Appendix to Software Library Adoption Process and Principles in Industry

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1 METHODOLOGY

Figure 1 provides an overview of the overall research method which was applied to the study.

2 SATURATION

Figure 2 shows how the concepts were discussed during each interview. The number denote how many times a concept was discussed by one particular interview. The more a participant discussed about a particular concept, the more red the corresponding cell is. For example, library search and analysis process was most discussed by P5 and after their interview, subsequently we did not have much to discuss about the search process. After P8, the concept almost saturated and we discussed very little about this concept with subsequent interviewees.

3 CODE SYSTEM

Figures 3 and 4 show the relationship between major categories, categories, and concepts in the code system. These concepts and categories contribute to the conceptual framework of the software library adoption process.

4 GUIDING PRINCIPLES

In this section, we present the six full patterns associated with the library adoption steps.
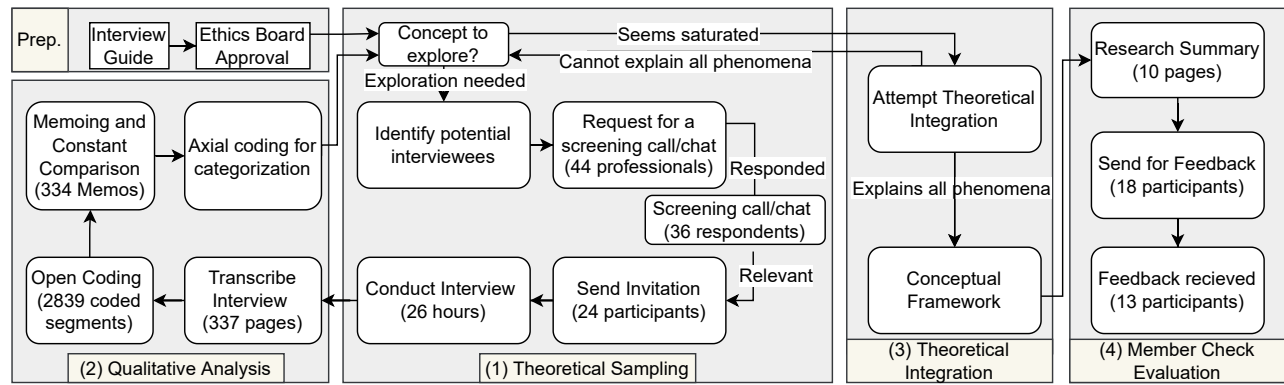
Figure 1: Grounded theory research method applied

Category	Concept	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24
Guiding Principles	Just Do It	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5	0	2	0	0
Guiding Principles	Resuse Robust Component	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	4	3	0	1
Guiding Principles	Improve Application Structure	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	2	1	3	2	1
Guiding Principles	Empower the Team	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	2	0	5	0	0
Guiding Principles	Ensure Compliance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	9	0	2	1	2	2	1	6
Guiding Principles	Maintain Stability Continuously	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	9	0	8	6	6	2	14	3
Double-edged sword	Barriers of Library Usage	1	0	0	2	0	0	0	1	1	1	0	11	1	0	1	0	0	11	0	0	0	0	0	0
Double-edged sword	Benefits of libraries	2	0	0	0	0	0	1	1	7	10	5	2	13	10	13	4	0	4	0	3	2	7	0	0
Double-edged sword	Baggage of libraries	0	0	1	1	2	0	0	0	4	11	0	4	4	30	15	2	8	6	14	10	10	5	17	7
Selection Process	Search	6	2	3	9	14	6	3	8	2	9	4	3	0	2	3	1	1	0	0	0	1	1	2	0
Selection Process	Compare	14	14	18	21	28	7	15	25	4	7	2	3	3	4	1	2	1	0	0	1	0	1	1	3
Selection Process	Review	20	10	12	11	15	1	8	26	3	9	2	1	9	4	7	2	1	0	2	2	7	0	0	1
Selection Process	Integrate	6	9	10	4	7	6	0	6	2	2	0	0	1	1	2	2	4	0	0	0	2	1	0	0
Selection Process	Maintain	2	4	5	10	6	5	3	6	1	7	0	0	0	18	4	3	8	6	4	8	4	3	7	1
Conditions	Environmental	9	0	3	3	7	5	8	0	0	3	0	0	1	2	1	2	4	2	2	0	0	0	0	0
Conditions	Organizational Influence	18	19	26	21	21	12	17	17	2	6	3	8	13	8	8	4	1	9	10	6	3	0	8	2
Conditions	Team Influence	19	13	12	9	10	4	15	21	0	9	2	1	6	6	9	4	1	0	2	5	1	0	3	0
Conditions	Individual Influence	7	6	6	7	6	11	16	12	0	3	3	1	3	2	8	0	4	0	1	5	0	1	1	0
Conditions	Technical	0	0	6	4	4	1	0	6	4	3	0	2	6	16	8	0	4	7	4	5	2	0	3	3
Opinion Sources	Human Sources	9	9	8	2	7	5	1	16	0	3	2	0	0	0	2	3	0	0	0	0	0	0	0	0
Opinion Sources	Online Search and Articles	4	14	9	5	9	2	2	6	2	10	4	2	0	2	2	1	2	0	0	7	0	0	9	0
Opinion Sources	Q&A Sites	4	4	4	2	2	2	5	6	2	2	2	0	5	2	2	0	1	0	1	0	1	0	0	0
Opinion Sources	Repositories	1	1	3	11	13	5	6	2	5	8	0	2	0	1	2	3	1	0	0	3	2	0	0	0
Opinion Sources	Organizational Sources	0	5	3	0	2	1	0	1	2	4	0	0	3	0	0	0	0	0	1	0	0	0	0	0
Selection Factors	Software Factors	25	9	17	31	23	10	49	13	5	20	23	9	14	13	8	6	5	7	10	8	9	5	8	13
Selection Factors	Commercial Factors	3	15	9	20	21	15	18	1	6	13	0	4	2	3	4	1	8	3	8	1	3	4	2	1
Selection Factors	Maintenance Factors	7	4	10	23	11	4	19	8	2	11	0	5	7	2	2	3	3	4	3	2	3	3	9	2
Selection Factors	External Factors	8	6	6	12	11	4	6	14	4	17	1	2	4	0	2	1	0	2	1	0	2	0	4	0
Definition	Definition	23	11	6	2	0	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	0	0	0	0
Concept Saturation by each participant		2	2	2	1	4	0	3	3	0	1	0	0	0	3	1	0	1	1	0	1	1	2	1	0
Cummulative Satuaration by all participants		2	4	6	7	11	11	14	17	17	18	18	18	18	21	22	22	23	24	24	25	26	28	29	29

Figure 2: Heatmap of concept saturation over the interviews. Red refers to higher discussion of a concept by an interviewee, the number refers to how many times interviewee has discussed a concept. Green refers to lower discussion of concepts by an interviewee. Thick black bordered cells refer to the most discussion reference of a concept among all participants. For example, review concept under selection process category was discussed 26 times in P08's interview and hence the corresponding cell is marked by thick border.

Table 1: How we recruited interview participants following theoretical sampling for Concept Saturation. (We could not enhance targeted concepts from the *-marked participants (P12, P16), rather enriched other important concepts.)

| P#	Concept we wanted to enhance	Why we selected this Participant	Concepts they enriched significantly
P1	Initial process and factors	Architect of a large system	Library definition, factors, influences
P2	Licensing and Security Issues	Working in a large structured company	License, company technology
P3	Mobile development Factors	12+ years experienced in mobile application	Cost, company tech, comparison
P4	Long term maintenance concerns	Being a CEO, takes decisions considering long term impact	Company application domain, active development of library
P5	Decision making processes	Stablishing the processes in a startup team	Information search, company culture
P6	Open Source factors	Has experience regarding OSS contribution and research	Open source, Personal motivation
P7	Factors for a startup	Being a startup CTO may share different priorities	Flexibility, Ease of Installation, Community Support
P8	Performance factors	Working in a cloud company that may requiew high performing libraries	Familiarity, Team Discussion, Library Migration
P9	Migration scenarios	Experienced to migrate company tech stack as architect	Legal risks, Lack of Stability, Less preferred than native support
P10	Visualization and front end libraries	Working as web developer for over a decade	Customer support, flexibility, existing repository
P11	Machine learning libraries	Experienced in machine learning in gradudate research studies and in industry	Talk to people, Performance, Outstanding library selection
P12*	DevOps Process for Library Security Issues	Consulted dozens of companies in DevOps process establishment	Barriers of library usage, Baggage of libraries
P13	Selection process in large organizations for legal and security risks	Has been an architect in a large team for 10+ years	Consent Process, Benefits of libraries, Tech Expert Opinion
P14	Library migration scenarios	Experienced in managing mobile apps with large user base in all platforms	Make life easy, Life long maintenance, Migration to other library
P15	Organizational process and motivation for libraries	Experienced in organization process since increased dev team from 3 to 300	Delivery Deadline, Don't Reinvent the wheel, Feature criticality
P16*	Process of security concerns	Cerified security professional actively developing security products	License issues, Data Transfer Security, Geographic Impact
P17	Security Process	Delivers custom software to customers and maintains SecOps in CI/CD	Post Integration Maintenance for Security
P18	C++ libraries in large scale long term products	Leads development of a 30 year old product written in C++ with 2M lines of code	Lifelong Maintenance Burden, Compatibility, Uniform Coding Style
P19	Company Culture, Open Source, Concept Saturation	Experienced working in start-up and large organizations who open source libraries	Standard practices in large organizations, Considerations in open source
P20	Challenges in mobile application libraries, Concept Saturation	Full career in mobile app development, mostly in iOS which requires more maintenance	Lifelong Maintenance Burden, Abandoned Libraries, Migration
P21	Company Culture, Open Source, Concept Saturation	Works full-time in a prominent open core company	Company policies, Guiding Principles
P22	Guiding Principles, Open Source	Experienced in persuing large corporation for open source library adoption	Guiding Principles
P23	ML libraries	Working in South America in ML domain	ML Library Dependency Issues
P24	Company Culture, Industry, ML Libraries	Working in health sector using ML libraries extensively.	ML Library deployment and upgrade issues
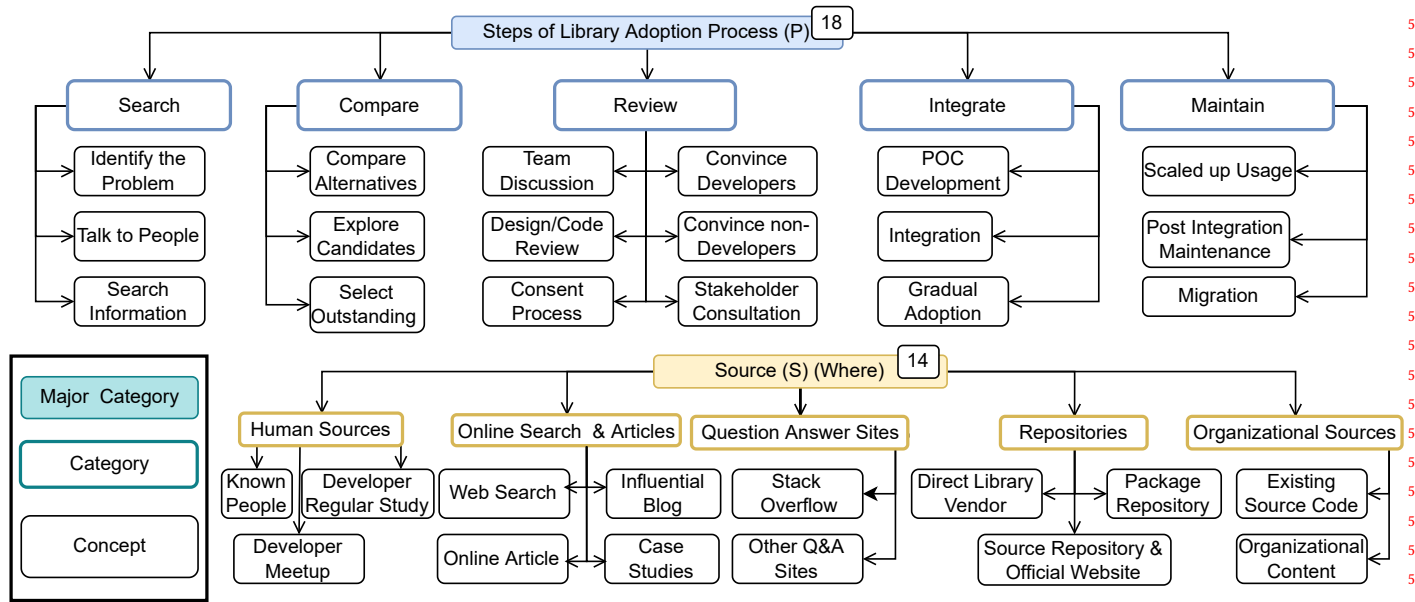
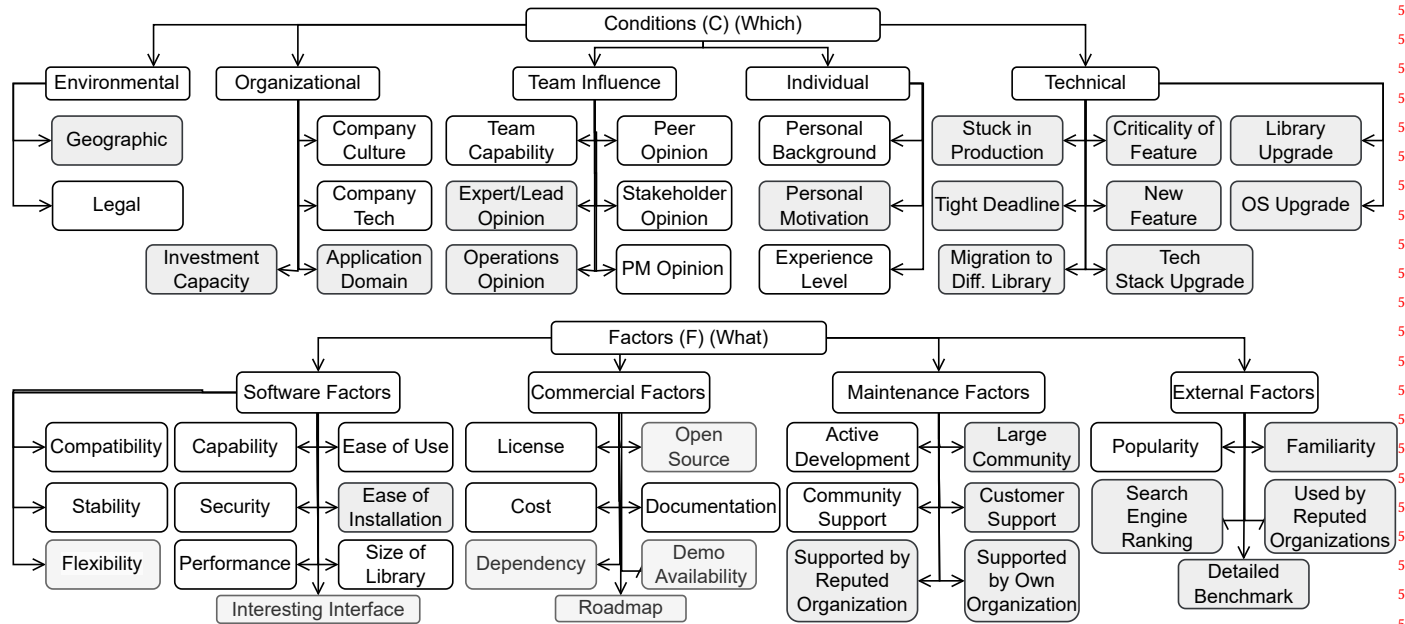**Figure 3: Concepts related library adoption process**

Figure 4: Concepts related with factors and conditions influencing library adoption process

Guiding Principle 1: Just Do It

Actor: Developers

Condition: Faster go to market is critical for business. Developers are often rewarded for delivering minimum viable product on time.

Concern: How the developers can meet the deadline with relatively less effort?

Solution: Use a third-party library that reduces the work load and delivery can be done on time

Consideration: The library should be easy to use, easy to install, popular, and even better if developer is already familiar with it.

Steps: Find libraries, compare them, and choose one according to the consideration. Take support from known people or use search engine or Stack Overflow

Example Data: *"For startups, a lot of it [priority] is just speed to market and how much resources is gonna eat up using any specific library."* - P07

Guiding Principle 2: Reuse Robust Component

Actor: Developers, Senior Developers

Condition: Mature organization with stable source code and release pipeline. Application performance and maintainability is a big concern for the team. Developers with higher experience are careful about the quality of the application source code.

Concern: How can the application avoid boiler plate code and follow best design principles?

Solution: Use a trusted proven third-party library that will keep the code clean and manageable.

Consideration: The library should be open source, trusted by community, stable and provide apppropriate performance metrics required

Steps: Find and compare libraries, review thoroughly by more than one developer. Look into the library's source code repository to analyze the stability, quality of the library, and also consider reputed technical blogs.

Example Data: *"So [this large corporation] as a whole is actually built on the open source libraries that are suitable for our use cases. But that actually has been one of our primary focus as well. If you find a library, use it; only build if you can't find anything."* - P13

Guiding Principle 3: Maximize Flexibility

Actor: Developers, Architects

Condition: Large scale software applications have their own structure which evolved over time and may follow some software design principles. System designers want to use new libraries in a way that improves the application structure, or at least does not deteriorate it.

Concern: How can the architecture be improved or be protected from unwanted rigidity while using a library?

Solution: Use a library that just fits right with the application in terms of the size and flexibility. Consider wrapping the third-party library in an API to allow replacement of the library without affecting dependent code.

Consideration: The library should be flexible and should not be too large in size compared to the system.

Steps: Find, compare, and review libraries. Conduct design review to assess impact on architecture. Review internal organizational content for design principles.

Example Data: *"The moment you have to bring something in because there are new requirements is the time to assess how you've structured your application and does it still serve you and your customers or the business requirements you have. So that's the opportunity to look at the structural aspect of the application and make sure you do want to avoid changing it or maybe it's the time to change it."* - P22

Guiding Principle 4: Empower the Team

Actor: Developers, Tech Leaders

Condition: Some organizations may have a strong company culture to improve the development skill set or for providing comfortable learning space for developers. Tech leaders may care more for their team's capacity, limitations, and motivations. The development team may have limitations or strengths in certain technologies.

Concern: Does the library fit well within the capability of the dev team? Will it provide any transferable skills?

Solution: Use a library appreciated by the developers

Consideration: The library should be well documented and should have a popular community so that developers can easily adopt and can refer in future. Also it can have customer support in case developers needs extra help.

Steps: Besides finding a library that fits well with the technology, thoroughly discuss with developers about their opinion and acceptance of the library. Look into official documentation of the library.

Example Data: *"So looking at community popularity helps because then it helps to hire people. It helps to retain people. They like to use technologies that are transferable."* - P19

Guiding Principle 5: Ensure Compliance

Actor: Developers, Information Security Experts, Legal Experts, Open Source Program Office

Condition: Because of regulatory compliance or for company culture, some organizations will be more cautious about using third-party libraries for legal, security, and privacy reasons. Developers will often have little technical expertise on such specialized issues. Sometimes small or early stage companies may even ignore the importance of compliance issues. A few application domains such as health, finance, media are also more regulated and require organizational policies for ensuring compliance.

Concern: Will there be any penalty or legal complication arising from using a third-party library? How to protect the organization?

Solution: Use a library which is compliant with the application security standards and legal requirements

Consideration: The license of the library should be compatible with the business and license of the target software. The security and privacy concerns should be clarified and well taken care of by the library contributors.

Steps: Reach out to specialists in the organization for taking their expert consent before adopting the library. See the license and security declarations in the library documentation in the source code or package repository.

Example Data: *"We had a very bad experience with this. With the legacy system, we were using so many different libraries and there is a licensing issue and we had to replace half of the library. Otherwise we had to pay lots of money. So that's why we are now very, very concerned about adding any external library, because if we don't comply with the license, it will be a legal problem."* - P09

Guiding Principle 6: Maintain Continuous Stability

Actor: Developers, DevOps

Condition: Some software applications are developed and maintained for long term. A third-party library used in such a product can have bugs or vulnerabilities that need to be fixed. Sometimes, the contributors of the library may not continue to fix bugs or improve with new features. Sometimes libraries may not have backwards compatibility and when developers upgrade, their existing system can break.

Concern: How will developers ensure that a library is well maintained in foreseeable future and that they can keep using the library without breaking their application?

Solution: Use a library with good history of maintenance and prepare to continuously upgrade the library in future

Consideration: Selected libraries should be actively maintained by contributors, supported by reputed organizations, and have larger community.

Steps: Analyze the maintenance and issue history of the library to assess the active development practices or the library. Establish a process for software bill of materials to document all third-party library dependencies and their upgrade plan in conjunction with DevOps teams. Look into source code commit and issue history from source repository and download usage trend from package repository.

Example Data: *"When we integrated the updated version our whole interface broke. And we had to change a lot of code, all the interceptors, interfaces, everything… This maintenance is quite hard. It's actually a full time work to always keep updated, to always stay updated."* - P14