of the number of minutes it takes to process a single modification type, taken from the input as derived from both interviews.
6 RESULTS

As described in section 3 we conducted two interviews with subject-matter experts as well as the analysis of modifiability of three architectural candidates utilizing ALMA, which was tailored to the evaluation of business rule architectures. First, we present the interview results regarding productivity levels in Figure 4. In this figure, the average time in minutes per modification is presented. From this, we derived the number of modifications per month assuming a theoretical maximum productivity. We assumed the theoretical productivity based on 22 working days per month, which can be transformed into 10,560 minutes. Furthermore, the best and worst case productivity averages per modification type are presented accompanied by their corresponding maximum capacity (in modifications) per month.

<table>
<thead>
<tr>
<th>Modification type</th>
<th>Average time per M</th>
<th>M’s/Month</th>
<th>Worst case average time per M</th>
<th>M’s/Month</th>
<th>Best case average time per M</th>
<th>M’s/Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td>4.25</td>
<td>2484</td>
<td>7.5</td>
<td>1408</td>
<td>1</td>
<td>10560</td>
</tr>
<tr>
<td>DD</td>
<td>16.25</td>
<td>649</td>
<td>22.5</td>
<td>469</td>
<td>10</td>
<td>1056</td>
</tr>
<tr>
<td>UD</td>
<td>8.5</td>
<td>1242</td>
<td>15</td>
<td>704</td>
<td>2</td>
<td>5280</td>
</tr>
<tr>
<td>CBR</td>
<td>1200</td>
<td>8.8</td>
<td>1200</td>
<td>9</td>
<td>1200</td>
<td>9</td>
</tr>
<tr>
<td>DBR</td>
<td>25.5</td>
<td>414</td>
<td>60</td>
<td>176</td>
<td>15</td>
<td>704</td>
</tr>
<tr>
<td>CC</td>
<td>109</td>
<td>96</td>
<td>210</td>
<td>50</td>
<td>7.5</td>
<td>1408</td>
</tr>
<tr>
<td>DC</td>
<td>150</td>
<td>70</td>
<td>150</td>
<td>70</td>
<td>15</td>
<td>704</td>
</tr>
<tr>
<td>UC</td>
<td>97.5</td>
<td>108</td>
<td>90</td>
<td>117</td>
<td>15</td>
<td>704</td>
</tr>
<tr>
<td>CFV</td>
<td>6.25</td>
<td>1689</td>
<td>7.5</td>
<td>1408</td>
<td>5</td>
<td>2112</td>
</tr>
<tr>
<td>UFV</td>
<td>6.25</td>
<td>1689</td>
<td>7.5</td>
<td>1408</td>
<td>5</td>
<td>2112</td>
</tr>
<tr>
<td>DFV</td>
<td>6.25</td>
<td>1689</td>
<td>7.5</td>
<td>1408</td>
<td>5</td>
<td>2112</td>
</tr>
</tbody>
</table>

Figure 4. Interview results regarding productivity of modifications (in minutes)

Utilizing the interview results we were able to predict the effort required to process the included scenarios for each architectural candidate. The results show that, concerning the COPD case, the RFO architecture scores best on effort prediction. Furthermore, the FO architecture shows a 2.8% of the additional effort required, while the DO architecture shows an additional 16% of the additional effort required to process the set of scenarios provided, see Figure 5. Additionally, results show that, concerning the DM case, the RFO architecture scores best on effort prediction, see Figure 6. Furthermore, the FO architecture shows a 49.14% of the additional effort required, while the DO architecture shows an additional 47.81% of the additional effort required to process the set of scenarios provided.

Figure 5. Effort prediction in hours (COPD)  Figure 6. Effort prediction in hours (DM)
Moreover, we utilized the available data to discover the theoretical best and worst case outcomes regarding total effort. To be able to do so we stopped utilizing the averages from both interviewees concerning the effort required in minutes per modification type. Both interviewees differ in experience level, where interviewee one has four years of experience working with the QOF, while interviewee two has one year of experience working with the QOF. We report on the less experienced employee as the theoretical worst case effort prediction, while the more experienced employee is reported as a theoretical best case effort prediction. The results for the COPD case are presented in Figure 7.

![COPD](image)

**Figure 7.** Worst versus best case effort prediction in hours (COPD)

The results presented in Figure 7 shows that a worst case approach is similar to the average effort calculation as presented earlier. The best case approach shows some difference, resulting just more than half an hour of effort predicted for each architectural candidate.

![Diabetes Mellitus](image)

**Figure 8.** Worst versus best case effort prediction in hours (DM)

The results regarding the second case, Diabetes Mellitus, are presented in Figure 8. Again, the RFO architecture scores best on both worst and best case effort prediction. The worst case architecture shows similar percentage differences compared to the average effort calculation and is therefore not
further elaborated upon. The best case effort prediction also resulted in the best performance by the RFO architecture, while the FO architecture shows a 13.38% of the additional effort required and the DO architecture shows an additional 12.79% of the additional effort required. Summarized, Table 1 presents the numeric results of the analysis outcomes with both the predicted effort as well as its corresponding percentage differences.

<table>
<thead>
<tr>
<th>COPD</th>
<th>RFO</th>
<th>FO</th>
<th>DO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort predicted (H)</td>
<td>1.75</td>
<td>1.80</td>
<td>2.03</td>
</tr>
<tr>
<td>Difference in effort (H)</td>
<td>N.A.</td>
<td>0.05</td>
<td>0.28</td>
</tr>
<tr>
<td>Difference in %</td>
<td>N.A.</td>
<td>2.8%</td>
<td>16%</td>
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<tr>
<th>DM</th>
<th>RFO</th>
<th>FO</th>
<th>DO</th>
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<td>Effort predicted (H)</td>
<td>25.68</td>
<td>38.30</td>
<td>37.96</td>
</tr>
<tr>
<td>Difference in effort (H)</td>
<td>N.A.</td>
<td>12.62</td>
<td>12.28</td>
</tr>
<tr>
<td>Difference in %</td>
<td>N.A.</td>
<td>49.14%</td>
<td>47.81%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COPD – Worst case</th>
<th>RFO</th>
<th>FO</th>
<th>DO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort predicted (H)</td>
<td>1.75</td>
<td>1.80</td>
<td>2</td>
</tr>
<tr>
<td>Difference in effort (H)</td>
<td>N.A.</td>
<td>- 0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Difference in %</td>
<td>N.A.</td>
<td>- 1.78%</td>
<td>1.75%</td>
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<table>
<thead>
<tr>
<th>COPD – Best case</th>
<th>RFO</th>
<th>FO</th>
<th>DO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort predicted (H)</td>
<td>0.57</td>
<td>0.56</td>
<td>0.58</td>
</tr>
<tr>
<td>Difference in effort (H)</td>
<td>N.A.</td>
<td>- 0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Difference in %</td>
<td>N.A.</td>
<td>- 1.78%</td>
<td>1.75%</td>
</tr>
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<thead>
<tr>
<th>DM – Worst case</th>
<th>RFO</th>
<th>FO</th>
<th>DO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort predicted (H)</td>
<td>25.68</td>
<td>38.30</td>
<td>37.71</td>
</tr>
<tr>
<td>Difference in effort (H)</td>
<td>N.A.</td>
<td>12.62</td>
<td>12.03</td>
</tr>
<tr>
<td>Difference in %</td>
<td>N.A.</td>
<td>49.14%</td>
<td>46.84%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DM – Best case</th>
<th>RFO</th>
<th>FO</th>
<th>DO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort predicted (H)</td>
<td>9.85</td>
<td>11.17</td>
<td>11.11</td>
</tr>
<tr>
<td>Difference in effort (H)</td>
<td>N.A.</td>
<td>1.32</td>
<td>1.26</td>
</tr>
<tr>
<td>Difference in %</td>
<td>N.A.</td>
<td>13.38%</td>
<td>12.79%</td>
</tr>
</tbody>
</table>

Table 1. Summary of results of the effort prediction utilizing ALMA

Analysis revealed that an average difference of 9.4% in the effort is predicted between all three included architectural candidates for the smaller COPD case. When analyzing the larger Diabetes Mellitus case, our findings show lower effort prediction for the rule family-oriented architecture compared to the other two included architectural candidates. Further analysis of the differences between the fact-oriented and decision-oriented architectures reveals a difference in impact between both cases. Results show that the predicted effort of the fact-oriented architecture increases as the case size increases. However, the opposite holds for the decision-oriented architecture, which suggests that whenever the case size increases, less impact is measured. The difference between both architectural candidates is most likely caused by the redundancy of data which increases when the case grows, caused by elements that are reused for other decisions in the same case. This implies that the modifiability of the fact-oriented architecture decreases when the case size increases. This is caused by the star-schemed structures that do not relate to each other with relationships. This results in an increase in the creation of redundant conditions and underlying fact types as the case size increases.
On the other hand, the opposite for the decision-oriented architecture is true due to the utilization of links between decisions which creates the opportunity to reuse, for example, conditions and underlying fact types for other decisions. This results in less predicted effort, thus higher modifiability of the architecture. A similar structure is adhered to by the rule family-oriented architecture, which relates architectural elements without creating redundant conditions and conclusions. Furthermore, the results show that the difference between the rule family-oriented architecture and the other two architectural candidates is caused by further separation of decision logic in their own separate logical functions by both the fact-oriented and decision-oriented architectures while this is not adhered to by the rule family-oriented architecture. This means less impact can be related to the logical functions in the architectural candidate. Lastly, results of the worst and best case perspectives reveal a similar outcome, i.e. to that of the perspective which takes into account the average productivity scores.

7 CONCLUSION AND DISCUSSION

The purpose of this research is to explore the concept of business rule architectures and their aspect of modifiability. Furthermore, we sought to evaluate a selection of architectural candidates concerning to what extent these are modifiable. To be able to do so we addressed the following research question: “Which business rule architecture design copes best with most common business rules modifications?” In order to answer this question, we utilized the design science approach to construct our artifacts and, additionally, conducted interviews with subject-matter experts to obtain case-specific productivity metrics needed to evaluate the artifacts on modifiability. Furthermore, scenarios based on earlier research were applied to analyze the modifiability of the selected architectural candidates. The analysis phase comprises the analysis of average effort, worst-case effort, and best-case effort required to modify the architectural candidates.

Based on the analysis conducted we can conclude that the rule family-oriented architecture scores best with regards to predicted effort utilizing our modification scenarios, also revealing that the underlying architectural structure of this architectural candidate is best modifiable of all three included architectural candidates regarding the two cases included in our analysis. Furthermore, our findings suggest that the modifiability of smaller cases potentially benefits from the utilization of the fact-oriented architecture. However, a larger case containing more BR’s potentially benefits from the utilization of the decision-oriented architecture. Lastly, the analysis of worst versus best case effort prediction further validated the previously mentioned findings as it presented similar results in the comparison of all three included architectural candidates.

Several limitations may have affected our results. The first limitation is related to the amount of interviewees included in this research, which is limited, but it should be noted that both interviewees are indeed the main subject matter experts for the NHS data creation, retrieval, and analysis. As those two experts are the only two employees responsible for these tasks, we managed to include all possible subject-matter experts regarding this particular case organization. This particular study, amongst its other goals, aimed to provide a starting point for future research, including significantly more interviewees and/or respondents. Moreover, the method of data collection regarding the productivity scores should be improved in future research, including experimental setups requiring subject-matter experts to process the modification types.

Other limitations are related to multiple key points in this research. First, the amount and differentiation of cases could be improved by including more clinical conditions, for example, CHD, which is relatively large, or Asthma, which is relatively small. Furthermore, other architectural candidates, featuring other architectural structures could be added to improve generalizability as well. Likewise, this study only featured an adapted version of ALMA as a method of analysis. Generalizability could be improved when more methods of analysis are utilized for the analysis of modifiability of business rule architectures. Therefore, future research could focus on the inclusion of more cases and architectural candidates while also utilizing and comparing the results of different
methods of analysis to reveal if a method of analysis could be tailored for utilization in the BRM domain.

From a theoretical perspective, our study provides new knowledge with regards to the business rule architecture proposition, as this is clearly a knowledge gap in the current body of knowledge and current research. From a practical perspective, our study provides input relevant for the design of products and/or services where BR’s are utilized to support (automated) decision making. BR’s, amongst other concerns in software engineering, is characterized by the highest change frequency, implying that modifiability is an important aspect to take into account.

8 REFERENCES


