AUTHORS' RESPONSE TO REVIEWERS' COMMENTS

Product Architecture Strategies and Effects Matrices for early evaluation and selection of product architectures

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We are grateful for the time spent by the reviewers and editors on behalf of this manuscript. We have improved the paper based on each of the reviewers' comments. Please note: The authors' responses are in blue, while the reviewer's comments are in Black. Excerpts from the improved text are provided below – indented – for convenience.

Reviewer 1

1.1 Overall, this is a well-written paper with a well-formed research objective. I believe the PASE matrix fills a need in design practice and I hope the authors continue work building the database.

Thank you for your time reviewing the manuscript and your comments to improve its quality.

1.2 I have just one suggested addition:
* With the rise of ChatGPT, I think it would be beneficial to compare the results to either ChatGPT or other AI to achieve the same task. For example, what result would AI give it it was asked for a design architecture strategy to increase reliability? I suspect the answer would probably be overly generic (or wrong), but I think it will be a question readers will have. Building the proposed database is quite time intensive, so I think it would be beneficial to justify the need over using available AI approaches.

We agree that others will have this question, just as we have had. In fact, in another paper we are currently writing, we are growing the PASE database with the help of AI, using our current database (the one described in this paper) as training data. Because that study is sizable and occupies its own paper, we have not added a substantial discussion/comparison of data from the present paper to ChatGPT results. We have however added the following paragraph in our concluding remarks to emphasize a major strength of the PASE Database and its matrices, which is that it links back to the sources for our data.

> While various AI tools, such as ChaptGPT (Kasneci et al., 2023), could also be used to identify some of these relationships; they lack the structured database that links the insights to specific sources and locations within those sources, thus losing traceability. However, AI-based data mining of full paper texts may be a powerful avenue to rapidly

grow the PASE database established in this paper, where the data in this paper will serve as truth data for AI training.

Reviewer 2

Comments to the Author:

2.1 The paper proposes a systematic approach based on textual analysis of literature to aggregate written statements on the effects of product architecture strategies, into a matrix/database showing each strategy's effect (both desired effect and side effects). The matrix/database can be filtered to support selection of suitable strategies given desired effects. Overall, I find the paper is quite interesting and is nicely written, however deserves more critical reflection to recognise and adequately address some obvious gaps prior to publication. In particular the research method grounding in literature is weak and the approach largely reduces a complex topic to a binary matrix format supported by various metrics, without adequate discussion of the complexities (such as contextual issues and how well each strategy is implemented, as well as whether the relationships posited in literature are grounded in enough evidence). Some of these points are mentioned at the end but seem almost an afterthought rather than integration of the issues throughout the paper.

I think these issues are somewhat significant needing more than a couple of sentences to address, however, could be addressed with a bit more work and critical thought to make the paper more sophisticated. Overall, the paper is quite interesting despite these flaws.

Thank you for the compliment and insights on the weaker portions of the paper. We can see that the original submission did not address these weaknesses clearly enough. Below, where detailed comments are provided by the reviewer on the weaknesses, we have provided a response and excerpts from the improved manuscript (See response 2.6 for Literature, and response 2.8 for Loss of Context).

Detailed comments:

2.2 The main contribution is stated on page 1 to be the methods used to analyze literature and form the matrix. Later on it seems that the idea of the PASE matrix and its application and the dataset created by the authors are also contributions. Perhaps this could be clarified.

Thank you. We agree this needs to be clarified. Below is the improved first paragraph in the Introduction Section on Page 1:

> Product architecture is the scheme by which the functions of a product are allocated to physical components {Ulrich1995}. Architecture decisions are extremely influential in engineering design. They impact not only a firm's ability to implement changes, produce variety, and increase performance in products, but the firm's management structure as well {Ulrich1995}. Many of these impacts are unexpected and

often negative {crawley2004}, with market success and failure often reliant on a product's architectural configuration {mikkola2007}. Research into product architecture and its effects has produced an overwhelming amount of information over decades, with fundamental sources like {Ulrich1995} being cited by over 4,000 other papers. The amount of knowledge can be difficult to fully absorb and use due to its sheer scope and size. This paper introduces a database structure for collecting architectural findings from peer-reviewed sources that can then be rapidly retrieved and visualized in matrix form to make informed early architecture decisions that exploit a wide range of downstream effects.

2.3 The description of the approach in section 2 is easy to understand. Consider adding brief comments to section 2.3 to indicate the situation in which the strategy-driven approach would be used.

Thank you for this insight; we have added the following about when to use a strategy driven approach:

> A strategy driven approach may be desirable when an architecture strategy has been decided upon, or is already in place, and the design team wants to verify that the strategy's downstream effects are compatible with the system, design, or requirements.

2.4 Section 3 describes the literature review method that was used to populate the database/matrix. The process seems appropriate. Ultimately though, only 16 papers seem to have been used to construct the matrix, which seems a bit light. This is surprising given the huge amount of literature on the topic – the authors mention 4000 citations to one seminal publication alone. These issues are acknowledged later on, but in section 3, how can you justify only using 16 papers and how confident are you that the important issues are captured?

We agree the use of sixteen papers is very limited. Our goal was to better understand the cause and effect relationships between architecture strategies and downstream effects. While this paper only has 16 papers in its database, it has already provided 451 relationships. We now see opportunities for expanding this in future work with a large language model AI in order to more comprehensively review the literature. As this will be a separate paper, we did not discuss it in detail here, but we have made it more clear that while useful information can already be gleaned from 16 papers, they are not considered comprehensive. Below is our improved initial paragraph for section 3.1:

> The PASE Database was built to aggregate knowledge observed from the literature about the downstream effects of product architecture on the development process. A systematic literature review was conducted by the lead author in order to find an initial selection of the literature for a large variety of architecture effects that could be processed by the research team. The papers selected were not intended to be

comprehensive, but to cover a range of product architecture topics with substantial detail.

We also made the following changes to the paragraph after Step 5 under Section 3.1:

> This database can be expanded upon over time using the same process above for adding sources and their subsequent information to the database. After the initial development, five more sources (Bonvoisin et al., 2016; Jiao et al., 2007; Farrell and Simpson, 2003; Sosa et al., 2000; Kuo et al., 2001) were processed and incorporated into the database, giving additional insights beyond those collected in the initial data. While 16 sources is a relatively small selection, over 450 unique relationships were identified as reported in Section 3.2, providing a significant amount of useful information.

2.5 The approach of text analysis to link statements about cause and effect seems reasonable. The authors give some space to describe the process by which insights were extracted from their selected papers. This is good but the obvious opportunity to discuss research methods for textual analysis (which is common in many disciplines) is missed – there are few or no references supporting or justifying the research method used.

We agree that we could have better explained our methods for extracting insights from the literature. While text analysis was not used in this paper, we do intend to use it in future work. For this paper, extracting the insights was intentionally done manually, to have more confidence in our initial dataset (see response 1.2). We have updated section 3.1 to more clearly reflect our method for organizing the insights into strategies and effects as shown below:

> **Initial Literature Review and Steps for Processing Sources**
> In the first step of the literature review, the influential articles The Role of Product Architecture in the Manufacturing Firm by Ulrich (1995) and Impact of Modularity Decisions on a Firm's Economic Objectives by Hackl et al. (2020) were selected. Ulrich (1995) was selected as his paper is recognized as a seminal work, having over 4000 citations. In order to include more recent efforts, the paper by Hackl et al. (2020) was selected as their research identified many effects of product architecture, was only two years old at the time of the literature review, and had already been cited over 20 times. Additional papers were then reviewed that were either referenced by these two foundational papers, or cited them. An initial selection was made of those papers based on keywords pertaining to product architecture in the titles (i.e. *product architecture, components, standardization, modularity, interfaces, design, and development*) resulting in a set of 199 papers. Next, the abstracts of all 199 papers were carefully reviewed, reducing the set to 45 papers the researchers believed had the greatest potential relevance. Finally, the bodies of the remaining articles were read, and categorized by which ones best explored key and varied architecture decisions, and their effects on downstream product development activities. As this was not intended to create a final,

definitive, or comprehensive database, some subjectivity was tolerated to create this initial selection to then be processed.

After reading the 45 papers, nine were identified as being highly likely to reveal effects of product architecture strategies. These nine papers, together with the two papers first referenced are the 11 papers from which the current PASE database was constructed. All 11 papers (Ulrich, 1995; Hackl et al., 2020; Brusoni et al., 2007; Clark, 1989; Danese and Filippini, 2010; Eppner et al., 2018; Stone and Wood, 2000; Ulrich and Seering, 1990; Ulrich and Ellison, 1999, 2005; Wyatt et al., 2012) were read thoroughly, and had data extracted and organized into a database, becoming sources. This reduction in the number of papers to be processed was done mainly to maximize the likelihood that time spent extracting data would result in pertinent strategies and effects. Any of the papers identified at the beginning could have been processed, though may not have contained as many relevant statements on product architecture and its effects.

The statements were printed onto 374 cards, and using the KJ method (Scupin, 1997) were grouped into categories, first by strategy, and then the strategies themselves were grouped. This was done by three researchers, all with backgrounds in mechanical engineering. These categorized observations were then broken down into their components that would make up the six rational tables of the database: Sources, Statements, Insights, Strategies, Effects, and Relationships, with each entry having its own unique identifier or identifier code. The research team decomposed the statements into their database components using the following steps:

2.6 The approach seems broadly sensible as long as the sources aren't questioned, but also raises many unanswered questions about the quality of the underpinning data: what to do if there are conflicting statements found in different sources? What is the quality of each source and what support is there for the particular statement in that source? I imagine some of the statements made in papers about product architectures could be throwaway comments or statements of opinion (or "something that is commonly known") without basis in evidence. Just because someone wrote it in a paper doesn't necessarily make it true! The authors could elaborate on how they dealt with such issues, which would make the paper much more convincing.

Our team also discussed the issue of source quality and conflicting information. We made the careful decision to simply report on what was claimed in the literature – without attempting to rate or rank the quality of the claim. While we believe there is future work in being able to do that, we built the present paper on the assumption that peer-reviewed papers are relatively reliable, and our database can trace every relationship back to a source statement. We agree this has shortcomings and some readers may or may not agree with this approach. As they need to take that into consideration when using the information provided by a PASE matrix, we have improved the first paragraph of 3.2 to clarify this:

The PASE Database is the source of information which forms a PASE matrix. At present, it does not contain information about the relative quality of the numerous statements contained therein (statements extracted directly from the literature). While such qualitative information could enhance the PASE database, we could not confidently extract that information from the literature during this study. However, the quality of the database itself (its construction, the amount of information within, etc.) could be confidently assessed in real-time using database metrics. These metrics for the database give insights into its health and quality, and are necessary for informed decision-making. These indicators for the consistency and credibility of the database require current, up-to-date metrics to be retrievable from the database in real time. This transparency is critical for user confidence.

2.7 Section 3.2 has some interesting points (mainly the saturation plot) and moves towards a statistical view. There are a few questionable statements such as 'reliability' of a strategy being the number of sources that agree with it (without information on how the link is supported in the original individual sources, the raw number of supports has little value – perhaps authors simply state something because the idea is known and they need to mention it, regardless of whether they can offer actual additional support). I see what you mean but the word reliability doesn't seem quite right.

We agree that the term 'reliability' may not fully capture the concept we're trying to convey, and simply counting the number of sources supporting a strategy doesn't measure the quality of support for an insight or relationship. We have improved the introduction paragraph for section 3.2 as seen above in response 2.6 We have also improved the "Ubiquity Ratio" paragraph in section 3.2 as follows:

> The number of sources that reference a given strategy (STR), effect (EFF), or relationship (REL), over the total number of sources in the database. This ratio can serve as a valuable tool in demonstrating the consistency of particular strategies, effects, or relationships found in the sources used in the database.

We also agree there is a shortcoming with assessing the strength of a link or relationship. Currently, we do not have a way for quantifying the strength of relationships based on the available literature, and believe this is an area that warrants further research and development. We have added the following second to last paragraph in our concluding remarks:

> While the PASE method provides insights on strategy-effect relationships, it does not yet capture information on the strength of those relationships. This is an area for possible future research.

2.8 The other aspect which raises questions is that it is not only the strategy that leads to an effect but how (well) it is implemented and how the suitability of a strategy or its effect might differ depending on design context. There is also the possibility to interpret many strategies in different ways. For example the strategy "use modular architecture" encompasses a massive array of issues and the modular architecture can be different depending on architect choices and module drivers selected as well as how they define and measure modularity. Similar issues could be raised for the effects such as 'increases component maturity'. Yes, modularity MIGHT increase maturity, but not necessarily. These (slightly but not very) subtle issues aren't really discussed in enough detail in the paper. Brief mention is made in section 4.2 including mention that the software displays the original statements from papers – this seems to be a potential solution, or part of one, but isn't adequately elaborated. Examples of how it looks could be presented.

This is an issue that we are working to better address and have also discussed at length within our team. As most effects are dependent upon the situation, we found it difficult to clearly and consistently capture the *how*, *when* and *why of a strategy*. We are working to make the original statements and sources easily available for anyone using our on-line tool so they can be referenced. To make this more clear we have added a second paragraph in Section 4.4 (formerly 4.2) as written below:

> As a visual summary of relationships the PASE matrix is necessarily terse, and lacks details on how, when and why a strategy causes a certain effect. Two effects may appear contradictory coming from the same strategy, but generally this is due to how the strategy was implemented. While the relationships between strategy and effect are found in the PASE database's sources, they do not always offer more detailed explanations. A designer alerted to an unfamiliar relationship by a PASE matrix may have to research it on their own.

Reviewer 3

3.1 This paper introduces the Product Architecture Strategy and Effect (PASE) Matrix as a means of exploring product architecture design decisions. The PASE Matrix approach aggregates and correlates 'strategies of interest' and 'effects of interest' that have been identified by the authors from the product architecture literature. Users of the PACE Matrix are shown related effects or strategies that they may not have originally considered. The authors describe the development of this approach and introduce metrics that can be used for assessing the maturity and robustness of the database.

The development of the PASE Matrix is intriguing and the continued development and testing of the database could provide a fascinating toolkit for exploring product architecture decisions. I can envision design studies centered around post-mortem analyses of product architecture decisions where decision-makers are asked how the PASE Matrix may have changed their

course of action. I can also envision design studies centered around real-time decision-making studies that explore how the identified 'strategies' and 'effects' of interest (and those that are unexpected but identified by PASE) influence decision-making.

Thank you for your time reviewing this manuscript. Your ideas on real-time-decision-making are interesting areas for potential future study we had not yet considered in much depth.

3.2 While I do like this paper and think that it contributes to design science, I have a few recommendations for how a restructuring of content could make the paper stronger:

The authors have missed a significant opportunity to draw a parallel to existing design tools. Specifically, I was surprised to see that the authors had not made a reference, oranalogy, to TRIZ. While these two approaches (TRIZ and PASE) have a different focus they have conceptual and structural overlap. Both:
  - Have matrix elements that are populated by an exploration of products, patents, and literature where fundamental principles have been distilled by the creators of the approach.
  - Are intended to be a decision-support tool that identifies principles that may have been missed or overlooked by the designer.
  - Support "earlier" design decisions, such as those in concept development where the interactions and interfaces between components/product architecture elements may not be completely understood.

Thank you for this insight. Our team also noted some of the similarities to TRIZ during our initial investigations, such as intent to aid in early design decisions. Below we have improved the second to last paragraph of the Introduction below:

As part of a method to make cause-and-effect insights gleaned from published findings more accessible for use by designers, this paper introduces the Product Architecture Strategy and Effects (PASE) matrix. A method for aggregating strategies and effects from the literature on product architecture into a structured data-set known as the PASE Database is also shown. This builds a digital system enabling visualization of the cause-and-effect relationships in a way that facilitates design decisions, and identifies areas where knowledge is potentially lacking. This method shares similarities to TRIZ (Moehrle 2005) because it aids early design decisions based on patterns emerging from the literature. Unlike TRIZ, the PASE method is not centered on conflict resolution. Instead, the PASE method is centered on revealing cause-and-effect relationships related to product architecture decisions.

3.3 I recommend moving Sections 2.2 and 2.3 to later in the paper when the authors demonstrate the application of the approach. Section 2.1 could become all of Section 2. I make this recommendation because the meat of the paper, in my opinion, is Section 3. The methodology feels a bit lost in the middle of the paper and I would like to see a stronger

emphasis placed on how strategies and effects were identified and consolidated from the literature review.

Thank you.

Relative to the last sentence of R3.3 above, we have discussed consolidation below in our response to comment R3.6.

To prevent the methodology from feeling lost in the middle of the paper we have moved Sections 2.2 and 2.3 – unchanged – to the beginning of Section 4 as suggested, with section 4.1 now becoming section 4.3. The introductory paragraph for Section 4 has been improved as shown below:

> **Section 4**
> In this section, we discuss the two approaches for creating PASE matrices and demonstrate how a design team could use them to aid in finding and evaluating architecture strategies. Importantly, we show how the matrix can be used to mitigate undesirable effects.

3.4 With a stronger focus on Section 3, I would like to see more information about how the authors made decisions around filtering down the papers used for identified strategies and effects. For example:

- What keywords were used to identify the set of 199 papers?
- What exclusion criteria were used to reduce the 199 papers to 45 papers? Did this process involve multiple authors? Was there discussion about whether a paper should be included or excluded?
- How did the authors decide to reduce the 45 papers down to 9? The authors mention that they use categories of which explored key architecture decisions. What does this mean?
- Were papers excluded because of resources available (time, researchers) or because they should not be considered in future development of the PASE Matrix? This becomes an important question when we consider the future development and expansion of the matrix. Should these papers be revisited or do they not contain useful information? Highlighting this is important for readers, and researchers, who want to use this tool or develop it further.

These are important questions that we see were not clearly addressed in the paper. The intent was to find around ten papers with a significant amount of information on a variety of topics within product architecture. All of the papers initially identified in the literature review could have been used in this database, as they discussed some part of product architecture. The original selection of 199 papers was reduced to just nine due to limited man-hours to read and process them. Below we have improved the initial paragraph as can be seen above in our response 2.5.

3.5 I would like to see more detail on the type of statements pulled from the text and how these statements were decomposed into insights. The authors also should provide additional clarity in Section 3.1 about the use of multiple readers/raters. Was the only paper coded by multiple readers the Jiao et al paper? There are established approaches for describing how text elements are identified from a document in a research study, and this paper doesn't feel like it follows those established practices. Commenting earlier in the step-process about how many readers were used on each paper, inter-rater reliability assessment, and background/expertise of the coders should occur.

We agree this information should be addressed sooner. In response 3.7 we give some specific examples of a statement pulled from the literature and how it is decomposed. We have improved paragraph 3.1 as shown in responses 2.5 and 3.8 to add clarity on the number of readers and that Jiao et al was the only one specifically tested.

3.6 Did the authors consolidate statements that were viewed as similar? Perhaps as an appendix or supplemental material it would be nice to see a full list of coded statements/insights that currently make up the PASE Matrix.

Thank you. We agree that the data should be publicly available and are making it available at the same location as the website GUI. To make this more clear, we have improved the second paragraph of Section 2.1 as follows:

> In order to build a PASE matrix, an existing database of strategies, effects, and their relationships is required. Our initial review of the literature revealed more than two dozen strategies and over 200 effects. These were used to construct the digital PASE Database, which was in turn employed to form the PASE matrices found in the remainder of this paper. Because the database contains several hundred relationships, a graphical interface was developed to interact with it and to automatically construct PASE matrices based on user selections. This interface is known as the PASE Matrix Generator and can be accessed through the following URL: https://www.design.byu.edu/resources/pasematrix. The rational tables used to construct the database are also available for download at this site.

3.7 I really like Figure 3. In the text, I would like to see a text-driven example of Figure 3 as well. Could a potential statement, insight, etc. be listed with each step?

We agree that a text-driven example of Figure 3 would significantly clarify the process of gathering and consolidating data in order to produce a PASE Database. The following is text from Subsection 3.1. Text-driven examples have been added to each step of the process.

1. **Read and Identify Potential Statements:** A statement is any quotation from a source in which at least one specific decision regarding product architecture led to, or was said to lead to, one or more effects.

   Example Statement
   ST-001: "Although consumption and wear is frequently accommodated through a modular design with replaceable parts another popular strategy is to dramatically lower the cost of the entire product, often through an integral architecture, such that the entire product can be discarded or recycled."

2. **Decompose Statements into Insights:** An insight is a one-to-one pairing of an architecture strategy and one of its effects found within a statement. Wording was kept as close to the original statement as possible, while reorganizing it into a cause-and-effect sentence.
   > **Example Insights** (from Statement ST-001)
   > I-001: Modular architecture can circumvent wear.
   > I-002: Integral architecture can circumvent wear.
   > I-003: Integral architecture can lower the cost of the entire product.
   > I-004: Integral architecture can facilitate disposable design.

3. **Group Insights & Consolidate:** Insights were grouped by their causes, and had their effects compared. Each insight was constrained to be unique and duplicates within a single source were ignored, as each source must be limited to affirming any specific insight only once. If several statements gave the same insights, then the statements were consolidated, leaving a single statement pointing to a unique insight within each source.
   > **Example Consolidation** (I-005 is from another statement)
   > I-003: Integral architecture can lower the cost of the entire product.
   > ~~I-005: Integral architectures can allow for a lower cost product.~~

   > **Note:** Similar or identical insights from different sources are not removed as they are seen as multiple sources affirming the same idea.

4. **Identify standard strategies, effects, and relationships:** From the groupings of insights, the causes and effects were refined and their language standardized before these parts were placed in the database as architecture strategies and their effects. This helped reduce redundancy within the database, as similar ideas from different sources were recognized despite variation in the wording and terminology used by the various authors.

   Next, the strategy and effect pair identified from the insight was recorded as a relationship. If in the database there was no existing strategy or effect that adequately fit the cause and/or effect, a new one was added to the corresponding table in the database. If there were identical relationships, i.e. two insights from the same source

communicated the same idea, one was removed as in step 3. If there was no existing relationship for the insight (such as when a new strategy or effect was described), then a new relationship was created. Relationships consist of simply their own identifier code, and the identifier codes for a strategy and an effect. Every insight was linked to a relationship's identifier code.

Example Strategy, Effect, and Relationship Identification
Strategies
ST-001 Use Modular Architecture
ST-002 Use Integral Architecture
Effects
E-001 Decreases wear concerns
E-002 Decreases cost per unit
E-003 Increases Disposability
Relationships
R-001: (ST-001 + E-001)
R-002: (ST-002 + E-001)
R-003: (ST-002 + E-002)
R-004: (ST-001 + E-003)

Note: Insights are the key element in the database pointing either forward to a relationship or back towards the statements and sources from which they originated.

5. **Verify and record all identified components:** All new strategies, effects and relationships were compared with any previously recorded in the database to again verify no duplicates had been included. All insights were ensured they linked to an identified relationship, and that relationships contained both a strategy and effect. All strategies, effects, insights, relationships, statements and the source were verified having been recorded in their own corresponding table with their own unique identifier code.

    Example Verification: R-002:(ST-002 + E-001), ~~R-005:(ST-002 + E-001)~~

    Special Note: All of the examples in the above steps are taken from Ulrich 1995. The identifiers follow the format used in the PASE Database and have been reassigned values that correspond to the scope of this example.

3.8 Can the authors explain the significant variability in Table 1 between the two coders? Did they have different backgrounds? Were there trends that explain why different statements and insights were coded by each? Was there a discussion where the unique statements and insights were debated?

This is indeed an important issue to address, especially as we endeavor to expand the PASE Database. The following are the paragraphs on researcher reliability, at the end of Section 3.1, edited to address these concerns.

Researcher Reliability

The experience and number of people used to identify statements from each paper is another factor that may introduce variation in which statements are recorded. In order to better understand the implications of this variation, the paper by Jiao et al. (2007) was independently processed as a source by two researchers according to the steps described. Both Researcher 1 and Researcher 2 had technical backgrounds in engineering. Though both had previously coded sources into the PASE Database, Researcher 2 had about 40 man-hours more than Researcher 1. The information added was then reviewed and compared, and key differences are noted in Table 1.

In total, the researchers recorded 33 distinct excerpts from Jiao et al. (2007). These excerpts were evaluated to see if they met the definition of a statement, i.e. they included at least one specific decision regarding product architecture that led to, or was said to lead to, one or more effects. This evaluation was completed by Researcher 2, with oversight and guidance from the primary author. Debate was an important tool in separating excerpts related to business or design strategies and effects from product architecture strategies and effects.

Of the 33 excerpts recorded, 19 were found to meet the definition of a Statement. Only seven of these 19 statements were noted by both researchers. Five of the statements were only found by Researcher 1, and another seven were unique to Researcher 2. Statements however, do not correlate one to one with insights. The 19 statements contained 44 insights, of which 23% were unique to Researcher 1, 36% to Researcher 2 and 41% were from the statements found by both. This indicates that anywhere from a quarter to one third of the data could have been lost (or not collected) had only one researcher been used on this source.

Regarding the excerpts that were rejected, six were unique to Researcher 1, two were unique to Researcher 2, and six were annotated by both. Thus the ratio of statements to total excerpts recorded was 50% and 64% for Researchers 1 and 2.

Due to the small dataset, no pattern was discernible that might explain the variation between researchers. That said, this exercise demonstrates the benefit of redundant researchers in maximizing the amount of data extracted from a source. This benefit does not extend to the quality of statements recorded. Regardless of the number of individuals used, the steps for processing data sources must be followed and debated to maintain the quality of relationships in the database.