FREE UNIVERSITY OF BOZEN-BOLZANO
FACULTY OF COMPUTER SCIENCE

Why Hardware Startups Fail

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Plagiarism Disclaimer

I, Heider Jeffer, hereby declare and confirm with my signature that this dissertation is my own original and autonomous work. All sources and aids used have been appropriately indicated. All texts, whether quoted directly or paraphrased, have been cited in-text. Full bibliographic details are provided in the reference list, which includes internet websites with URLs, theme nodes, case studies in NVivo Software (in Doc format), content analysis in NVivo software (PDF format), and my contributions available at Mendeley.

I also declare that no part of this dissertation has been created inappropriately, either by plagiarizing or infringing on any third party's copyright. Furthermore, no portion of this dissertation has been used for any other paper or submitted to any other higher education institution, research institution, or educational institution.

Lastly, I declare that this research is open-source Copyleft research, licensed under the MIT license. The laboratory aspects of the research, including codes, materials, software, and database, are available in the official research repository, Gilgamesh, on GitHub.

Signature: 

Heider Jeffer

Bolzano, Italy 2022

" Those who can see beyond the shadows and lies of their culture will never be understood, let alone believed, by the masses."

Plato

” Fasten the throne [first], then engrave [it].”

" In mathematics, you don't understand things. You just get used to them."

John von Neumann

Abstract

Problem Statement: Hardware startups often fail, relying heavily on trial-and-error, intuition, and individual convenience without the support of scientific papers, models, or theoretical foundations to understand and mitigate these failures. There is a significant gap in scientific research addressing the reasons for the high failure rate of hardware startups, which could improve their future success and the startup ecosystem overall.

Research Objective: The primary research question addressed in this thesis is: why do hardware startups fail? This thesis aims to develop a strategy to identify and extract the factors contributing to the failure of hardware startups.

Approach: Secondary data were collected from CB Insights and gray literature. A comprehensive strategy was developed to process the data collection and analysis relevant to the research question. Thematic analysis tools were used to extract case studies from the included data and identify failure factors. Hardware startup information was then extracted from these case studies, and the failure factors were grouped into identical categories. All study materials were stored in the research's official repository, Gilgamesh, on GitHub.

Research Findings: The major categories causing the failure of hardware startups are Customer & Market, Hardware Product & Experts, Financial, Lack of Business Model, and Legal Issues. Product strategy mistakes emerged as the most frequent and fatal failure factor, reflecting the complexity of hardware startups. Pricing and cost issues also significantly explain the challenges and high failure rates of hardware startups.

Contribution: This study highlights the lack of previous research as an opportunity to underscore the need for further studies. The secondary data collected can benefit IoT, data science companies, institutions relying on hardware startups, and qualitative data analysis. Additionally, this study provides clear guidelines on following a strategy to process data and conduct thematic analysis.

Future Work: While significant factors contributing to hardware startup failures have been identified, further research can enhance the depth and breadth of these findings. Future studies could include thematic analysis of video and audio data to extract case studies and failure factors, and adjust search keywords in gray literature to encompass AI and IoT hardware startups, thereby expanding the scope of data collection.

Keywords: hardware startups, failure factors, Gray literature, case study

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1 Introduction

Problem and Motivation

The central research question of this paper is:

Research Question (R.Q.): Why Do Hardware Startups Fail?

Research Objective

The objective of this research is to develop a systematic approach consisting of logical steps and rules for processing, collecting, analyzing, managing, and extracting failure factors from datasets of varying sizes, structures, and formats.

Startups are initiatives aimed at creating products or services and establishing sustainable business models to generate profits amidst uncertainty and extreme conditions (Ries, 2011); (Baldridge and Curry, 2022).

Hardware startups specifically refer to ventures that develop physically tangible products with mass and volume (Cage, 1986); (Stoltzfus, 2020).

Despite their potential, hardware startups often face high failure rates, making it challenging to find successful examples initially (Tom Eisenmann and Eisenmann, 2021); (Lydia Ramsey Pflanzer, 2019).

Notably, Theranos initially stood out as a successful hardware startup valued at $9 billion (Joseph Rago, 2013); (Lydia Ramsey Pflanzer, 2019); (Kunthara, 2021). However, like many others (Pfizer, 2016); (Salzman, 2018), Theranos ultimately ended in a tragic downfall (JINA L. CHOI, 2018); (US Food & Drug Administration, 2022).

Theranos's story serves as a crucial lesson for all hardware startups, highlighting the perils of relying solely on individual convenience, intuition, or trial-and-error without a solid theoretical foundation, scientific models, or empirical validation (CB Insights, 2021a); (KPMG, 2016); (Ritholtz, 2015).

Recent years have seen established companies such as Intel and Lenovo increasingly supporting hardware startups globally (King, 2022); (Alsop, 2022), underscoring the growing importance and potential of this sector. Guiding hardware startups towards success demands significant dedication, time, and effort, as emphasized in this research (Stock and Seliger, 2016); (Nguyen-Duc, Weng and Abrahamsson, 2018).

The methodology developed in this study aims to process diverse datasets comprehensively to answer the fundamental research question: Why do hardware startups fail? (Griffith, 2017); (Li and Seering, 2019).

Research Process and Results

In this section, I outline the research process and the initial results achieved.

Startups Diagram Development:

I have developed a comprehensive Startups Diagram that defines and distinguishes between startups, startup failures, hardware startups, and specifically hardware startup failures. This diagram serves as a foundational tool to strategize the identification and differentiation of failure factors unique to hardware startups within the broader startup ecosystem.

The Startups Diagram is crucial in providing clarity and focus on understanding why hardware startups fail compared to other types of startups. It aids in delineating the specific challenges and characteristics that contribute to the failure of hardware startups, offering a structured approach to analyze and address these issues.

Next Steps

Moving forward, the research will utilize this Startups Diagram as a framework to systematically collect, analyze, and categorize failure factors specific to hardware startups. By leveraging this structured approach, the goal is to uncover deeper insights into the underlying reasons for the high failure rates observed in hardware startups.

Expected Contributions:

The development of the Startups Diagram is expected to contribute significantly to the field by providing a clear methodology for identifying and understanding the unique challenges faced by hardware startups. This structured approach will enhance the ability to develop targeted strategies and interventions aimed at improving the success rate of hardware startups in the future.

Overall, the initial development of the Startups Diagram marks a critical step in the research process, laying the groundwork for more detailed analysis and insights into the factors contributing to the failure of hardware startups.

Data collection and data analysis

In this section, I detail the strategy developed for collecting and analyzing data on hardware startup failures from Gray Literature and CB Insights, along with the phases involved.

Data Collection

Step 1: Define and Refine Search Keywords: Keywords were carefully selected and refined to optimize searches on Google, distributed across three blocks (Block 1, Block 2, Block 3).

Step 2: Apply Search Keywords: Applied refined keywords to the Google search engine, resulting in approximately 43,000,000 units of data.

Step 3: Export Search Results: Extracted and exported relevant search results, yielding 580 URLs.

Step 4: Apply Inclusion/Exclusion Criteria: Implemented criteria to filter and refine [Search Results Collection A], resulting in 122 URLs.

Step 5: Identify Relevant URLs: Identified and selected relevant URLs from [Search Results Collection B], resulting in 70 documents.

Step 6: Extract Relevant Cases: Extracted pertinent case studies from the 70 documents, resulting in 18 cases.

Step 7: Include Cases from CB Insights: Incorporated additional relevant cases from CB Insights, totaling 24 cases.

Step 8: Merge Case Collections: Combined Case Collection A and Case Collection B, resulting in 42 unique cases.

Step 9: Remove Duplicate Cases: Eliminated duplicate cases from Case Collection G, resulting in a final set of 38 unique cases.

Data Analysis

Step 10: Extract Relevant Data: Extracted detailed information on hardware startups from Case Collection C.

Step 11: Coding for Failure Factors: Conducted coding of Case Collection C to identify 17 distinct failure factors.

Step 12: Group Failure Factors: Categorized the identified 17 failure factors into 5 major categories based on thematic analysis.

Results

Through this research, I identified 17 major failure factors from 38 case studies of hardware startups. These factors were categorized into five major groups: Customer and Market, Hardware Products and Experts, Financial, Lack of Business Model, and Legal Issues. The 17 failure factors address the central research question: Why do hardware startups fail?

Key findings include:

- **Critical Failure Factors:** Product strategy mistakes, pricing cost issues, and poor product quality emerged as the most critical factors leading to the failure of hardware startups.

- **Detailed Explanations:** Each failure factor is explained in detail, with at least one exemplar case illustrating its impact.

The study also developed a comprehensive guideline for data collection and analysis, which can serve as a valuable resource for future researchers. This guideline includes steps for processing large datasets and extracting relevant failure factors.

Limitations

1. **Lack of Previous Research:** There is a significant gap in the literature regarding hardware startup failures, making this research largely exploratory. This lack of previous studies influenced the methodology and approach.

2. **Gray Literature and Self-Reported Data:** The reliance on gray literature and self-reported data poses limitations due to potential biases and the unverified nature of the information. These sources were used to compensate for the lack of existing scholarly research but inherently limit the reliability and comprehensiveness of the findings.

Implications for Future Research

- **Exploratory Nature:** Given the exploratory nature of this study, there is a need for more rigorous and extensive research on hardware startup failures. Future studies should aim to build on this foundational work and explore additional data sources and methodologies.

- **Methodological Enhancement:** Future research could benefit from incorporating more diverse data types, such as video and audio data, to extract case studies and failure factors more comprehensively. Expanding the search keywords to include AI and IoT hardware startups could also enhance the breadth of data collection.

- **Practical Applications:** The guidelines and findings from this research provide a practical framework for both researchers and practitioners in the field. By following the outlined strategy, future researchers can systematically collect and analyze data to further understand and address the challenges faced by hardware startups.

In conclusion, this research represents a significant contribution to understanding the reasons behind the failures of hardware startups, offering a structured framework for data collection and analysis. Despite its inherent limitations, the study sets a solid foundation for future investigations and provides actionable insights to enhance the prospects of success for hardware startups.

The study's findings underscore several key points:

- **Structured Approach to Analysis**: By categorizing and analyzing failure factors, the research provides a systematic way to comprehend the complexities surrounding hardware startup failures. This structured approach aids in identifying patterns and root causes, essential for informed decision-making and strategy formulation.

- **Implications for Future Research**: The study highlights the importance of adopting a more inclusive and adaptable approach to data collection and analysis in future research endeavors. Incorporating diverse data formats, such as video, audio, and refined search keywords in gray literature, can enrich insights and overcome the limitations associated with self-reported data.

- **Enhancing Success Rates**: Insights derived from this research are pivotal for developing targeted strategies aimed at improving the success rates of hardware startups. By addressing identified challenges comprehensively, future studies can contribute to creating an ecosystem that fosters innovation and sustainability in the hardware industry.

Moving forward, ongoing research efforts are essential to further refine methodologies, validate findings across different contexts, and explore emerging trends in technology and

entrepreneurship. This continuous pursuit of knowledge is crucial for evolving strategies that mitigate risks and support the growth of hardware startups worldwide.

In essence, this study not only deepens our understanding of hardware startup failures but also lays the groundwork for future initiatives focused on fostering resilience and success in this dynamic sector. By embracing innovation in research methodologies and staying attuned to industry developments, we can collectively drive positive change and empower hardware startups to thrive in competitive markets.

2 Thesis Structure

The remaining part of this thesis is organized as follows:

- **Chapter 3: Background and Related Work**
  This chapter provides a comprehensive review of the existing literature on hardware startups and their failure factors. It sets the context for the research question by discussing relevant theories, models, and prior studies.

- **Chapter 4: Research Approach**
  This chapter details the methodology used in this study, including the development of the Startups Diagram, the three-phase strategy for data collection and analysis, and the specific steps involved in each phase. It explains how the data was sourced, processed, and analyzed to identify the failure factors.

- **Chapter 5: Research Findings**
  This chapter presents the results of the study. It identifies the 17 major failure factors and categorizes them into five groups: Customer and Market, Hardware Products and Experts, Financial, Lack of Business Model, and Legal Issues. Each failure factor is explained in detail, with exemplar cases illustrating their impact on hardware startups.

- **Chapter 6: Discussion**
  This chapter discusses the implications of the research findings. It analyzes the critical failure factors, such as product strategy mistakes, pricing cost issues, and poor product quality, and provides guidelines for data collection and analysis. The chapter also reflects on the limitations of the study and discusses potential areas for future research.

- **Chapter 7: Conclusions**
  The chapter summarizes the key findings of the study and their implications. It discusses how the study contributes to the understanding of hardware startup failures and offers suggestions for future research, including the use of diverse data formats and refined search keywords to expand the scope of analysis.

- **Chapter 8: Implications for Future Research**
  Use thematic analysis on video and audio data alongside text to gain deeper insights into hardware startup failures. Include AI and IoT in search keywords for gray literature to better reflect current industry trends and understand hardware startup failures more accurately. Expand keywords to cover IoT, AI, CPU, Mouse, Monitor, Keyboard, Headphones, and Laptop for a comprehensive view of factors influencing hardware startup failures.

- **Chapter 9: Closing Remarks**
  This study identifies critical failure factors for hardware startups and encourages future research to refine methodologies and deepen our understanding. By leveraging advanced analytical techniques and targeted data collection, we aim to foster resilience and success in the hardware industry.

By following this structure, the thesis systematically addresses the research question and provides a thorough examination of the factors leading to hardware startup failures.

3 Background and Related Work

3.1 What is Hardware Startup

- **Startups** are projects undertaken by an entrepreneur to create, seek, develop, and validate goods or services, aiming to establish sustainable business models. These ventures attempt to build products, sell them, and generate profits amidst significant uncertainty and risk (Ries, 2011); (Baldridge and Curry, 2021).

- **Startup Failure** refers to a scenario where a startup ceases operations, leading to losses for creditors and stakeholders due to its inability to turn a profit (Cash, 2014).

- **Hardware Startups** is a startups, focus on creating products with physical mass and volume, including tangible items like computer components (e.g., CPU, monitor, mouse, motherboard) and various metal tools or machinery parts used in industrial, military, or general applications (Cage, 1986); (Stoltzfus, 2020).

- **Hardware Startup Failure** specifically pertains to the failure of startups that produce physically tangible products with mass and volume.

Figure 1 illustrates the intersection of hardware startups and startup failures. The diagram highlights how hardware startups are a subset of general startups, and hardware startup failures are a subset of overall startup failures.

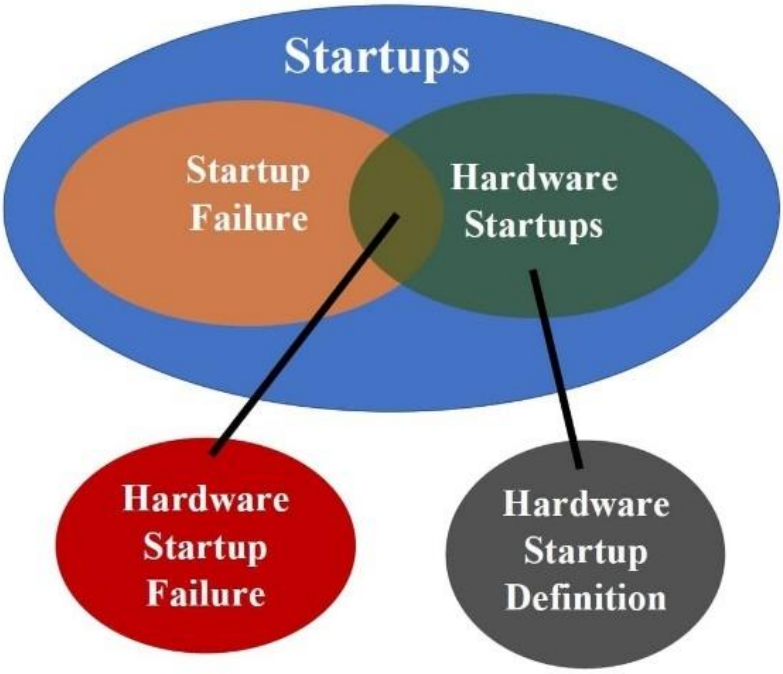


Figure 1 Startups Diagram

3.2 Why Startup Fail

The primary goal of startups is to generate enough revenue to cover production costs and satisfy shareholders. However, creating an ideal revenue model is challenging.

According to a study by the European Association of Business, out of 390 million founders, 140 million run businesses, and 50 million new projects are launched annually (approximately 137,000 daily). Despite this activity, 90% of startups fail within 1-3 years, making startup ventures significantly riskier than traditional business models (Croft and Cruse, 2004); (EBAN, 2018).

In 2016, KPMG reported that 90% of startup projects fail within 18 months, and only 37% of startups generate revenue (69% earn up to 50 thousand euros, 23% earn more than 50 thousand euros, and 8% earn more than half a million euros), while others fail to generate any revenue (Ing. Richard Bednár and Ing. Natália Tarišková, 2017).

CB Insights is a U.S. company that compiles data and analyzes startup failures, producing "startup failure post-mortems" since 2014.

In 2018, CB Insights studied 101 startup failure post-mortems and identified the "Top 20 reasons for startup failure" (Staff reporter, 2018). A subsequent study in 2021 outlined the "Top 12 reasons startups fail" (CB Insights, 2021b).

Table 1 shows the variation in CB Insights' failure factors from 2018 to 2021:

Table 1 2018 - 2021: variation of CB-Insights failure factors

Failure Factors	CB Insights 2018	CB Insights 2021
Ran out of cash	29%	38%
No market need	42%	35%
Get outcompeted	19%	20%
Legal Issues	8%	18%
Price cost issues	18%	15%
Poor product	17%	8%
Disharmonious team/investor	13%	7%

Over three years, failure factors such as "Price cost issues," "Poor product," and "Disharmonious team/investor" have seen improvements, decreasing by 3%, 9%, and 6% respectively. Conversely, factors such as "No market need," "Running out of cash," "Getting outcompeted," and "Legal Issues" have increased by 7%, 9%, 1%, and 10% respectively.

This analysis underscores the dynamic nature of startup challenges and highlights the need for continuous adaptation and strategic planning to mitigate the risk of failure.

3.3 Studies on Hardware Startups

Several key studies reflect the unique dynamics and challenges faced by hardware startups:

1. **Advanced Research Materials and Hardware Startups**
    - This study addresses the development of innovative hardware startups, emphasizing the complexity of creating tangible products that often consist of mechanical, electrical, and software components. The research highlights the multifaceted nature of hardware development and the critical integration of various technological disciplines (Stock and Seliger, 2016).

2. **Tech Communities and Industry 4.0**
    - This research explores the participation of significant game changers in the tech communities, particularly in the realms of the Internet of Things (IoT), cyber-physical systems, and robotics. It also examines the role of Industry 4.0 in the rise of hardware startups, noting that the entry barriers for starting a hardware-related business have never been lower due to the increasing popularity and support within hardware ecosystems (Nguyen-Duc, Weng and Abrahamsson, 2018).

3. **Business Models and Open Source in Hardware Startups**
    - This study presents a business model that explores the relationship between startup founders and users, focusing on hardware startups driven by the Linux community. It discusses the integration of open-source principles in hardware development, involving the essential Linux distribution Redhat and its community. The research underscores the importance of open-source frameworks in fostering innovation and collaboration in hardware startups (Li and Seering, 2019).

These studies collectively highlight the diverse factors influencing hardware startups, from advanced material research and tech community engagement to the adoption of open-source business models. They provide a comprehensive view of the challenges and opportunities within the hardware startup ecosystem, offering valuable insights for future research and practical applications.

3.4 Related Work on Hardware Startups Failure

While the IEEE database lacks specific studies addressing the research question, "Why do hardware startups fail?", we have identified two relevant articles that provide insights into hardware startup failures:

1. **Wired's Analysis of Hardware Startups**

    - **Summary**: A study from Wired highlights several reasons why hardware startups often fail. Key issues include the lengthy and costly process of bringing hardware products to market and the founders' insufficient efforts to attract investors. The article also points out that while crowdfunding can provide initial funding, it does not guarantee market success for hardware startups.

    - **Exemplar Cases**: The study mentions several notable hardware startup failures, including Jawbone, Njoy, Juicero, Fuhu, Zeebo, and Hello. These cases illustrate the common pitfalls hardware startups face and are utilized as examples in this paper (Griffith, 2017).

2. **GeekWire's Insights on Consumer Demand and Burn Rate**

    - **Summary**: An article from GeekWire identifies lack of consumer demand and high burn rate as major factors contributing to the failure of over 360 hardware startups. The study notes that many hardware startups raise funds based on ideas rather than actual products, which can lead to financial instability and eventual failure.

    - **Exemplar Cases**: The article provides examples of hardware startup failures such as Lily Drones and Coolest Cooler. These cases are also used in this study to illustrate specific failure factors (ANUP CHATHOTH, 2020).

These articles contribute to the understanding of hardware startup failures by highlighting critical factors such as market demand, financial management, and investor relations. They offer practical examples that align with the findings of this research, further supporting the identified failure factors and categories.

4 Research Approach

The research area concerning hardware startup failures is nascent, with limited prior studies available to support this investigation. Consequently, this research adopts an exploratory approach to address the lack of previous studies on the research question (RQ): Why do hardware startups fail?

To circumvent the absence of existing literature on this topic and to expedite data collection while avoiding legal agreements, copyright issues, and costs, I utilized Gray Literature(Fourth *et al.*, 2014) and CB-Insights to gather secondary data.

Data Sources and Justification

- **Gray Literature**: This source provides a vast and high-quality database, making it a valuable asset for collecting and processing data independently. Gray Literature data is readily available from various resources and may have been used in previous studies related to hardware startup failures, facilitating easy integration with other studies.
- **CB-Insights**: The data from CB-Insights was provided by a researcher (Rafiq *et al.*, 2021). I reviewed his research and discussed his findings to gain insights and incorporate relevant data into this study.

I developed a three-phase strategy to systematically process the data. This strategy is detailed in Figure 2 and includes:

Data Collection

- **Step 1**: Define and refine search keywords for Google.
- **Step 2**: Apply search keywords to the Google search engine.
- **Step 3**: Export search results.
- **Step 4**: Apply inclusion/exclusion criteria to the search results collection.
- **Step 5**: Identify relevant URLs from the refined search results.
- **Step 6**: Extract relevant cases from the document collection.

    - **Step 7**: Include cases from CB-Insights.
    - **Step 8**: Add case collection B to case collection A.
    - **Step 9**: Merge duplicate cases in the final case collection.

2. **Data Analysis**
    - **Step 10**: Extract relevant data from the case collection.
    - **Step 11**: Code the case collection to identify failure factors.
    - **Step 12**: Group the identified failure factors into major categories.

3. **Storing Research Materials**
    - Store the research materials and the outcomes of the 12 steps from Phases 1 and 2 in the designated repository.

Tools and Implementation

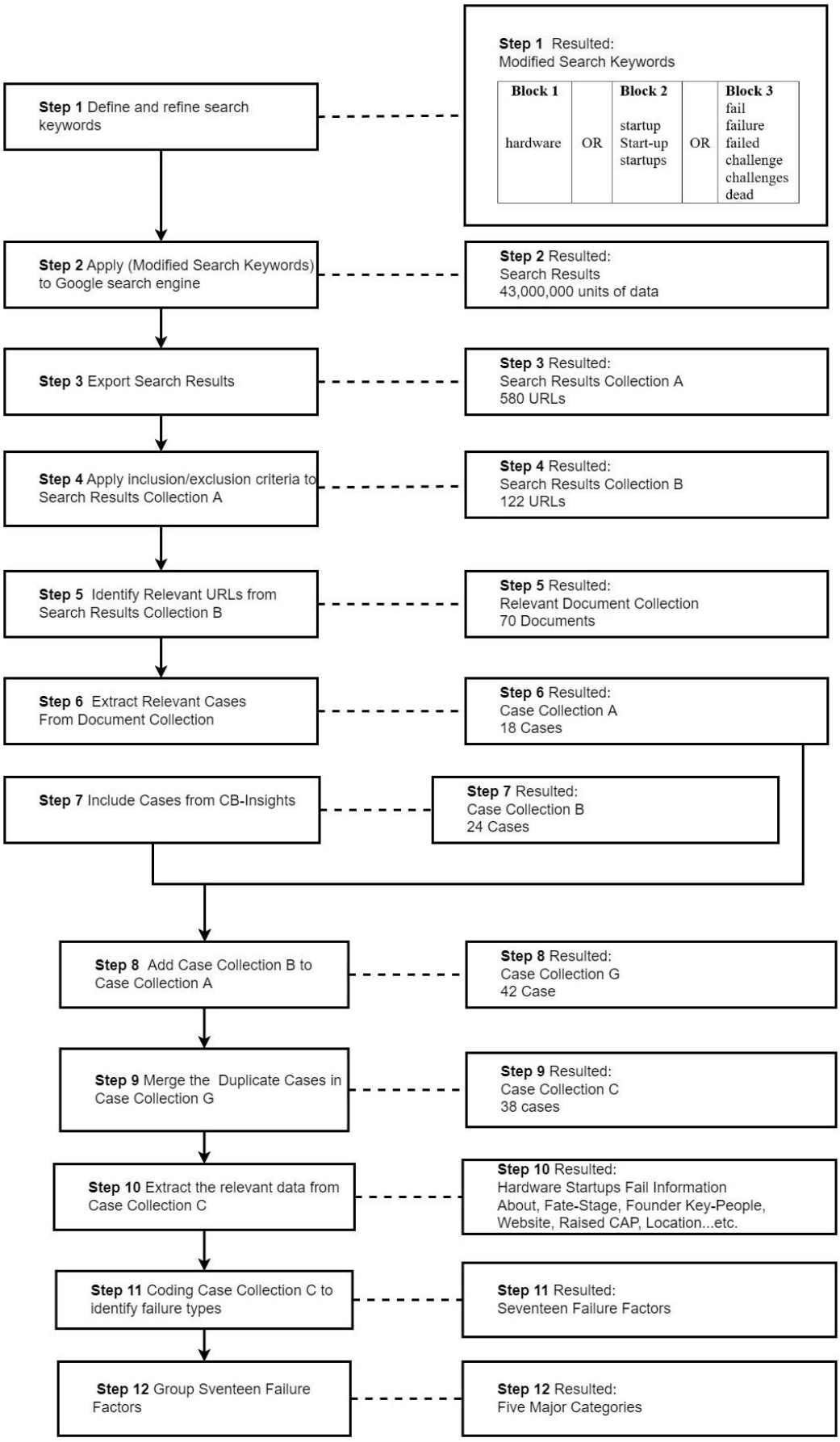
- **NVivo Software**: This software was used to process thematic data analysis in Phases 1 and 2. NVivo's capabilities in managing, analyzing, and visualizing qualitative data made it an ideal choice for this research.

The strategy is well-suited to the nature of this research (Bajwa *et al.*, 2017). It provides a structured approach to data collection, analysis, and storage, ensuring that the study's objectives are met comprehensively.

Figure 2 **Data collection and analysis diagram:**

In the following sections, I will elaborate on each phase and its corresponding steps, providing a detailed explanation of the methodology and processes involved. This structured approach ensures thorough data processing and robust analysis to answer the research question effectively.

Figure 2 Data collection and analysis



4.1 Data Collection

Step 1: Define and refine search keywords for Google

In this step, we created three blocks of keywords. Initially, we defined the keywords, and then we refined the search strings. The results for one keyword, two keywords, and three keywords were assigned to Block 1, Block 2, and Block 3, respectively. The modified search keywords are as follows:

Modified Search Keywords:

(”hardware”) AND (“startup” OR “start–up” OR ”startups”) AND (”fail” OR ”failure” OR ”fails” OR ”failed” OR ”challenge” OR ”challenges” OR ”dead”)

Table 2 Define and refine search keywords

Block 1		Block 2		Block 3
hardware	OR	startup startup startups	OR	fail failure failed challenge challenges dead

Step 2: Apply Modified Search Keywords in Google Search Engine

Using the Chrome browser, we applied the modified search keywords in the Google search engine. This step yielded 43,000,000 units of data in the search results.

Step 3: Export Search Results

In Google Advanced Search, we narrowed down the search results by setting the language to English only. This resulted in [Search Results Collection A], which contained 580 URLs distributed across 17 pages.

Step 4: Apply Inclusion/Exclusion Criteria to Search Results Collection A

To filter the websites relevant to our study, we implemented the following inclusion and exclusion criteria:

Inclusion Criteria:

- The website is about hardware startup failures.
- The URL is not broken and can be accessed.
- The website language is English.
- The website is current, relevant, authoritative, and accurate.

Exclusion Criteria:

- The website is non-text-based sources (videos, audio), [left for future work].
- The website is on Facebook, Quora, SlideShare, and LinkedIn.

This step resulted in [Search Results Collection B], containing 122 URLs.

Step 5: Identify Relevant URLs from Search Results Collection B

Using the Startups Diagram in Figure 2.1, we identified relevant information from [Search Results Collection B] and distinguished hardware startups from other startups. This step resulted in 70 websites being converted into DOC format, forming the [Document Collection].

Step 6: Extract Relevant Cases from Document Collection

We performed qualitative analysis on the cases extracted from the [Document Collection]. Each document was read thoroughly to ensure it reflected hardware startup failure and explained the reasons behind it. We checked the quality of the documents based on the following assurance quality criteria:

Inclusion Criteria:

- The document explains why hardware startups fail and includes at least one example of a hardware startup failure.

Exclusion Criteria:

- The document explains why hardware startups fail but does not include at least one example of a hardware startup failure.

This step resulted in 18 documents being included in [Case Collection A], containing 18 case studies.

Step 7: Include Cases from CB-Insights

We included 24 cases from CB-Insights provided by a researcher. We applied the same criteria used in Steps 5 and 6 to test these cases. This step resulted in 24 cases being included in [Case Collection B].

Step 8: Combine Case Collection B with Case Collection A

We combined the 18 case studies in [Case Collection A] with the 24 cases in [Case Collection B], resulting in 42 cases in [Case Collection G].

Step 9: Merge Duplicate Cases in Case Collection G

We identified and merged 4 duplicate case studies (Jawbone, Lumos, Theranos, and Hello) in [Case Collection G]. This step resulted in 38 case studies in [Case Collection C].

4.2 Data Analysis

Step 10: Extract Relevant Data from Case Collection C

In this step, we performed a thorough reading of the documents in [Case Collection C] and used NVivo software to extract and analyze relevant information about hardware startup failures. The data extracted included:

- **Founded Year:** The year the hardware startup was established.
- **Stage-Fate:** The stage at which the startup failed and the nature of its failure.
- **Total Raised (CAP):** The total capital raised by the startup before it failed.
- **Location, Country, Region:** The geographical details of the startup.
- **Website:** The startup's official website for further reference.

- **Release Date:** The date when the product or service was released to the market.
- **Key People:** The main individuals involved in the startup, such as founders and key executives.

To ensure the completeness and accuracy of the data, we gathered additional information by visiting various sources, including:

- **Hardware Startup Failure Homepage:** The official website of the failed startup, if available.
- **Web Page:** Other web pages that provided information about the startup.
- **Wikipedia:** Wikipedia entries related to the startup.
- **Social Media:** Social media profiles and posts from the startup or key people involved.

We copied and pasted the collected information into NVivo software and then used NVivo to code and categorize the data, enabling a detailed analysis. The coded data helped in identifying patterns and factors contributing to hardware startup failures.

Step 11: Coding [Case Collection C] to Identify the Failure Factors

Using thematic analysis tools within NVivo software, I systematically analyzed the 38 case studies in [Case Collection C] to identify the underlying factors that led to hardware startup failures. This process involved the following steps:

1. **Data Familiarization:** Thoroughly reading and re-reading the documents to become deeply familiar with the content.
2. **Initial Coding:** Generating initial codes for the data segments that appeared relevant to hardware startup failures.
3. **Searching for Themes:** Organizing the codes into potential themes or categories that represent broader patterns of failure.
4. **Reviewing Themes:** Refining the themes by reviewing the data associated with each theme, ensuring they accurately reflect the data.
5. **Defining and Naming Themes:** Clearly defining and naming each theme to ensure clarity and consistency.

The thematic analysis resulted in the identification of **17 distinct failure factors**. These factors were extracted from the case studies and represent the primary reasons for hardware startup failures. The identified failure factors are visually represented in Figure 3.

List of Identified Failure Factors:

1. **Product Strategy Mistakes:** Missteps in planning and executing the product strategy.
2. **Pricing Cost Issues:** Challenges in setting appropriate prices and managing costs.
3. **Poor Product Quality:** Issues with the quality and reliability of the product.
4. **Market Need:** Failure to address a significant market need.
5. **Outcompeted:** Being outperformed by competitors.
6. **Legal Issues:** Problems related to legal compliance and intellectual property.
7. **Financial Mismanagement:** Ineffective management of financial resources.
8. **Team Disharmony:** Conflicts and lack of cohesion among the team or with investors.
9. **Poor Timing:** Launching the product at an inopportune time.
10. **Supply Chain Issues:** Difficulties in managing the supply chain effectively.
11. **Distribution Challenges:** Problems with getting the product to market.
12. **Customer Feedback Ignored:** Failure to listen to or act on customer feedback.
13. **Regulatory Hurdles:** Challenges in navigating regulatory requirements.

14. **Technological Challenges:** Technical difficulties that hinder product development.
15. **Scaling Problems:** Issues with scaling the product or business operations.
16. **Market Saturation:** Entering an already saturated market.
17. **Marketing Failures:** Ineffective marketing strategies and execution.

Each failure factor will be discussed in detail in Chapter 4, including specific case study examples that illustrate how these factors contributed to the failure of hardware startups.

The identification of these failure factors provides a comprehensive understanding of why hardware startups fail, serving as a foundation for developing strategies to mitigate these risks in future ventures.

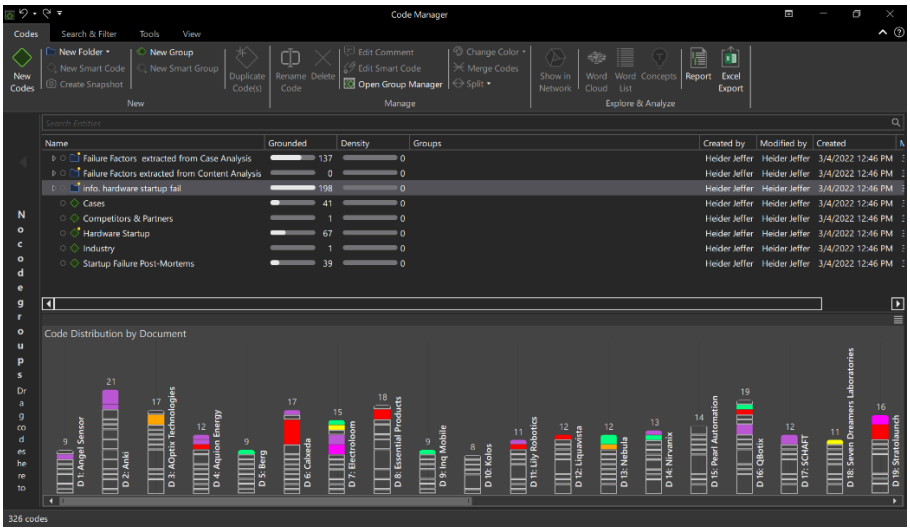


Figure 3 Diagram from Gilgamesh Case studies and Failure Factors(Atlas ti version)

Step 12: Grouping 17 Failure Factors into Five Major Categories

After identifying the 17 distinct failure factors from the 38 case studies in [Case Collection C], the next step involved grouping these factors into broader categories based on their common characteristics and themes. This process is essential for organizing and synthesizing the data to provide a clearer understanding of why hardware startups fail.

Five Major Categories of Failure Factors:

1. **Customer and Market:** Factors related to understanding customer needs, market demand, and customer acquisition.
2. **Hardware Products and Expertise:** Issues concerning product development, quality, and technical expertise.
3. **Financial:** Challenges associated with financial management, funding, and budgeting.
4. **Lack of Business Model:** Problems related to business strategy, revenue generation, and scalability.
5. **Legal Issues:** Issues involving legal compliance, intellectual property rights, and regulatory challenges.

Detailed Explanation in Chapter 5.2

In Chapter 5.2, each of these five major categories will be discussed in detail. I will elaborate on the specific failure factors that fall within each category and provide examples from the case studies in

[Case Collection C]. This structured approach will help in comprehensively analyzing the reasons behind the failure of hardware startups and understanding the broader implications for future research and practice.

By grouping the 17 failure factors into these major categories, I aim to provide a systematic framework that can guide entrepreneurs, investors, and researchers in identifying and addressing potential pitfalls in hardware startup ventures. This framework not only helps in understanding past failures but also serves as a valuable tool for improving strategies and decision-making in the development and management of hardware startups.

4.3 Storing Research Materials

In this part of the research, the focus is on establishing a comprehensive repository named "Gilgamesh" on GitHub. This repository serves as the central hub to store all research materials, including data collected during Phases 1 and 2, analysis outputs, and related documentation. The use of version control through Visual Studio software ensures that all changes and updates to the repository are tracked systematically.

Gilgamesh Repository on GitHub

Purpose and Structure: The Gilgamesh repository is designed to facilitate efficient management and access to research materials throughout the study. It serves several key purposes:

1. **Centralized Storage:** All data collected from various sources, including Gray Literature and CB-Insights, are stored securely in one location. This includes the 38 case studies from [Case Collection C], the 17 failure factors grouped into five major categories, and any supplementary documentation.

2. **Version Control:** By using Visual Studio software integrated with GitHub, the repository enables version control. This means every change made to the research materials, whether it's data updates, code revisions, or documentation edits, is logged and tracked. This ensures transparency, accountability, and the ability to revert to previous versions if needed.

3. **Accessibility:** Researchers, collaborators, and stakeholders involved in or interested in the study can access the Gilgamesh repository. This promotes collaboration, peer review, and the sharing of findings within the academic community and beyond.

Visual Studio for Version Control

Visual Studio software is utilized specifically for its capabilities in managing code and project files efficiently. It provides robust tools for version control, allowing researchers to commit changes, manage branches, and synchronize updates seamlessly with the GitHub repository.

Benefits of Using Gilgamesh:

- **Organizational Efficiency:** Centralized storage simplifies access to research data and analysis outputs, promoting organizational efficiency and minimizing the risk of data loss or fragmentation.

- **Collaborative Platform:** Facilitates collaboration among researchers by providing a platform for sharing insights, discussing findings, and refining methodologies.

- **Transparency and Reproducibility:** Enhances the transparency of the research process and promotes reproducibility of results by maintaining a clear audit trail of all changes made to the research materials.

Figure 4 **: Gilgamesh Repository on GitHub, Version Control with Visual Studio**

The figure accompanying this phase illustrates the interface of the Gilgamesh repository on GitHub, integrated with Visual Studio for version control. It visually represents the structure and functionality of the repository, highlighting its role in storing and managing research data effectively.

By establishing the Gilgamesh repository and leveraging Visual Studio for version control, this research ensures robust data management practices, promotes collaboration, and supports the integrity and reliability of the study's outcomes.

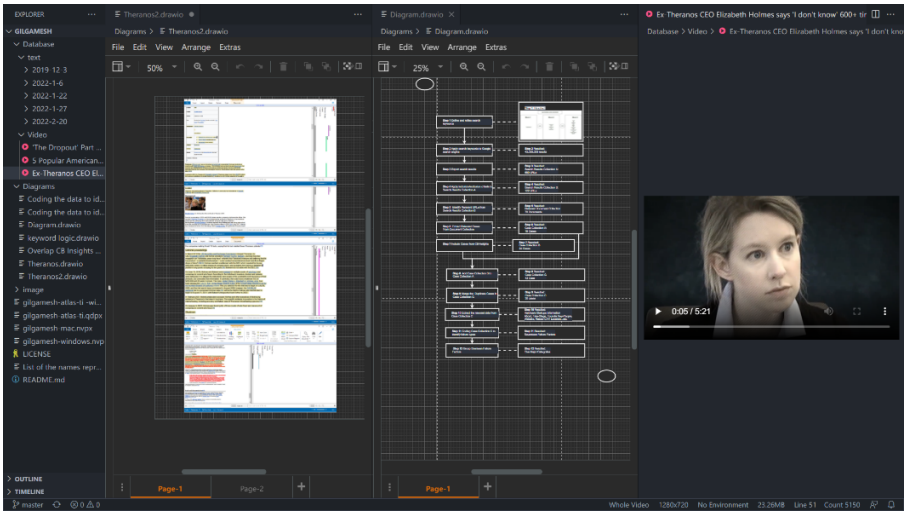


Figure 4 Gilgamesh user interface in local machine

5 Research Finding

5.1 Critical Failure Factors for Hardware Startups

Based on the analysis of 38 case studies, we identified 17 major failure factors for hardware startups, which we have categorized into five distinct categories. These categories reflect common themes among the factors contributing to the failure of hardware startups.

Table 3: Major Failure Factors Categorized for Hardware Startups

Table 3 Seventeen Failure Factors assigned in Five Failure Categories

Category	Failure Factors
Customer and Market	Lack of market need
	Inadequate understanding of customer requirements
	Failure to pivot in response to market changes
	Poor product-market fit
Hardware Products and Experts	Technical challenges in product development
	Quality issues with the hardware product
	Lack of technical expertise
Financial	Ran out of funding
	Cost overruns
	Inability to raise additional capital
Lack of Business Model	Poor revenue model
	High cost structure
Legal Issues	Intellectual property disputes
	Non-compliance with regulatory requirements

Explanation:

- **Customer and Market:** These factors pertain to issues related to understanding customer needs, adapting to market changes, and achieving product-market fit.
- **Hardware Products and Experts:** Challenges in product development, quality control, and technical expertise are critical factors in hardware startup failures.
- **Financial:** Financial factors include funding issues, cost management problems, and difficulties in securing additional capital.
- **Lack of Business Model:** Issues such as poor revenue models and high operating costs contribute significantly to startup failures.
- **Legal Issues:** Legal challenges, including intellectual property disputes and regulatory compliance issues, pose risks to hardware startups.

These categories and failure factors provide a comprehensive framework for understanding why hardware startups fail, based on empirical data and case study analysis.

5.2 Understanding Failure Factors: Insights from Key Case Studies

In this section, we will explore each failure factor identified for hardware startups, accompanied by exemplar cases that illustrate how these factors contributed to the startups' failures.

Table 4 Failure Factors Explained with Exemplar Cases

NO.	Failure Factor	Exemplar Case	Description	Outcome
1.	First-Mover Disadvantage	Pebble Watch	Pebble Technology faced intense competition in the wearables market, particularly from giants like Apple, leading to market share loss despite early success.	Pebble sold its IP to Fitbit, unable to sustain against established competition.
2.	Neglecting User Feedback	Jawbone	Jawbone's neglect of customer service and support led to widespread dissatisfaction and customer attrition.	Jawbone faced backlash and eventual closure due to customer dissatisfaction.
		Jibo	Jibo's abrupt cancellation of international orders damaged customer trust and market expansion efforts.	Jibo's failure to deliver on orders undermined its market growth.
3.	Misaligned Product Market Fit	Liquavista	Liquavista's technology aimed at improving battery life lost relevance with advancing mobile tech, diminishing demand.	Amazon's acquisition did not translate into market success as demand waned.
		Hello	Hello's Sense sleep sensor struggled to differentiate in a crowded smart home market, failing to capture significant market share.	Hello's inability to meet market needs led to market failure despite initial interest.
4.	Inability to Scale Post-Crowdfunding	ZionEyez	ZionEyez's failure to manage technical and financial challenges post-crowdfunding led to operational setbacks and customer disillusionment.	Despite crowdfunding success, ZionEyez's failure to deliver led to customer dissatisfaction.
		Zano Drones	Zano Drones faced production delays and technical issues post-crowdfunding, disappointing backers and damaging its reputation.	Zano's failure to meet expectations and deliver functional products led to its downfall.
5.	Ineffective Market Communication	QBotix	QBotix's struggle with market acceptance due to ineffective marketing hindered its growth.	QBotix's inability to convert market interest into sales limited its market impact.

6.	Lack of Technical Proficiency	Pirate-3D	Pirate-3D's lack of expertise in designing and manufacturing 3D printers led to technical and production challenges.	Pirate-3D's failure to deliver reliable products undermined its market position.
7.	Strategic Directional Issues	Better Place	Better Place's lack of strategic planning for electric vehicle charging stations mismanaged resources and led to financial strain.	Better Place's misaligned strategy resulted in financial strain and operational inefficiencies.
8.	Production Challenges	Angel Sensor	Angel Sensor faced manufacturing issues, including materials and technology, causing delays and quality control problems.	Manufacturing setbacks prevented Angel Sensor from scaling effectively.
9.	Substandard Product Quality	Zeebo	Zeebo's gaming console suffered from poor build quality and functionality issues, affecting market perception and adoption.	Zeebo's failure to deliver a competitive product led to decline in the gaming console market.
10.	Market Timing Issues	Jibo	Jibo's repeated product shipment delays eroded customer trust and market position.	Jibo's delays in meeting market expectations contributed to customer dissatisfaction.
11.	Strategic Planning Errors	Calxeda	Calxeda's persistence with outdated technology despite market shifts led to missed opportunities and competitive disadvantage.	Calxeda's failure to adapt to market changes undermined its competitiveness.
12.	Unsustainable Spending	Pearl Automation	Pearl Automation's high burn rate in developing automotive products led to financial struggles and eventual closure.	Despite initial funding, Pearl Automation's inability to achieve profitability led to closure.
13.	Lack of Investor Confidence	Schaft	Schaft's failure to secure growth capital hindered its ability to scale operations and innovate in the robotics market.	Schaft's inability to attract sufficient funding affected its growth potential in robotics.
14.	Financial Mismanagement	Zeebo	Zeebo's pricing challenges in international markets impacted consumer adoption and market penetration.	Zeebo's failure to adjust pricing led to market failure and obsolescence.
15.	Financial Insolvency	Airware Drone	Airware Drone's financial insolvency due to high costs and competitive pressures led to operational shutdown.	Depletion of financial resources forced Airware Drone to cease operations.

16.	Absence of Sustainable Business Model	Electroloom	Electroloom's lack of a viable business model and market validation hindered investor interest and customer adoption.	Electroloom's failure to establish a sustainable business model led to investor disinterest.
17.	Regulatory and Legal Challenges	Theranos	Theranos faced legal battles and regulatory scrutiny over fraudulent practices and misleading claims.	Legal issues severely damaged Theranos's reputation and financial stability.
		Coolest Cooler	Coolest Cooler faced legal investigations and failed to fulfill crowdfunding promises, impacting its operations.	Legal and financial issues strained Coolest Cooler's resources and market position.
18.	Customer Service Issues	Skully Helmets	Skully Helmets' poor customer service, including delayed shipments and unresponsive support, led to customer dissatisfaction.	Skully Helmets' reputation suffered due to inadequate customer support.
19.	Failed Acquisition	Pebble	Pebble's acquisition by Fitbit did not sustain its market presence, reflecting risks in strategic acquisitions.	Fitbit's acquisition did not maintain Pebble's market share.
20.	Founders Mistakes	Zano	Zano's internal disputes and mismanagement contributed to operational inefficiencies and bankruptcy.	Leadership issues and mismanagement undermined Zano's operational success.

6 Discussion

This discussion encapsulates the critical failure factors identified in our study and acknowledges the limitations encountered during research, emphasizing opportunities for future investigation and improvement in understanding hardware startup failures.

6.1 Key Factors Contributing to Hardware Startup Failures

In our study, several key factors emerged as critical contributors to the failure of hardware startups. Understanding these factors is crucial for identifying pitfalls and improving the success rate of future ventures.

6.1.1 Product Strategy Mistakes

Product strategy mistakes were identified as the most frequent failure factor in our study. This factor transcends the backing of powerful industries like Intel and Google. Even with substantial support, hardware startups failed when they made critical errors in their product strategy. These mistakes could include misalignment with market needs, poor timing, or failure to differentiate from competitors effectively.

6.1.2 Pricing Cost Issues
The complexity and cost associated with hardware startups underscored the challenges faced by these ventures. Factors such as sourcing hardware parts, managing manufacturing costs, navigating taxes and VAT, and coordinating technical expertise all contributed to the difficulty of operating in this sector. Pricing cost issues highlighted the necessity for startups to meticulously manage expenses and optimize their supply chain to maintain competitiveness and profitability.

6.1.3 Poor Product
The quality of the product itself significantly influenced the success or failure of hardware startups. Startups that produced substandard products faced an uphill battle in gaining market acceptance and sustaining customer satisfaction. This factor underscores the importance of balancing cost and quality to deliver products that meet consumer expectations and stand out in the competitive landscape.

6.2 Limitations of the Study
Our research encountered several limitations that warrant consideration for future studies and endeavors in this area.

6.2.1 Lack of Previous Research on Hardware Startup Failures
The scarcity of prior research on hardware startup failures posed a significant challenge. While it presented an opportunity to explore an underexplored area, the absence of established frameworks and findings limited our ability to contextualize our results within existing literature. This gap underscores the need for further research to comprehensively understand and address the complexities of hardware startup failures.

6.2.2 Dependence on Gray Literature and Self-Reported Data
To overcome the lack of primary research, we relied on gray literature and self-reported data. This approach provided access to a broad spectrum of insights and perspectives on why hardware startups fail. However, the reliance on secondary data and self-reported accounts introduced potential biases and limitations. These biases could skew findings due to the subjective interpretations and experiences of interviewees, necessitating careful interpretation and validation of the collected data.

Despite these limitations, our three-phase research strategy aligned with the nature of self-reported data, enabling a comprehensive thematic analysis. This methodological choice facilitated efficient data processing and synthesis, albeit with inherent constraints associated with secondary data sources.

Moving forward, addressing these limitations through rigorous primary research and validation of findings will be essential. By building upon our insights and refining methodologies, future studies can contribute to a deeper understanding of how to mitigate the factors contributing to hardware startup failures and enhance their prospects for success.

7 Conclusions
This conclusion underscores the significance of the study's findings, outlines actionable implications for future research, and emphasizes the potential for continued advancements in understanding and addressing hardware startup failures.

This study has comprehensively examined the factors contributing to the failures of hardware startups, offering a taxonomy that categorizes these factors based on extensive data analysis. Key achievements of this research include:

- **Taxonomy Development**: We have developed a taxonomy that classifies failure factors for hardware startups, encompassing both internal startup dynamics and external market conditions. This taxonomy aids in understanding the nuanced reasons behind startup failures.

- **Data Collection and Analysis**: Through the collection and analysis of vast datasets, including over 43,000,000 units of initial data and detailed case studies and content analyses, we have provided empirical insights into why hardware startups fail. Thematic analysis tools were utilized to extract and interpret relevant patterns and insights from this data.

- **Guidelines for Identifying Failure Factors**: Guidelines have been formulated to assist researchers and practitioners in identifying and prioritizing failure factors relevant to specific datasets. This approach facilitates a more focused analysis and enhances decision-making processes aimed at mitigating startup failures.

- **Future Research Directions**: This study serves as a foundational framework for future research endeavors. By establishing a structured approach to analyzing failure factors, we encourage further exploration of alternative methodologies and innovative ideas to enhance our understanding of hardware startup failures.

8 Implications for Future Research

To advance the field of research on hardware startup failures, several implications for future studies have been identified:

8.1 Implications on Thematic Analysis of Video and Audio Data

Future research should explore the application of thematic analysis techniques to video and audio data alongside textual formats. This multidimensional approach will enable researchers to capture and analyze failure factors from diverse sources, thereby enriching the depth and breadth of insights gathered. By incorporating video and audio data, researchers can mitigate the limitations associated with self-reported data and broaden the scope of understanding in hardware startup failures.

8.2 Implications of Adjusting Search Keywords in Gray Literature

There is a need to refine and expand search keywords used in gray literature and secondary data collection processes. Specifically, adjusting search criteria to include terms relevant to emerging technologies such as AI and IoT will enhance the relevance and applicability of data collected from industry giants like Intel and Ubuntu. This adjustment ensures that future research remains aligned with current technological trends and industry developments, thereby providing more accurate and comprehensive insights into the factors influencing hardware startup failures.

8.3 Example: Adjusting Search Keywords in Gray Literature and Secondary Data

Expand the scope of keywords to encompass specific technologies and products relevant to hardware startups:

IoT, AI, CPU, Mouse, Monitor, Keyboard, Headphones, Laptop

By incorporating these keywords, researchers can capture data that reflects the contemporary landscape of hardware startups, incorporating insights from influential industry players and technological innovators.

9 Closing Remarks

In conclusion, this study not only identifies critical failure factors for hardware startups but also sets the stage for ongoing research aimed at refining methodologies and expanding knowledge in this field. By addressing the identified implications, future studies can leverage advanced analytical techniques and targeted data collection strategies to deepen our understanding of startup failures and pave the way for more resilient and successful ventures in the hardware industry.

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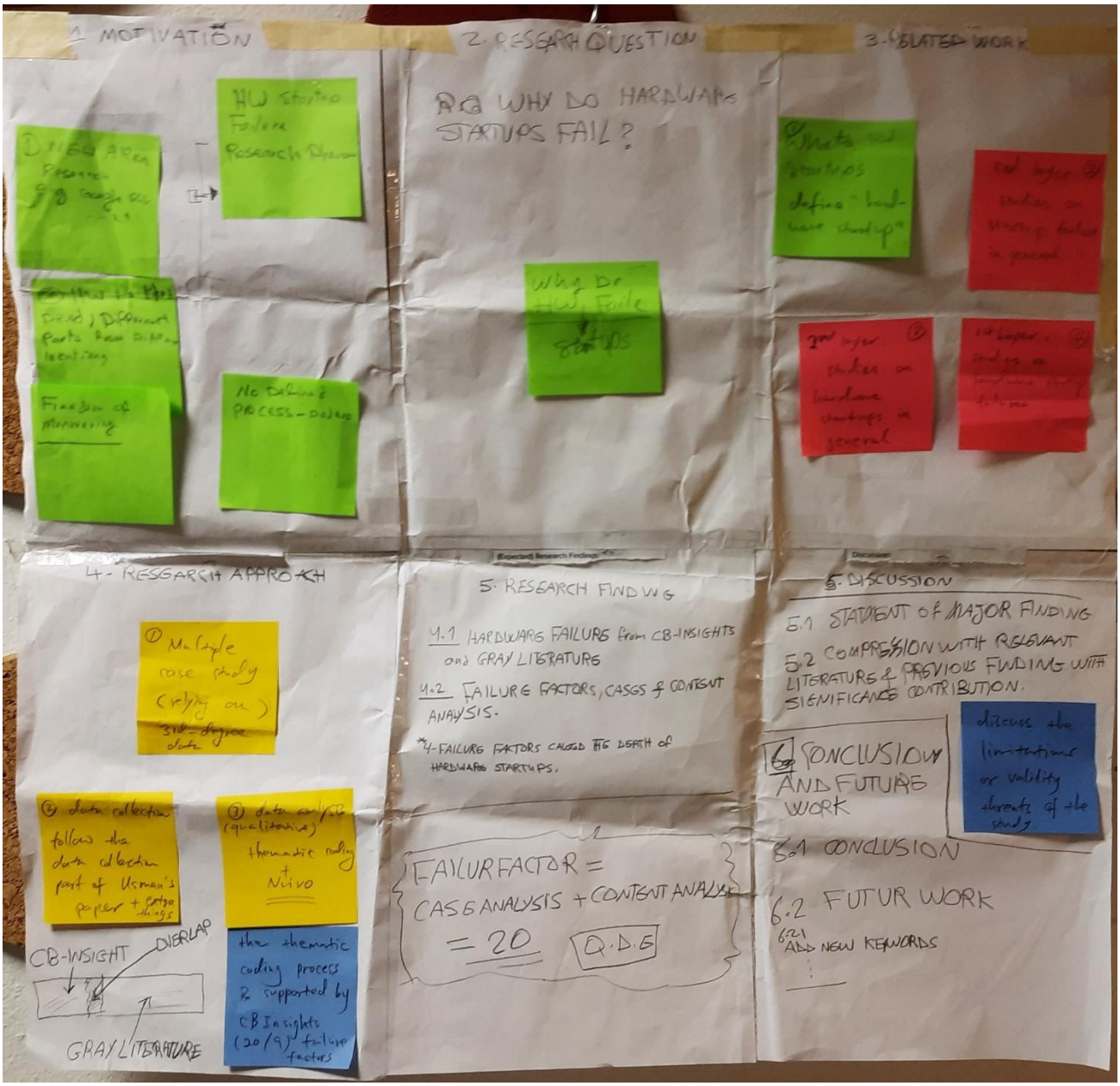
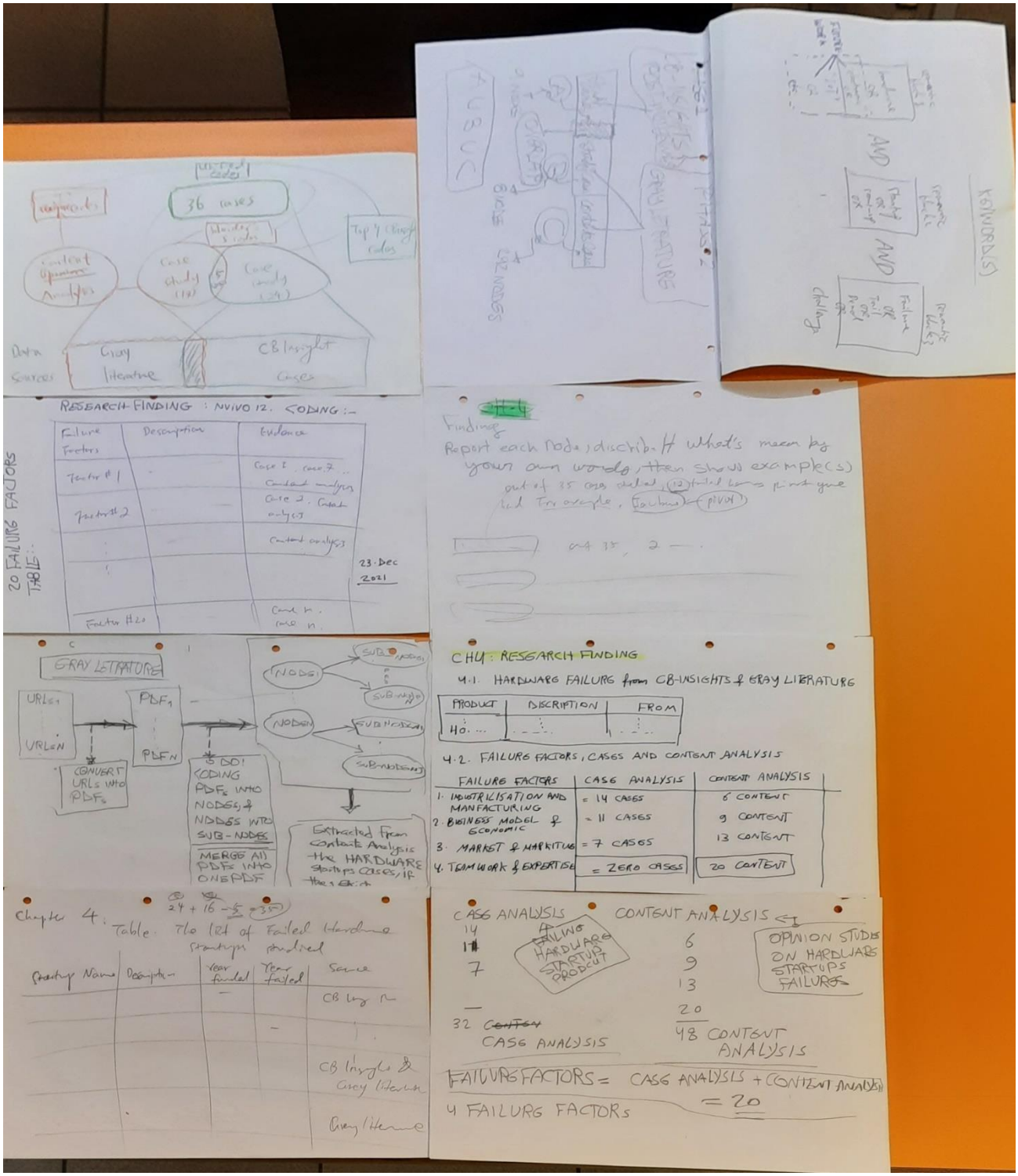
11 APPENDIX

11.1 PAPER-PROTOTYPE

A 1 Paper-prototype - first activity

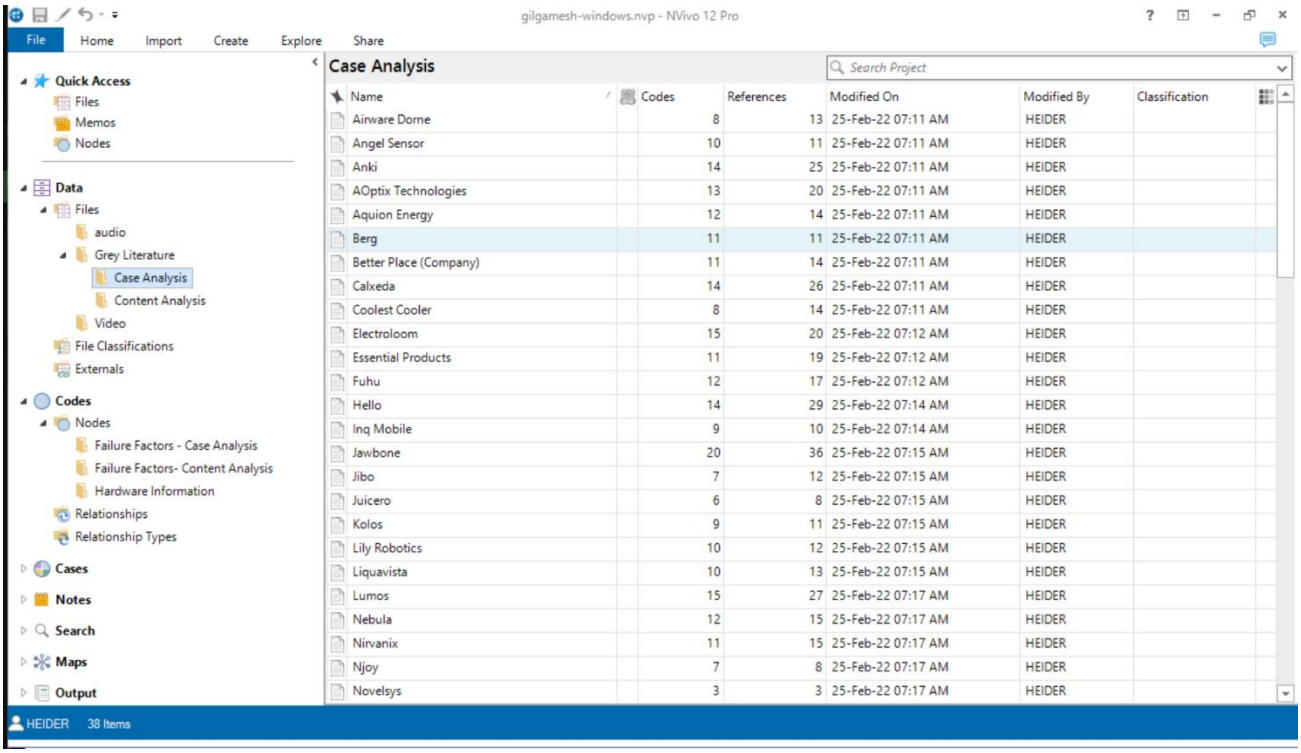


A 2 Paper-prototype - second activity - Processing the Data Collection

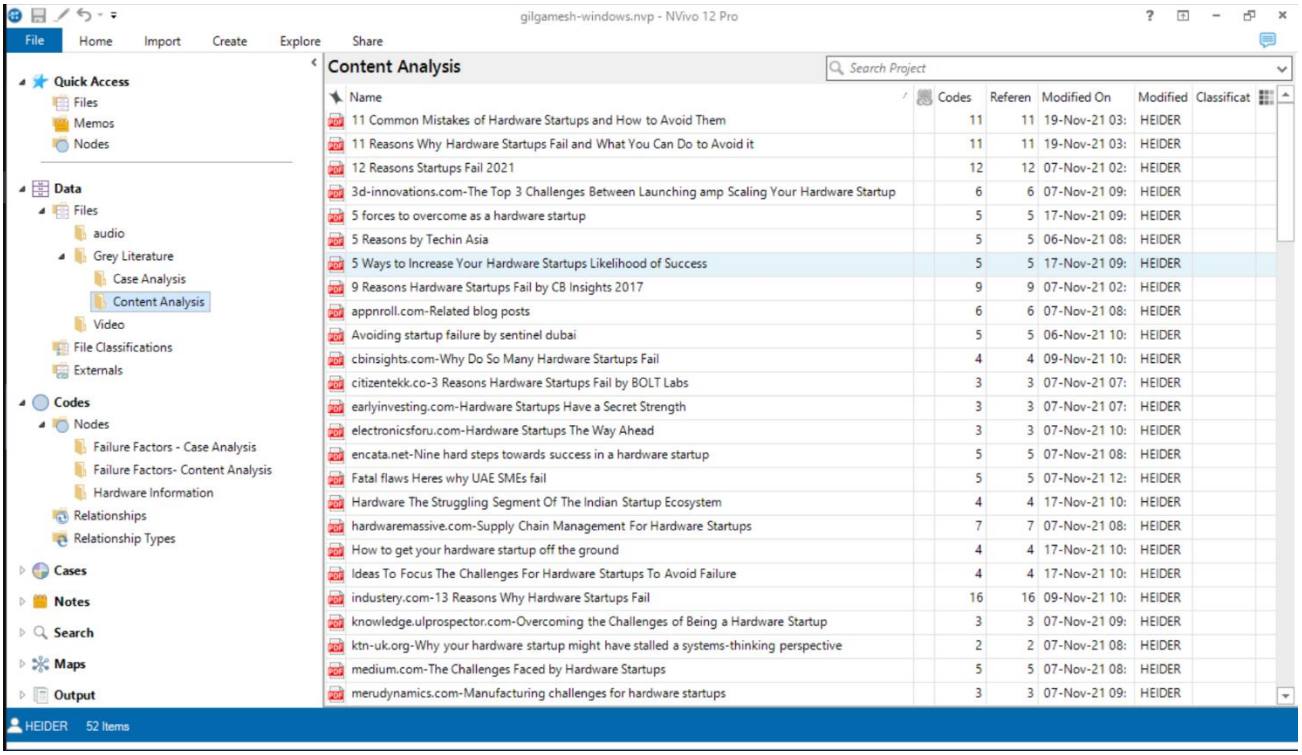


11.2 Data collection and Data Analysis with NVivo Software

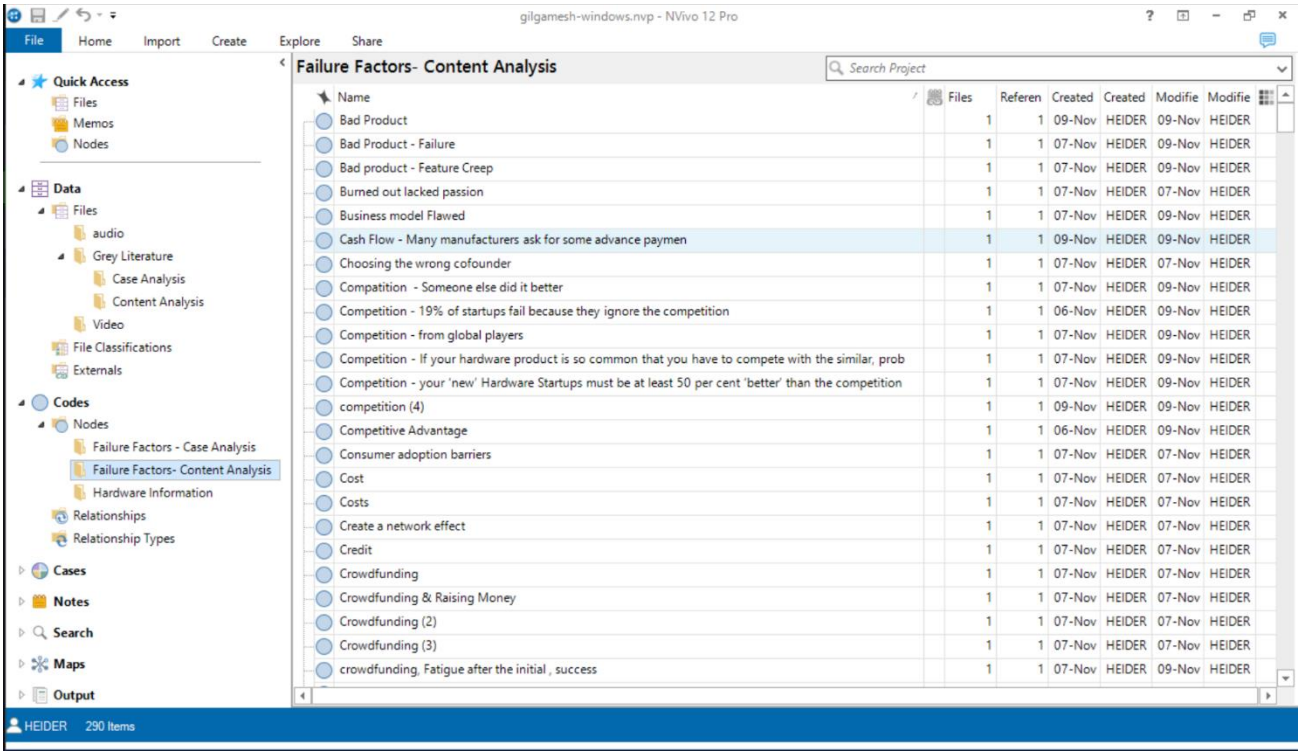
A 3 Data Analysis: 38 Case in [Case Collection A] - NVivo



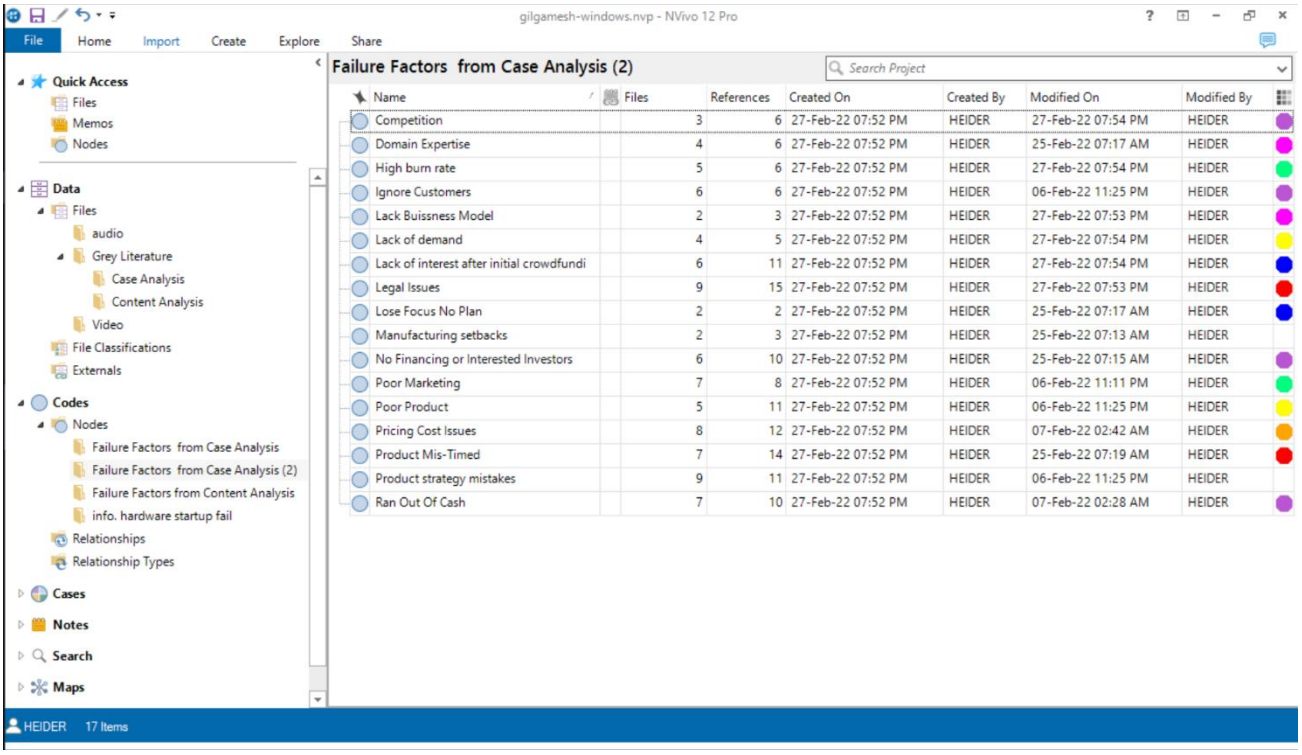
A 4 NVivo: 52 Content Analysis



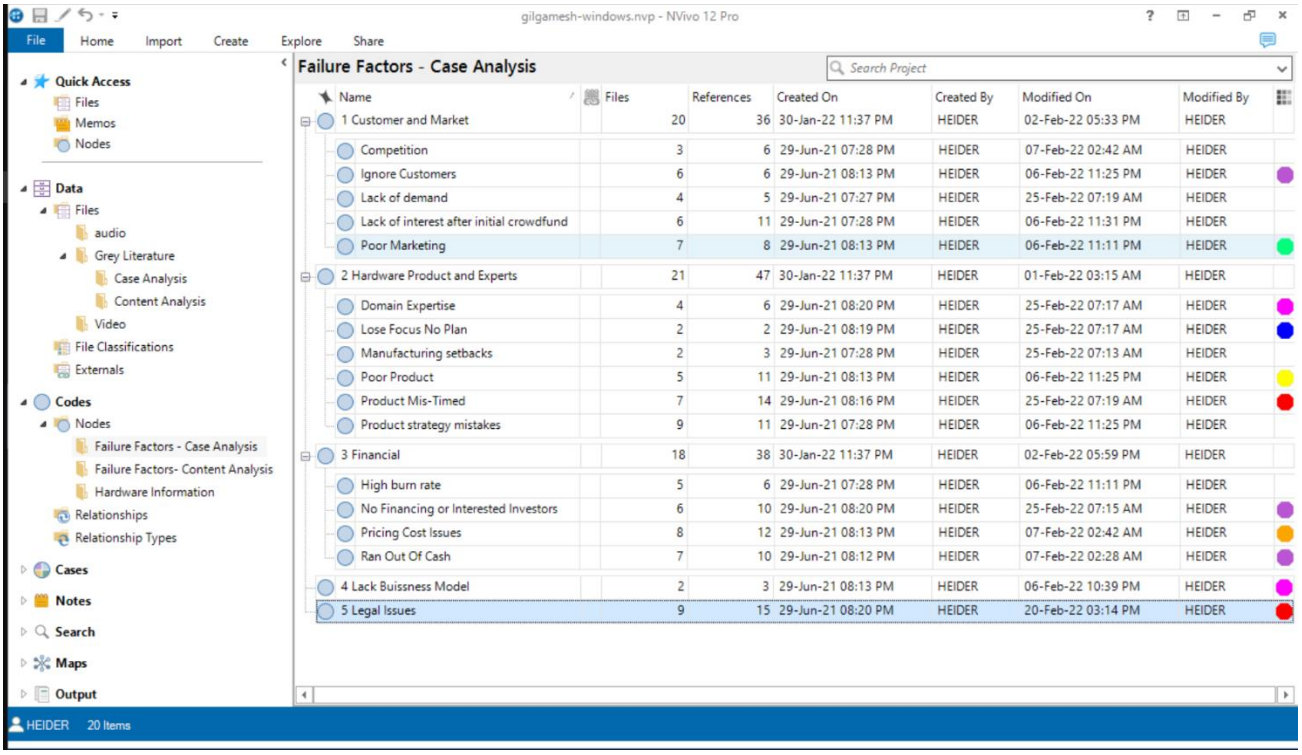
A 5 Future Work: Coding the 52 Content Analysis, NVivo



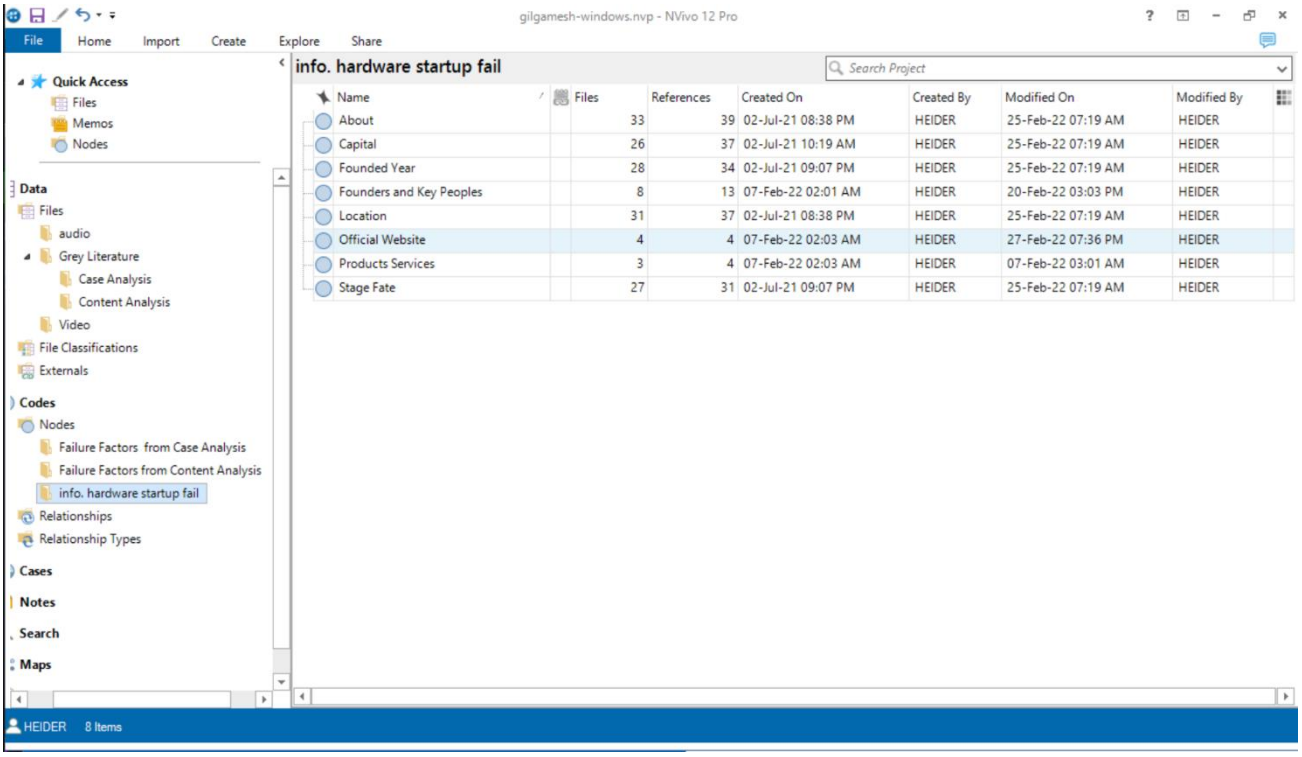
A 6 17 failure factors extracted from 38 case study, NVivo



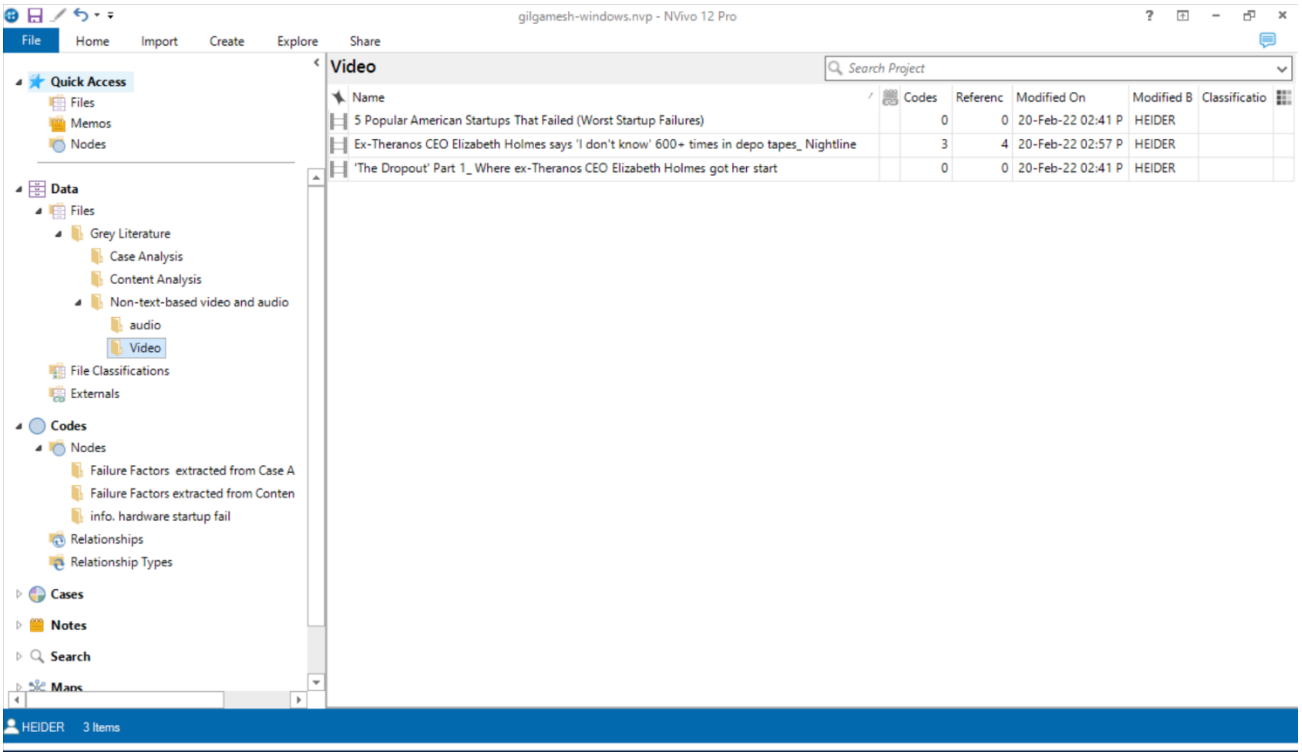
A 7 Groping 17 failure factors into 5 major categories, NVivo



A 8 Extracting Hardware Startups Fail information, NVivo



A 9 Future Work: including video and audio in the data collection



11.3 Data of [Case Collection B]

You can the output of: Extracting the relevant data from Case Collection B, in Gilgamesh at:

https://github.com/HeiderJeffer/Gilgamesh/blob/master/Outcome%20of%20Extracting%20the%20relevant%20data%20from%20Case%20Collection%20B.pdf