ITC

T-3, CS 7980 Research Capstone

Oct 2, 2024

Problem

The rapid growth of the Information and Communication Technology (ICT) sector is contributing significantly to global greenhouse gas emissions, accounting for approximately 2-3% of total emissions. Software plays a critical role in energy consumption, as it drives hardware usage, which in turn impacts resource and energy consumption. **However, there is currently no standardized framework for measuring software's resource and energy efficiency.** This leads to inconsistent and incomparable results, hindering efforts to reduce software-driven environmental impacts.

While various researchers and industry groups have developed tools and methods to measure energy consumption, there is no unified approach. The absence of a comprehensive measurement model complicates efforts to assess and improve the environmental efficiency of software. **Software practitioners lack the tools and guidelines to integrate energy efficiency into everyday software development processes.**

Problem

Environmental Impact of Software: As digital transformation accelerates, software running on data centers, servers, and devices consumes significant energy, driving high hardware resource consumption and **increasing global greenhouse gas emissions**.

Lack of Standardized Measurement: Currently, there is no unified framework to measure software's resource and energy efficiency, making it difficult to compare the environmental impact of different software, **which hinders developers from optimizing energy consumption**.

Impact on Global Sustainability Goals: Standardizing resource efficiency measurements not only **reduces energy consumption** in individual projects but also drives the entire **software development ecosystem toward a greener future**, contributing to global efforts to **reduce carbon emissions and combat climate change**.

Proposed Solution - literature review

- **Software practitioners are aware of the problem, but lack of resources and tools**

  (An Empirical Study of Practitioners' Perspectives on Green Software Engineering)

- **Requirement and Design phases are of most interest**

  (Green and Sustainable Software Engineering - a Systematic Mapping Study)

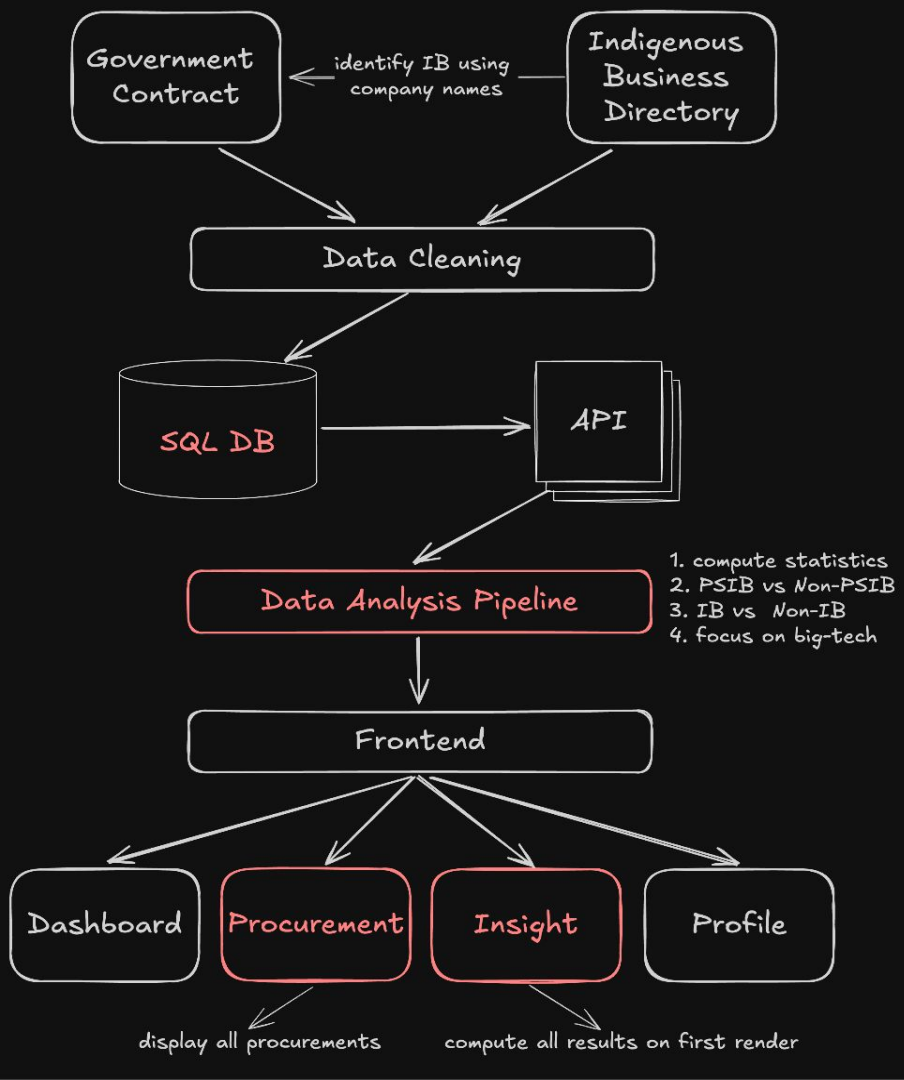
- **Lessons that could be learned from Mobile Application Development**

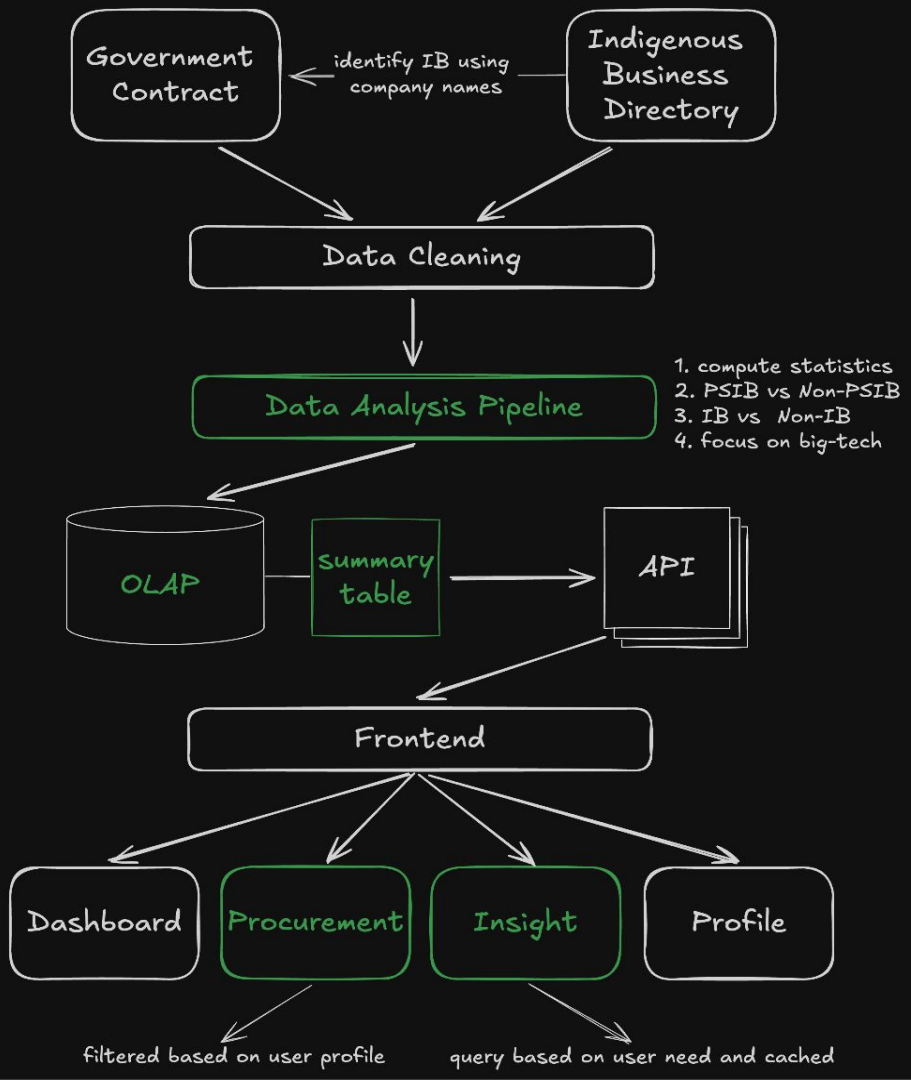
  (RMVRVM - A Paradigm for Creating Energy Efficient User Applications Connected to Cloud through REST API)

  (Energy Patterns for Web: An Exploratory Study)

Proposed Solution - filling the gap

- **Current studies are abstract and lack of concrete examples because they:**
  - either focus on best practices but without quantifying the impact
  - or propose an evaluation methodology without examples from real-world applications
- **We aim to fill this gap by answering these research questions:**
  - What are the options to consider for a greener system design in the real-world scenario?
  - How to quantify the impact of a greener implementation by adopting an existing evaluation method?
  - Which components may have contributed to the most difference in energy consumption?


Government Contract
identify IB using company names
Indigenous Business Directory
Data Cleaning
SQL DB
API
Data Analysis Pipeline
1. compute statistics
2. PSIB vs Non-PSIB
3. IB vs Non-IB
4. focus on big-tech
Frontend
Dashboard
Procurement
Insight
Profile
display all procurements
compute all results on first render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OLAP
summary table
API
Frontend
Dashboard
Procurement
Insight
Profile
filtered based on user profile
query based on user need and cached

Evaluation Plan for simulation

1. Define the Measurement Goals

- **Objective**: Assess the energy and resource efficiency of software.
- **Metrics to Measure**:
  - **CPU Usage**: One of the key indicators of energy consumption.
  - **Energy Consumption**: Use direct or modeled data to estimate energy use (in Joules or kWh).
  - **Memory (RAM) Usage**: Measure how much memory is consumed.
  - **Network Traffic**: Estimate resource and energy impact from data transfer.
  - **Duration of Tasks**: Evaluate how long tasks take to complete, as it impacts resource consumption.

2. Establish a Baseline

- Before running the software, measure the baseline energy and resource consumption to isolate software-induced energy usage.

3. Measurement Setup

- **Usage Scenarios**:
  - **Idle State**: Record when the system is active but no tasks are being performed.
  - **Task Execution**: Run typical tasks or workloads and record the energy consumption and CPU, memory, and network usage.
  - **Load Test**: Simulate stress scenarios by increasing the number of users or requests to test how energy usage scales.
- **Hardware/Software Setup**:
  - Ensure consistency in hardware to make comparisons across different runs. If using containerized software, tools like the **Green Metrics Tool** can measure specific container resource consumption.

Evaluation Plan for simulation

4. Data Collection

- **Raw Data**: Collect raw logs of CPU, memory, and energy consumption from the scenarios described.
- **Energy Calculations**: Calculate energy consumption. For GPU and CPU, use internal power logging where applicable.

5. Analysis and Reporting

- **Efficiency Metrics**: Calculate the energy efficiency factor.
- **Comparative Analysis**: Compare different versions of the software or different configurations to determine the most efficient setup.

Primary Data: Federal procurement data, Indigenous business directories, and economic indicators from:

- Government contracts(2023): For federal spending, contract awards, and procurement categories.
- Indigenous Business Directories: National and regional directories of certified Indigenous businesses

Reference:

Guldner, Achim & Bender, Rabea & Calero, Coral & Fernando, Giovanni & Funke, Markus & Gröger, Jens & Hilty, Lorenz & Hörnschemeyer, Julian & Hoffmann, Geerd-Dietger & Junger, Dennis & Kennes, Tom & Kreten, Sandro & Lago, Patricia & Mai, Franziska & Malavolta, Ivano & Murach, Julien & Obergöker, Kira & Schmidt, Benno & Tarara, Arne & Naumann, Stefan. (2024). Development and evaluation of a reference measurement model for assessing the resource and energy efficiency of software products and components—Green Software Measurement Model (GSMM). Future Generation Computer Systems. 155. 10.1016/j.future.2024.01.033.

Siti Rohana Ahmad Ibrahim, Jamaiah Yahaya, Hasimi Salehudin and Aziz Deraman, “The Development of Green Software Process Model” International Journal of Advanced Computer Science and Applications(IJACSA), 12(8), 2021. http://dx.doi.org/10.14569/IJACSA.2021.0120869

Evaluation Timeline

Evaluation Activities	Timeframe	Details
1 . Define Measurement Goals	week 1	Set specific evaluation goals and select the metrics and scenarios to measure.
2. Setup Baseline Measurement	Week 1	Perform idle and baseline measurements of system.
3. Conduct Idle and Usage Tests	Week 2	Run tasks in controlled environments, measuring energy consumption.
4. Run Load Tests	Week 3	Simulate stress scenarios to capture high-resource usage performance.
5. Data Collection	Week 4	Gather all raw data for energy, CPU, and memory consumption during tests.
6. Analysis and Initial Report	Week 5	Analyze the data to compute energy efficiency and performance metrics.
7. Comparative Analysis	Week 6	Compare different versions of your software or configurations.
8. Draft Final Report	Week 7	Summarize the findings, highlighting energy consumption patterns and efficiency improvements.
9. Final Adjustments and Review	Week 8	Make final changes to the report and review the results for accuracy.

Representation of Results - Data Analysis Objectives

- Proportion of the number and amount of contracts
- Details of non-Indigenous Business(IB) contracts in the proportion
- Identify the proportion of contracts in different sectors(focus on the techpart).
- Based on the analysis above, we'll use the top 20 tech companies list provided by ITC to pick some representative companies and analyze the reasons behind their success.

Overview of Our Dataset

- Government Contracts (2023)

  Total Entries: 81,000

  Attributes: 48

- Indigenous Business Directory - Company Profiles
  Total Entries: 2,960
  Attributes: 20

- Tech Companies List : Includes 20 Major Tech Companies

Data Analysis - Challenges and Action Plan

Challenges We Faced:

- Large Volume of Data: The dataset is vast, making processing and analysis difficult.
- Incomplete Information: Some entries lack key details or contain irrelevant information.
- Detailed Classification: Hard to distinguish details in categories, requiring more analysis.
- Attributes Relationships: Identifying meaningful connections between attributes.

Steps to Take:

- Select Key Attributes: Identify and match relevant features in the dataset for deeper analysis.
- Data Cleaning: Remove irrelevant entries and filter for contracts with values over $10,000.
- Data Processing: Classify contract details into more specific categories.
- Data Analysis: Perform statistical and comparative analysis to gain actionable insights.

Preliminary Result

According to the federal website, there are 2,960 Indigenous businesses listed in the directory.

Indigenous Business Directory	Count of Contract	Sum of contract_value	value %
Non-IB	79168	39281079606	98.93%
IB	1796	423265998	1.07%
Total	80964	39704345604	100.00%

The Procurement Strategy for Indigenous Business (PSIB) is a Canadian government program designed to support economic growth for Indigenous-owned businesses by helping them secure government contracts.

gov provide contract	Contracts number	Contrcts number %	Contracts Value	Contracts Value %
PSIB	3834	4.77%	1173814048	2.96%
Non - PSIB	76465	95.23%	38530514574	97.04%
Grand Total	80299	100%	39704328622	100%

- Despite the PSIB initiative, Indigenous businesses still capture a minor portion of total contract value

Contract Distribution: Indigenous vs Non-Indigenous

PSIB : Indigenous business VS non- Indigenous business

Contracts Number % :	34.64%	65.36%
Contracts Value %:	23.13%	76.81%

- Conclusion: Indigenous businesses receive smaller-value contracts within PSIB.

NON-PSIB : Indigenous business VS non- Indigenous business

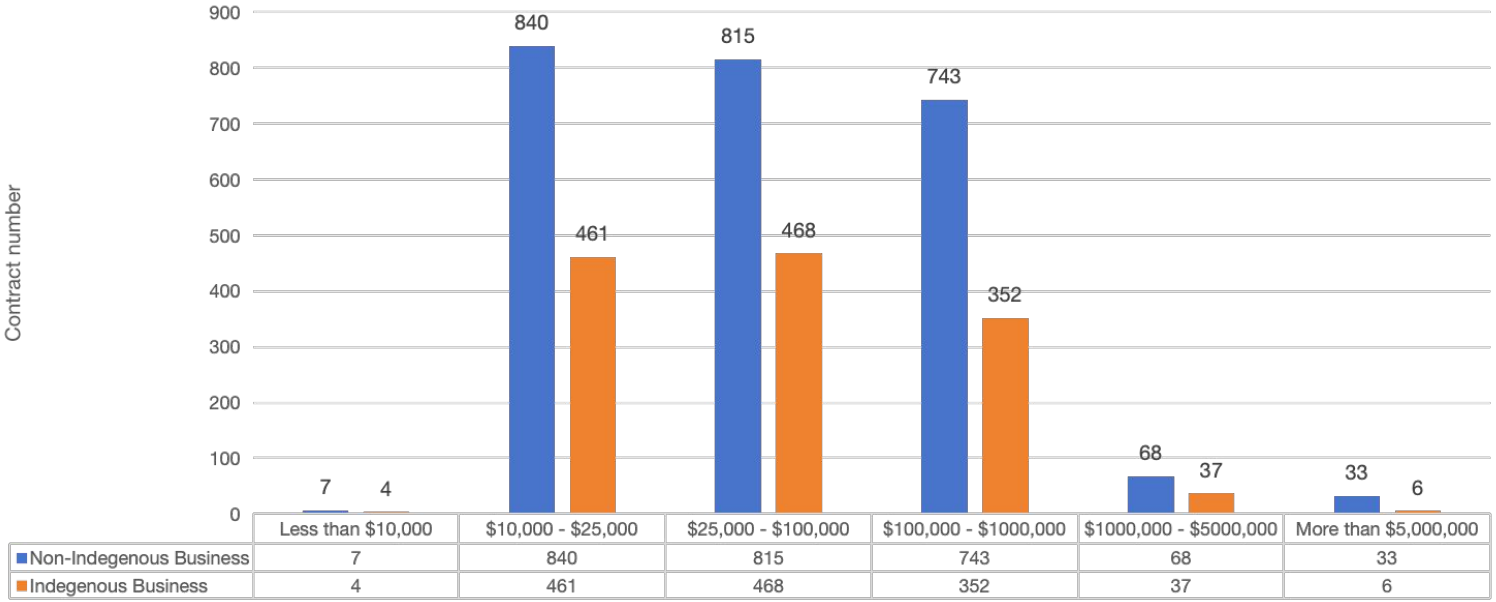
Contracts Number % :	0.59%	99.41%
Contracts Value %:	0.39%	99.61%

- Conclusion: Non-Indigenous companies dominate in both number and value of contracts outside PSIB.

Divide Data by Contract Value

- Focus on Procurement Strategy for Indigenous Business (PSIB)

Most contracts fall within the $10,000 - $1,000,000 range

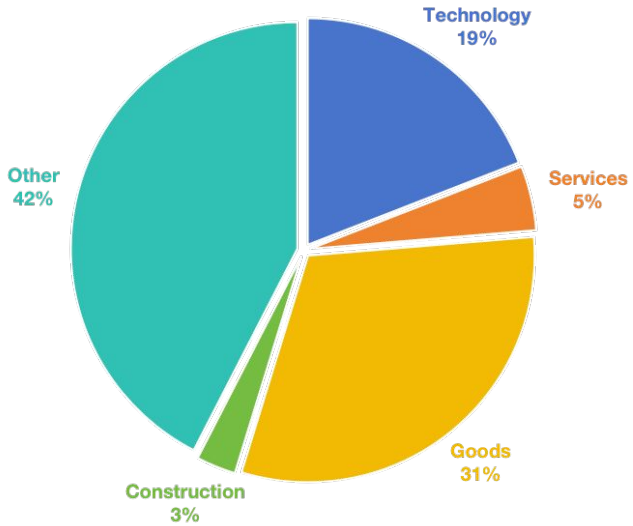


	Less than $10,000	$10,000 - $25,000	$25,000 - $100,000	$100,000 - $1000,000	$1000,000 - $5000,000	More than $5,000,000
Non-Indegenous Business	7	840	815	743	68	33
Indegenous Business	4	461	468	352	37	6

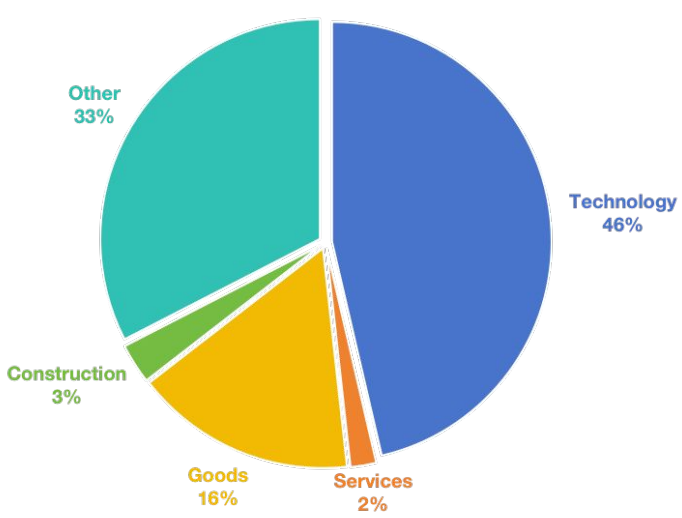
Divide Data by Group

- Focus on Procurement Strategy for Indigenous Business (PSIB)

Contracts Amount



Contracts Value

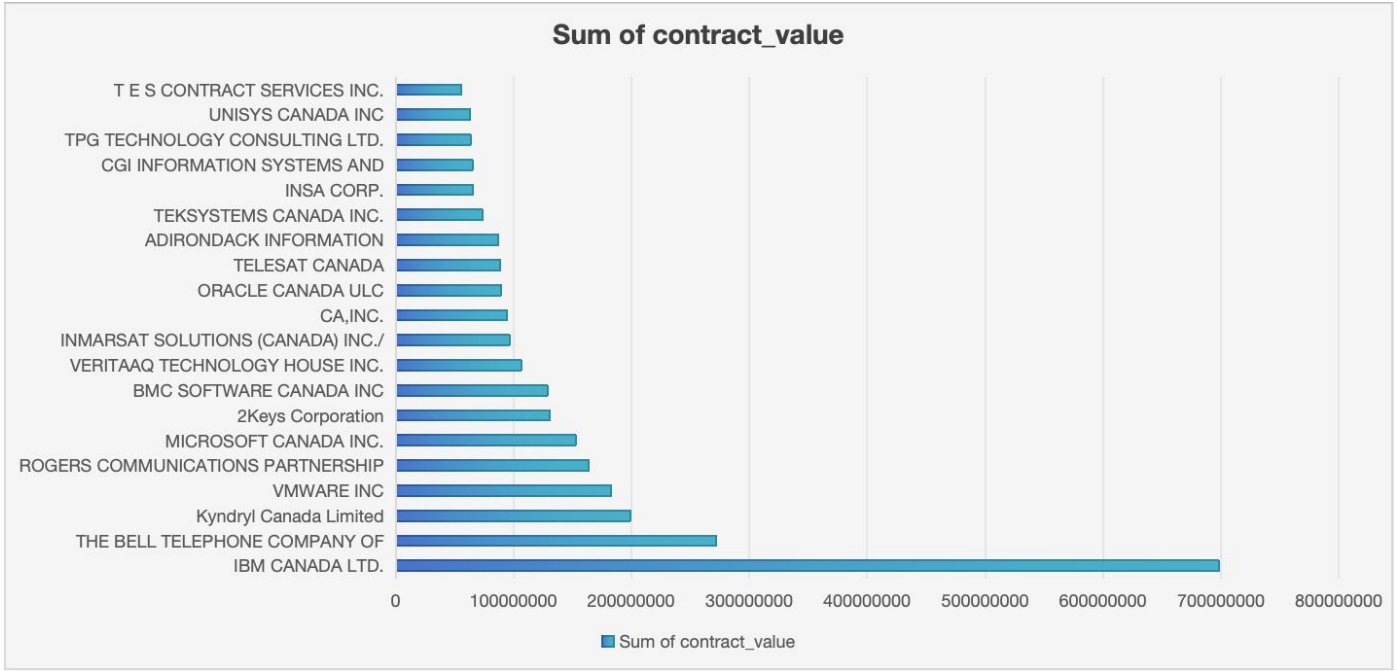


From these two tables, we can see that the tech sector holds the most valuable contracts.

Also, under the PSIB program, the government allocates a relatively high proportion of contract value to the tech sector.

Divide Data by Group - Focus on Tech Area

- Top 20 Non-Indigenous Business Companies



1. **Microsoft Canada**
2. Google Canada
3. TELUS
4. **IBM Canada**
5. Cisco Canada
6. Accenture
7. Shopify
8. SAP Canada
9. Amazon Web Services (AWS)
10. Salesforce
11. Rogers Communications
12. **Bell Canada**
13. Apple Canada
14. Deloitte Canada
15. PwC Canada
16. KPMG Canada
17. CGI Group
18. Intel Canada
19. Facebook (Meta)
20. Hewlett Packard Enterprise (HPE)

Based on the contract value data, we plan to select three companies from this list for an in-depth analysis of their contribution to Indigenous communities. These companies will be chosen based on their contract amounts and their influence in promoting reconciliation through their procurement strategies.

Analysis for Selected Tech Companies

award_criteria	Microsoft Canada	IBM Canada	Bell Canada
Not applicable	88%	78%	37%
Technical Merit	6 %	19%	8%
Variations or combinations	5%	0%	2%
Lowest Price	1%	4%	56%

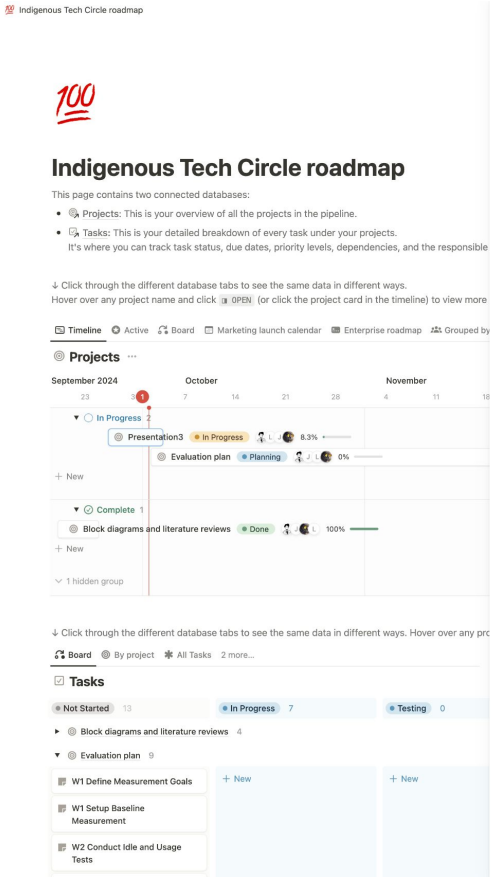
- The award criteria indicate that while Microsoft and IBM focus more on unspecified criteria, Bell Canada emphasizes competitive pricing.

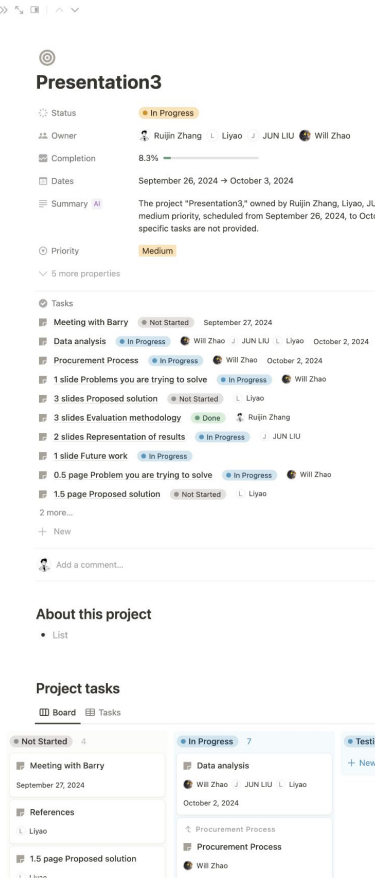
Analysis for Selected Tech Companies

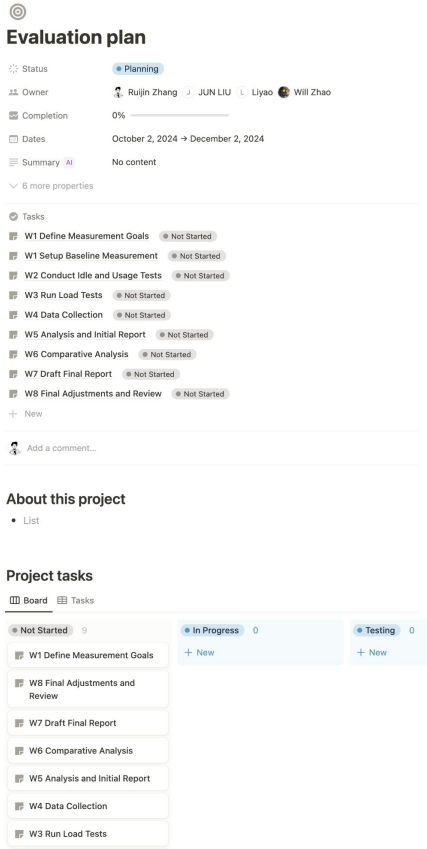
procedure	Microsoft Canada	IBM Canada	Bell Canada
Competitive – Open Bidding	21%	17%	12%
Competitive – Selective Tendering	9%	29%	4%
Competitive – Traditional	26%	16%	67%
Non-Competitive	44%	38%	17%

- The table suggests that Bell Canada leans more towards traditional competitive procurement, while Microsoft Canada balances between non-competitive and competitive processes. IBM Canada, on the other hand, prefers selective tendering in its competitive strategies.
- This diversity in procurement methods reflects each company's strategic approach to securing government contracts.

Future work







Further Digging into the data analysis

Evaluation on greenness

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