UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Materials and Resources in Buildings at UBC: Identifying and Reducing Harmful Material

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Materials & Resources in buildings at UBC

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Identifying & Reducing Harmful Material

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1. Executive Summary

The research began with studying the current "Red-List" framework created by "Lorena Polovina". The framework was based on giving each material hazard classification a certain color code for easy identification. Her developed framework targeted the reduction in using hazard material within UBC context across the different material usage life cycle periods. By, deep-diving into the framework formulation, it has been noticed that the framework lacks critical factors, tools, and concerns to enable it to fulfill its function. These missing factors have been summarized as follows.

The lack of additional considerations in selecting materials. Also, the framework did not rely on any quantifiable measurements. There were many data gaps addressing many materials. Despite mentioning the material usage phases, there wasn't a solid prioritization for every single phase. As a whole, the list was a long table which signs impracticality when being used as an actual selection aiding tool.

The team investigated firstly the LEED V4 framework addressing building material hazard mitigation which is a common goal with UBC's "Red-List". It has been found that the concerned framework would benefit from a solid credited scoring system which will encourage the use of healthier material and reward compliant designers and renovators. It drew our sight into how to mitigate the manufacturer's resistance in releasing data by various methods as hazard screening and third-party verification. We have concluded that by having an easy to a research tool, the system will be used in a practical way.

Post collecting these data from the LEED V4 framework, life cycle strategies from Life building challenge, Elixir, IDP and International Living Future Institute have been studied. The study resulted in very promising takeaways that would directly improve the "Red-List" framework. The study outcomes promoted the favoritism of renewable, recyclable and local building materials over the others. Also, phases prioritization and UBC influence in each phase have been pointed out giving the majority of priority to the occupancy phase, followed by the installation and recycling phases and identifying the sourcing and manufacturing priorities as the least concern in UBC context. At the end of this study, it has been concluded that UBC can use its influence in filing the framework's data gaps at certain usage phases.

After collecting the above-mentioned insights the team has prepared a specific improvement strategy for UBC "Red-List" framework consisted of six steps. It started by adding vital selection consideration to the hazard category as exposure, renewability, durability, and origin. The second step is giving percentile prioritization to material usage phases followed by constituting an effective scoring system for each building material. Afterward, options have been given to UBC policymakers on how to use their influential power in filling the data gaps with the red list. A material selection tool was then introduced to cultivate the fruitfulness of the improved framework. Moreover, the team ended the improvement sequence by proposing search easiness methodology to make transform the whole system into a practical platform.

2. Introduction

Renowned for its leadership in sustainability research and rigor green building commitment toward the environment as well as the safety of its occupants, the University of British Columbia has prepared the Green Building Action Plan (GBAP). Such a plan consists of major components addressing their targeted area of interest to reach a state-of-art sustainable campus.

The Material component, one of the emerging components in UBC GBAP, has focused on a set of metric goals that must be achieved. One of them is reducing the use of harmful materials in buildings and ultimately to 100% by 2035. To address such a challenge, one of UBC's researchers (Lorena Polovina), has achieved remarkable research. The research studied and analyzed hazard elimination and identification frameworks from Living Future Institute, Perkings + Will and Healthy Building Network. Thus, created a fruitful framework tailored to UBC's context evaluating the hazard content of building materials for elimination and mitigation.

Though the current "Red-List" framework is ultimately beneficial in evaluating building materials, its usability prospects were questioned. Through her report, she pointed out the further research is recommended to formulate such a framework into a usable tool.

Other key challenges that were pointed out in her report that the framework needs to prioritize important traits of material hazard. Also, it needs to assess the hazard while having health impacts as an important factor. The proper mechanism to link the whole framework to a solid measurable life-cycle analysis is required to be set.

Furthermore, taking into consideration the need to design buildings to stand with low hazard content for a very long time, the "Red-List" framework shall be complete with a wide range of materials data to rely on in reducing hazardous material usage in UBC buildings.

Post assessing Lorena's report, the project team have investigated various material selection frameworks focused on eliminating the use of hazardous materials. LEED V4, Life Cycle Analysis strategies, Life Building Challenge frameworks were the sources of invitation. From these rigor investigations, useful insights have been drawn to mend all the "Red-List" framework's gaps in terms of usability, reliability, and effectivity.

The team cultivated these insights into actionable steps targeting that transformation of the whole framework from a color-coding identification table into a quantifiable and practical database. Moreover, an addendum has been introduced to be used in conjunction with the improved "Red-List" framework as a simple but effective material selection tool. Also, proposed recommendations have been provided to guide UBC future research toward a toxic-free campus.

3. UBC Relevant Hazardous Materials Elimination Framework (Red-List):

Throughout UBC's continuous policy improvement, and by having a solid belief in reaching an optimal sustainable campus, the UBC green building action plan (UBC GBAP) has been formulated and issued. The GBAP has been divided into major components affecting major factors of green buildings. However, for the action plan to be successful, each component has been given a set of goals to achieve at a specific timely milestone. One of these immensely important goals is eliminating the use of hazardous materials in UBC buildings by 2035.

In April 2018, a breakthrough has been achieved by one of the SEEDs program projects. It introduced a creative framework for "UBC Relevant Red List of Material". This list is a major achievement which helps in assessing material hazard content and effects on the surrounding users. Not such that, it also accurately identified material hazardous effects in each phase of material usage. The described phases were as follows.

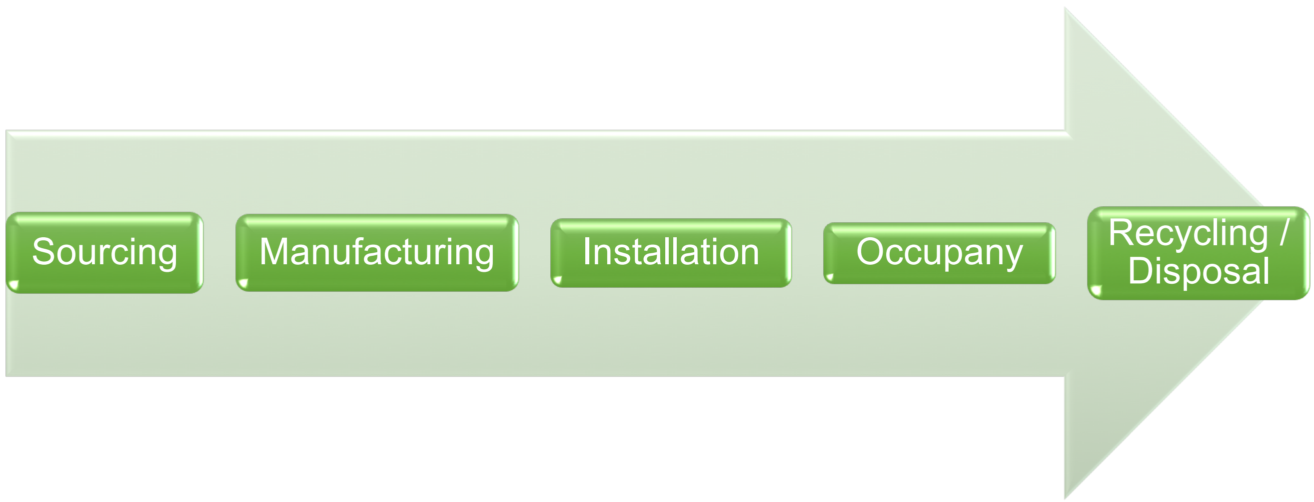


Figure 1: Material life cycle phases

By introducing this revolutionary Red-List, UBC officials, as well as designers and contractors, can know which materials are acceptable for usage in buildings. The list is so defined that material hazardous ingredients, name, supplier, description, type, and the manufacturer can be tracked for each specific material.

Master format	Product Type	Product Description	Product Name	Supplier/ Manufacturer	Potentially Harmful Ingredients	Phase I - Sourcing	Phase II - Manufacturing	Phase III - Installation	Phase IV - Occupancy Phase	Phase V - Recycling/ Disposal
09 65 19.23	Vinyl Flooring		Commercial Flooring Vinyl Composite Tile	Armstrong Flooring	BBP, DEHP, PVC, CASRN					

Table 1: Red list framework sample

For the “Red-List” to be fully comprehensible, each hazardous effect has been given an accurate concern, a detailed description, and a unique color code. By such identification, UBC can easily allocate highly concerned hazardous materials for elimination strategies. In the following table, hazard concern, colo, and description are illustrated.

Concern	Color	Description
Highest		Products in this category almost always contain items found in the LFI Red List and are hazardous for bioaccumulation and toxicity
High		High hazard carcinogens fall under this category
Moderate		Respiratory sensitizers fall under this category, along with flammable and reactive items
Low		Skin irritants fall under this category, along with chemicals that might have harmful but reversible health and environmental effects
None to Very Low		Materials in this category have not been found to pose any health or environmental risks

Table 2: “Red-List” framework hazard classification

3.1. “Red-List” Framework Limitations:

The “Red-List” potential in assessing and eliminating the usage of unwanted material. Through investigating the framework closely, it was found that the currently developed framework has unique aspects. We believe that some of them are very advantageous while others are hurdles in the face of exploiting the full capabilities the “Red-List”. These aspects can be categorized and identified as follows.

Advantages:

- Distinguished code for each material (no confusion between similar material types).
- Each material can be traced back to supplier and manufacturers.
- The hazardous effect can be identified for each phase of usage.

Disadvantages:

- Inability to differentiate between similar materials having the same color codes.
- Material selection relies solely on hazard declaration and neglecting other material selection criteria that can be important in such a process.
- Occupancy phase has been given the highest priorities while other phases lack prioritization.
- Difficulties in filling information gaps and verifying them and also adding new materials specifications to make the list a valuable resource.
- Difficulty in searching for specific material information.
- It is not formulated to be used as a selection tool rather than an identification matrix.

By reaching the root-cause issues in the current framework, a straightforward approach shall be implemented to amend these issues. To succeed in such, the improvements are proposed to be added.

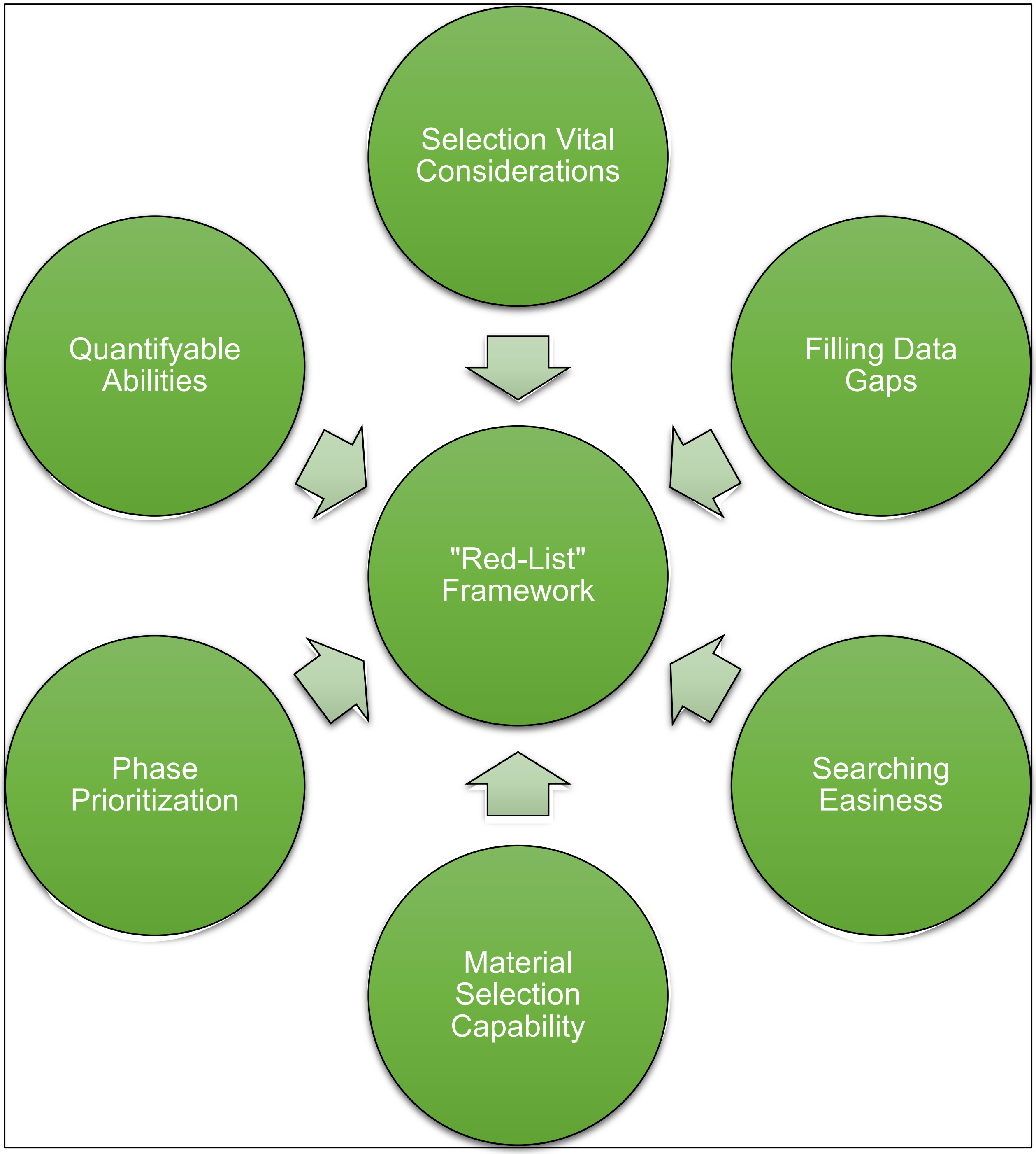


Figure 2: "Red-List" framework Improvement

To successfully implement these improvements, best practices and methodologies have been investigated through the following sections. Thus, giving useful guiding insights for enhancing implementations.

4. Investigations:

4.1. LEED V4 Framework:

LEED policy approach in reducing hazard material usage is clustered under three major sections. Each section consists of credited steps that designers should get a score to their building LEED certification is achieved. This approach encourages designs to reduce the use of harmful materials to acquire recognition.

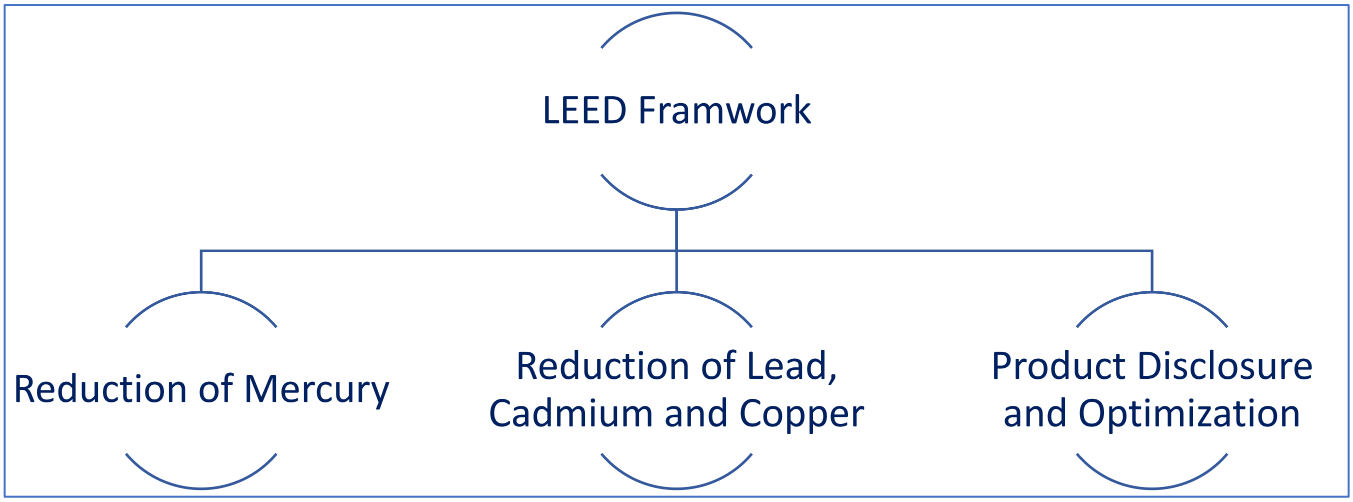


Figure 3: LEED Hazard Reduction Framework

4.1.1. Reduction of Mercury:

Lamps contain mercury, which is a bio-accumulative toxin. Longer lamp life can lower mercury use because replacement is less frequent, which lowers hazardous waste disposal costs.

Moreover, less frequent replacement also decreases the likelihood of spills, which could expose staff and patients to contamination and entail costly remediation procedures.

The proposed requirements for the reduction of mercury is to specify and install fluorescent lamps with low mercury content.

There are two steps for the reduction of mercury, and each step has one credit for its scoring criteria.

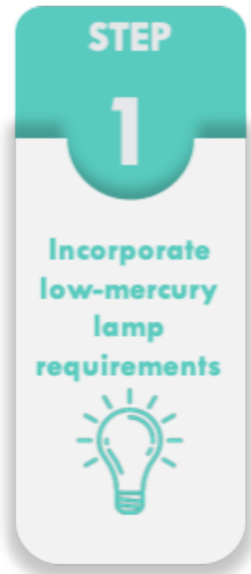


Figure 4: Step 1 for mercury elimination

1. Prohibit circular fluorescent lamps because of the high rate of breakage and associated with the risk of exposure for people.
2. Use pulse-start instead of probe-start metal halide lamps. The latter are prohibited because of their relatively short lamp life.
3. Consider installing high-efficiency, non-mercury lamps such as LEDs to replace high-pressure sodium (HPS) lamps to further reduce mercury in buildings. Alternatively, avoid cycling HPS ballasts.

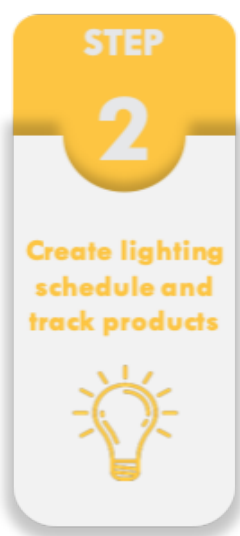


Figure 5: Step 2 for mercury elimination

1. Track specified and purchased lamps during construction with a material checklist or tracking form.
2. Prepare a lighting schedule that specifies the mercury-containing lamp type, ballast type, rated hours, and mercury content.
3. Review manufacturers' documentation before installation to ensure that only qualifying lamps are used.

4.1.2. Reduction of Lead, Cadmium, and Copper:

Both lead and cadmium are persistent bio-accumulative toxins (PBTs). PBTs released during the manufacture, use, or disposal of a product can travel far beyond their source point by wind and water, becoming more harmful the longer they persist in the food chain and posing risks to ecosystems on a wide scale. PBTs have a wide range of health effects, including cancer, endocrine disruption, immune system disorders, impaired brain development, and birth defects.

Copper, another PBT, corrodes when exposed to acidic air or water. Copper pipe corrosion can release high levels of copper into aquatic ecosystems, not only creating potentially toxic conditions for aquatic life but also affecting human health as its bio-accumulates and moves up the food chain.

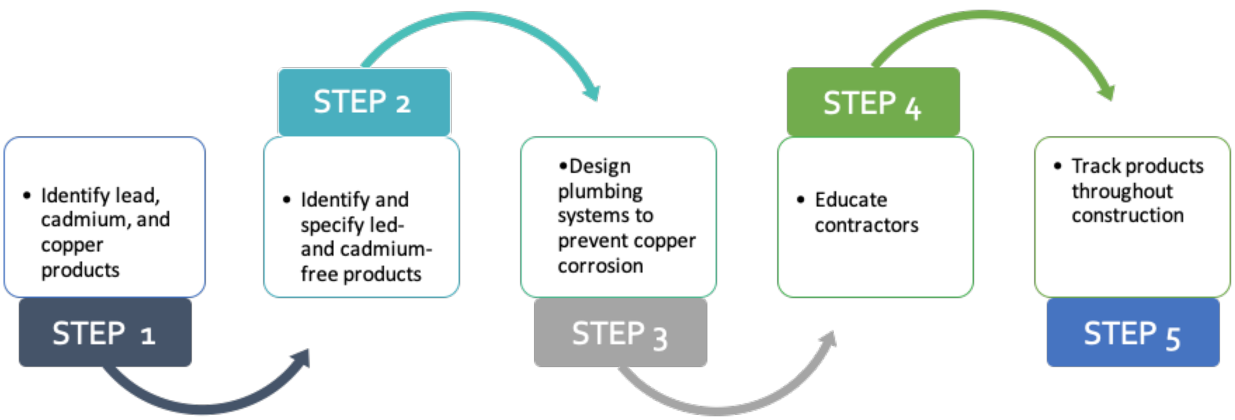


Figure 6: Steps for reduction/ elimination of hazardous materials

There are five steps for the reduction of Lead, Cadmium, and Copper, and each step has one credit for LEED scoring criteria.

Steps	Description
Step (1)	• Review preliminary project design and material specifications to identify building materials that may contain any of the substances in the credit requirements. • For example, roofing and flashing materials, pipes and fittings that convey water for human consumption.
Step (2)	• Identify lead-free roofing and flashing through manufacturers' information. • Identify lead- and cadmium-free paints using Green Seal certification for metal-free paints or an equivalent source of lead- and cadmium-free documentation.
Step (3)	• Minimize flow direction and piping size changes and water temperature and velocity. • Use compatible materials (e.g., copper straps for copper pipes) to reduce galvanic corrosion and similar problems.
Step (4)	• Provide education and training to contractors and subcontractors on PBT source reduction goals, common problem areas, and targeted strategies. • For example, provide a PBT source reduction plan to contractors, for them to distribute to subcontractors and field personnel.
Step (5)	• Track specified and purchased materials during construction with a material checklist or PBT tracking form. • Check the products' material safety data sheets (MSDS) and manufacturers' documentation before installation to ensure that only qualifying materials are used.

Table 3: Five steps for the reduction of copper, lead and cadmium

4.1.3. Building Product Disclosure and Optimization:

LEED constituted product disclosure and optimization in terms of material ingredients. The intent is to reward project teams for selecting products verified to minimize the use and generation of harmful substances, and also to reward raw material manufacturers who produce products verified to have improved life-cycle impacts.

There are two steps in the LEED framework to address these goals as follows.

4.1.3.1. Demonstrate the Chemical Inventory of the Product

Step (1)
2 Credits

- Materials defined as trade secret or intellectual property may withhold the name but must disclose role, amount and hazard screen.
- The hazard screen must be applied to each trade secret ingredient and the inventory lists the hazard category for each of the health hazards
- Moreover, the end use product must have a published, complete Health Product Declaration with full disclosure of known hazards in compliance with the Health Product Declaration Open Standard.
- The Declare product label must indicate that all ingredients have been evaluated and disclosed.

4.1.3.2. Optimizing Product Manufacturer Supply Chain

Step (2)
1 Credit

- This step is to ensure that all the products in the project are sourced from product manufacturers who engage invalidated and robust safety, health, hazard, and risk programs which at a minimum document at least 99% of the ingredients used to make the building product or building material.

- In addition, the products in the project are sourced from product manufacturers with independent third party verification of their supply chain that at a minimum verifies processes are in place to communicate and transparently prioritize chemical ingredients along the supply chain according to available hazard, exposure and use the information to identify those that require more detailed evaluation.

- As well as the processes are in place to identify, document, and communicate information on health, safety and environmental characteristics of chemical ingredients.

4.1.4. Source Insights Addressing "Red-List" Improvements

Sr. No.	Drawn Insight	Addressed Issue
1	The credited scoring system is beneficial in encouraging and rewarding stakeholders in identifying their material hazard content	Quantifiable Abilities
2	Hazard Screen is a suitable way to declare hazard without declaring material manufacturing secrets	Filling Data Gaps
3	Materials shall be periodically tracked, monitored and updated by easy to use online platforms capabilities	Searching Easiness
4	Their party verification of hazard-free material can be used to avoid manufacturer resistance in declaring information	Filling Data Gaps
5	Rewarding raw material manufacturers upon hazard-free products	Quantifiable Abilities

Table 4: Source improvement insights

4.2. Material Life Cycle Analysis Framework:

The life cycle approach will shift the focus from individual components to the entire life cycle of the procedure or the product. This approach can offer more sustainable solutions for building material selections.

When we are considering to use less harmful material and to reduce the environmental impact, one important aspect is taking the material & resources' whole life cycle into consideration. From raw materials acquisition to final disposition, each stage would require energy and produce potential waste (potential harmful chemical) and generate environmental impact. Recycle and reuse cycle can be created within manufacture, consumption, disposition. Below is a life cycle flow diagram showing the general processes of the materials' life cycle.

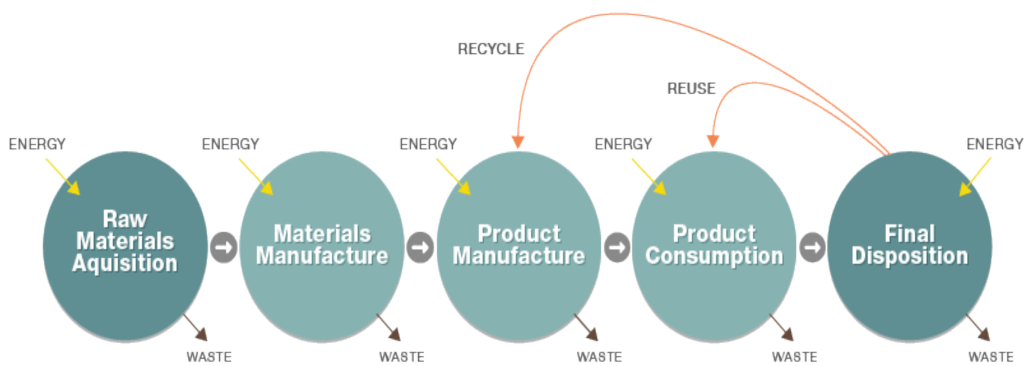
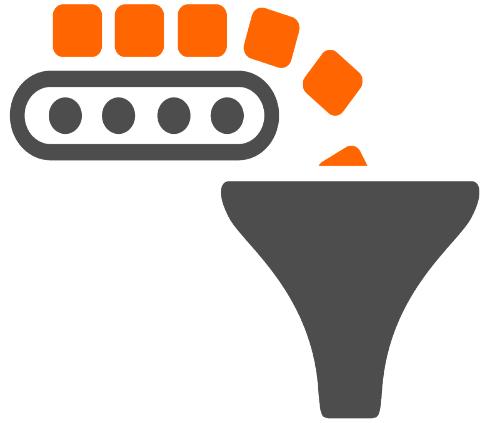


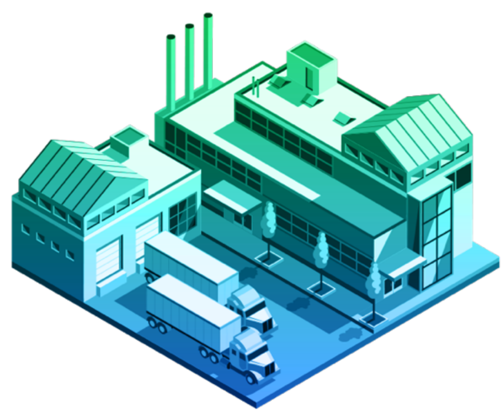
Figure 7: Material Life Cycle Flow Diagram (Elixir, 2019)

4.2.1. Phase (1): Raw material acquisition



- At the raw material acquisition stage, majority of the building raw material extraction and processing often have negative impacts on the environment such as soil degradation, water shortage, biodiversity loss, damage to ecosystem functions and greenhouse emission, etc.
- Especially when using non-renewable raw material, the impact will be amplified.
- To mitigate the issue, the use of renewable raw material sources or material uses green technologies should be first considered when doing the selections.
- For example, choose timber structure building over a concrete structure when possible.
- For the materials created in the lab, there are could be potentially harmful chemicals generated.
- To mitigate this, it relies on the raw material processors to provide the processing method or ingredient list to avoid potential impact.

4.2.2. Phase (2): Manufacturing:



- At this phase, the material is being processed to become the product for building construction and renovation.
- Potential Red List hazardous material could be added to form the final product or reactions between chemicals that could cause water pollution or produce off-gas harmful emissions. The workers could be harmed if personal protective equipment (PPE) is not properly used.
- UBC will need to rely on the manufacturer to release their product ingredients to gain an insight into potential hazardous material being used.
- This was extremely challenging at the early stage when LEED v4 and Living Building Challenging first asking applicants to submits their material list.
- There was a strong backlash from the manufactures due to trade secrets and patent protection.
- Declare®, the Institute’s ingredients label for building products, is a publicly accessible label and online database (International Living Future Institute, 2017).
- UBC could either partner up with Declare® to request the contractors to submit the material list or use the Declarer’s existing database to identify the potentially harmful product.

4.2.3. Phase (3): Product Transportation

- When considering product transportation, long distance logistic will produce more GHG emission and potentially cause more environmental concerns.
- Currently, if UBC requires manufactory to report the material ingredient and its health and environmental impact during all phases of the product life cycle, we could face two challenges.
- First, the local provider does not meet the material requirement for health and environmental concerns.
- Second, local providers do not willing to share the information required.
- If we have to choose between regional sourcing of materials versus remote sourcing health materials, what is the balanced approach to material selection?
- The recommendation is, if logistics is the only difference between healthy materials and potentially harmful material, UBC should give the preference to healthy material.
- The impact from GHG emission could be reduced by providing proper logistic management, such as combine the scheduling for shipping, and bulk quantity ordering.
- And by insisting and widely adopting green initiatives, the regional retailer could gain the incentives to provide more

4.2.4. Phase (4): Installation

- During the installation phase, the most harmful impact will happen to construction workers.
- The potential health effect could happen through eye contact, skin contact, inhalation, Injection.
- For example, repeated or prolonged skin contact of some adhesive bonding material may cause skin irritation and/or dermatitis, and even cancers.
- If the impact of the material is short term and only during the installation period, UBC could enforce the use of PPE to mitigate the potential impact.
- And if the impact extends to the occupancy phase, UBC should consider using the alternative material.

4.2.5. Phase (5): Occupancy:

- The occupancy phase is considered to be the most critical stage amongst all material life cycle.
- The design period for buildings at UBC is 100 years, and during the time, the harmful chemical could cause potential long-term damage to human health and to the environment.
- Finishes such as wall paint, flooring, and ceiling are particularly important since their inside of the building and may release harmful chemical gas that could be inhaled by occupants as well as cause skin problems through direct contact.
- Given the circumstances, UBC should consider implementing different levels of enforcement in terms of material selection.
- Before the transparency of the ingredient issue to be resolved, UBC should mandatory to provide the material ingredient for finishing material, and the selections are only given to the healthy product.
- In addition, by choosing more durable health material would minimize the wear and tear, and as a result, the maintenance/replacement period would get extended, this is also an efficient way to reduce the life cycle impacts.

4.2.6. Phase (6): Reuse/Recycle:

The reuse and recycle of the material usually occurs at the deconstruction phase.
In general, the reuse and recycle of the material are encouraged to promote sustainability.
Additionally, UBC should consider promoting the use of more durable products as they would encourage reuse of the material and reduce the impacts on the life cycle.

Post analyzing the previous phases we deduced the following features for each phase in regard to UBC influence and current priority.

Phase No.	Phase (1)	Phase (2)	Phase (3)	Phase (4)	Phase (5)	Phase (6)
Influence Power	Low	Medium	High	High	High	High
Priority	Low	Low	Medium	Medium	High	Medium

Table 5: UBC Influencing and Prioritization

Traditional building design follows a sequential approach that architectures and engineer consultants design the building, and contractors receive the drawings once most of the designs have been completed. This leaves the contractors and trades have not too much power to contribute to the material selection. But in reality, the contractors and trades may have more experiences about potentials knowledge about the hazardous material especially with the sourcing and installation. By switching from the sequential approach to an integrated design approach, it is also a good strategy that UBC can adopt to improve the material selection process in general. Below is a diagram showing the IDP team formation.

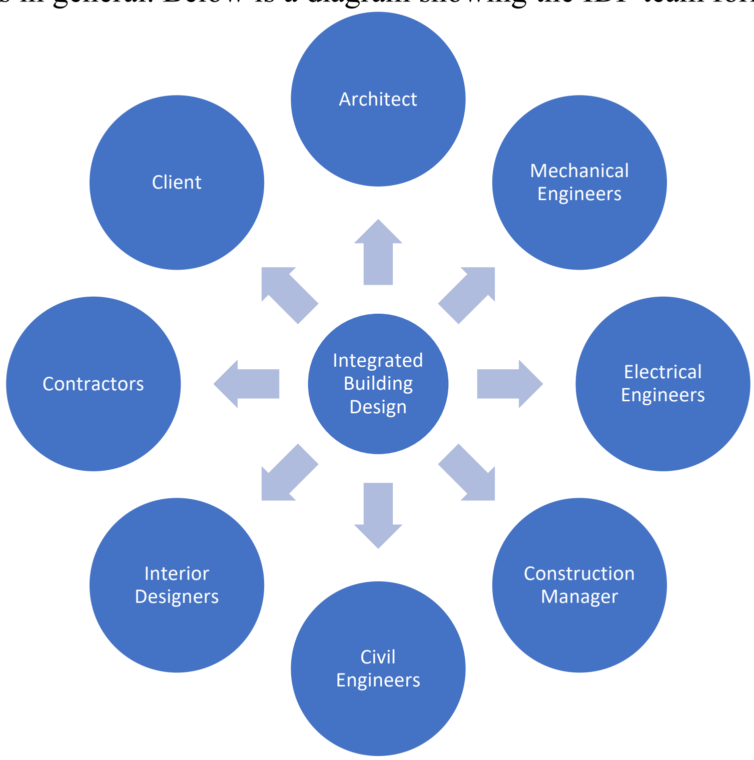


Figure 8: IDP Framework

4.2.7. Source Insights Addressing "Red-List" Improvements

Drawn Insight	Addressed Issue
Renewable materials shall be favored over non-renewable or non-recyclable materials	Selection of Vital Considerations
Living building challenge, Declare® can be used as a guide to filling material information addressing hazard implications	Filling Data Gaps
Exposure to hazardous material in different phases shall be accounted for and rewarded when mitigated properly	Selection of Vital Considerations
Local materials shall be given the advantage over imported ones without increasing hazard effects	Selection of Vital Considerations
Prioritization of each material aspect (not just hazard) must be evaluated in regard to UBC phase priority as specified in the table (4)	Phase Prioritization
UBC should use its influence power in certain phases	Filling Data Gaps
"Red-List" shall imitate IDP practicality in selection and decision making	Material Selection Capabilities

Table 6: Source Improvement Insights

5. Exploiting the “Red List” Potentials:

Throughout the previously illustrated framework investigations, it has been shown that their valuable insights can effectively address the current “Red-List” proposed improvements. Yet, for the improvements to be quantifiable, feasible and logical, these improvements shall be divided into clear achievable steps. We can easily link and summaries the investigations insights from the table (4) and table (6) in the form of added factors and items to the framework improving steps as follows.

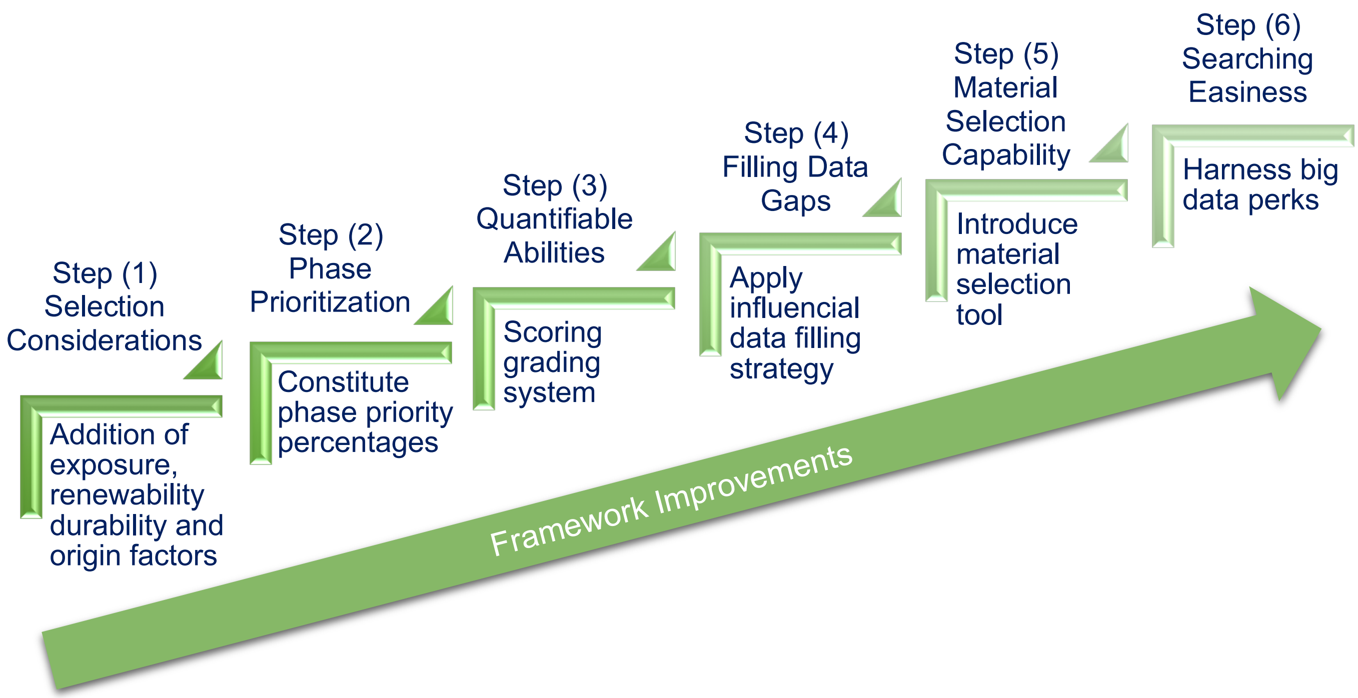


Figure 9: Framework Improvements

5.1. Step (1): Selection Considerations:

The required selection considerations were pointed out by drawing insights from the table (6). Each consideration addresses several material characteristics that are directly related to the category of the consideration itself. For example, if the material is in “full contact” with users, then this characteristic identifies its “Exposure” category state.

The description of each consideration category is as follows.

5.1.1. Exposure :

The material selection decision can highly vary if the hazardous material (emitting toxins or dormant type) is in direct contact with humans or enclosed safely in each phase of material usage. According to the "Red List" framework, exposed toxic material to individuals in the occupancy phase is higher risk than the same exposure during the other phases since workers can wear protective gears.

Related Characteristic	Description
No contact	The material is excluded from users direct contact or/and coated with isolated layer/s
Limited contact	The material is not or/and limited coated with rare users contact
Full contact	The material is not coated or/and in possible frequent contact with users

Table 7: Contact category characteristics

5.1.2. Renewable / Recyclable:

This factor is important since it counts for future generations prosperity, UBC shall consider the usage of degradable material as well as generative ones. For example, petrol-polymers (nonrenewable and nonbiodegradable) are widely used in construction materials such as sealants, insulations, and piping. Giving priority to renewable and biodegradable materials will promote the usage of non-toxic degradable raw materials. Recyclable and/or renewable materials should be encouraged over non-recyclable and/or non-renewable ones.

Related Characteristic	Description
Renewable & recyclable	The material comes from a regenerative source and can be reused at the end of its life cycle
Renewable & non - recyclable	The material comes from a regenerative source but cannot be reused at the end of its life cycle
Non-renewable & non - recyclable	Neither the material comes from a regenerative source nor it can be reused at the end of its life cycle

Table 8: Renewable/ recyclable category characteristics

5.1.3. Durability:

UBC projects tend to be cost-effective and have the most feasible investment outcome. Thus, while reducing hazardous material used in building construction, material durability must be considered. Comparing two materials having the same low hazard threat with different durability factors will lead to the favoritism for the better economically viable option. This can segregate material likability to usage as follows.

Related Characteristic	Description
100% of building life-cycle	The material will not be changed during the occupancy phase
75% of building life-cycle	The material will go through minor renovation near the end of the occupancy phase
50% of building life-cycle	The material will go through a major renovation during the occupancy phase
20% of building life-cycle	The material is temporary and will be replaced or/and be renovated frequently during the occupancy phase

Table 9: Durability category characteristics

5.1.4. Origin:

UBC shall use the wave of reducing toxic material used to promote local economy booming in this sector. We have seen clearly the advantages of local transported material over the imported ones. This shall be considered bearing in mind the ultimate goal of hazardous material elimination.

Related Characteristic	Description
Local by origin	The material has been sourced and/or manufactured from/by local origin
Imported by origin	The material has been sourced and/or manufactured from/by overseas origin

Table 10: Origin category characteristics

We can summarize the whole addition of this step as follows.

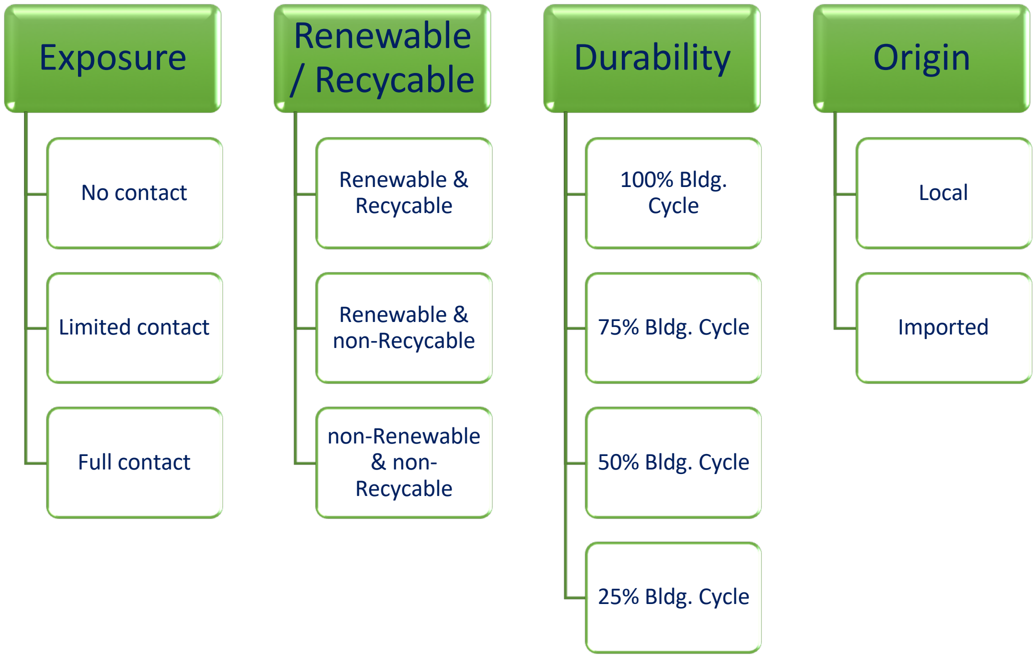


Figure 10: Durability category characteristics

5.1.5. Step Incorporation in the "Red-List" framework:

By adding such factors to the current framework, we can find that some of these categories are affecting some phases. The exposure category affects all material usage life cycle as contact can be traced from material sourcing till recycling. On the other hand, the "Renewable/Recyclable" category only affects the sourcing phase since it constitutes the material basic traits which will have no effect on further phases. The durability category also affects only one phase which is the occupancy. Furthermore, the "Origin" category affects both the sourcing and manufacturing phases. Such is logical since it addresses material acquisition and processing only. The following sample table shows such incorporation.

Model Format	Existing Product information columns	Category	Phase (1): Sourcing	Phase (2): Manufacturing	Phase (3): Installation	Phase (4): Occupancy	Phase (5): Recycling
06 16 33.31	Description: Particle Board Name: TemStock-FR Particleboard Supplier/ Manufacturer: Temple-Inland Potentially Harmful Ingredients: Formaldehyde, Boric Acid, SLS	Hazard					
		Exposure					
		Renewable					
		Durability					
		Origin					

Table 11: Proposed Red List framework with additional factors

5.2. Step (2): Phase Prioritization:

Investigating material lifecycle frameworks showed us the logical priority for each material usage phase. As drawn from the table (6), the occupancy phase has the highest priority and high influence power for UBC while other phases are difficult to control and influence. Material favoritism shall benefit from this criteria to inhibit hazard material usage within most affecting UBC population during installation, occupancy and recycling phases. We can relate such to the clear understanding that these phases happen on the UBC campus and shall be controlled.

As a result, we have divided UBC concern priority by percentage as shown in the following table.

Phase number and Description	Phase (1): Sourcing	Phase (2): Manufacturing	Phase (3): Installation	Phase (4): Occupancy	Phase (5): Recycling
Priority Percentage	10%	15%	20%	35%	20%

Table 12: Proposed Red List framework with additional factors

5.2.1. Step Incorporation in the "Red-List" framework:

This step shall be an overall governor for UBC's concern toward material evaluation categories. Basically, hazardous material in the occupancy phase shall be red flagged and pointed out for elimination rather than a similar hazardous material which only affects the manufacturing phase. Thus, pinpointing the elimination strategy to the benefit of the UBC campus as the highest priority to tackle and resolve.

Model Format	Existing Product information columns	Category	Phase (1): Sourcing	Phase (2): Manufacturing	Phase (3): Installation	Phase (4): Occupancy	Phase (5): Recycling
06 16 33.31	<u>Description:</u> Particle Board <u>Name:</u> TemStock-FR Particleboard <u>Supplier/ Manufacturer:</u> Temple-Inland <u>Potentially Harmful Ingredients:</u> Formaldehyde, Boric Acid, SLS	Priority	10%	15%	20%	35%	20%
		Hazard					
		Exposure					
		Renewable					
		Durability					
		Origin					

Table 13: Proposed Red List framework with prioritization

5.3. Step (3): Quantifiable Abilities:

- We were impressed by the multiple sources emphasizing the importance of a scoring system that constitutes exact measurable metrics.
- This enables them to aim their efforts in achieving calculated goals.
- The scoring systems offer encouragement of using healthy materials and rewards abiding partners with credits, points, and certifications. LEED scoring system, Living Building Challenge framework (LBC) showed us clear and solid examples of such success.
- We can translate this principle as an improvement to the current “Red-List” framework. Adding a numerical scoring system to the existing color coding as well as the other categories will lead in giving building materials an overall score.
- The overall score can be used to give a holistic evaluation number for specific material.
- But to do so accurately, the scores shall force high hazard non-renewable, non- recyclable, full contact, low durability materials into disadvantage besides other materials.
- Keeping in mind that a proposed scoring system requires intensive trials and continuous enhancement, logical scores have been given to each category features as follows.

-

Hazard Category		
Feature	*Color*	*Proposed Score*
Highest		-3
High		-2
Moderate		-1
UBC Minimum acceptable Line (Proposed)		
Yellow		1
Green		2

Exposure Category	
Feature	*Proposed Score*
No Contact	2
Limited Contact	1
Full contact	0

Renewable / Recyclable Category	
Feature	*Proposed Score*
Renewable & Recyclable	3
Non-Renewable & Recyclable	2
Non-Renewable & Non-Recyclable	1

Durability Category	
Feature	*Proposed Score*
100% Building Lifecycle	2
75% Building Lifecycle	1.5
50% Building Lifecycle	1
25% Building Lifecycle	0

Origin Category	
Feature	*Proposed Score*
Local	1
Imported	0

By incorporating the scoring system in the current "Red-List" framework, we demonstrated such fusion as follows.

Model Format	Product information columns	Category	Phase (1): Sourcing	Phase (2): Manufacturing	Phase (3): Installation	Phase (4): Occupancy	Phase (5): Recycling	Category Sub-score	Evaluation Score
06 16 33.31	Material Description as per the original list framework	Priority Multiplier	10%	15%	20%	35%	20%	10%	-3.45
		Hazard	-2	-3	-1	NA	-1	-4.05	
		Exposure	0	1	0	0	0	0.15	
		Renewable	0					0	
		Durability				1		0.35	
		Origin	1	NA				0.1	

Table 14: Evolved "Red-List" framework with a scoring system

5.3.1. How the evolved "Red-List" framework works:

- Each material will have its description as per the proposed Red List framework.
- For each category, use the proposed scoring criteria to provide scores by keeping the color-coding for the hazard section.
- Multiply each number by the priority percentage for each corresponding phase.
- Add the multiplied scores in each category row to the category subtotal cell.
- Add all subtotals into an "Evaluation Score" for the material.

5.3.2. Benefits of the scoring system:

- Each material produced by each manufacturer will have a distinctive overall evaluation score.
- Evaluation score covers the material categorial features and rules out unwanted material usage by giving negative scoring for hazardous ones.
- aspects of material effects within the UBC context for effective targeting of UBC GBAP material and resources component.
- Accurately compares between different materials having the same hazard content by relevant important ruling categories.
- Will aide UBC in setting the achievable benchmark to gradually reduce the use of hazardous material till the achievable goal by 2035.

5.4. Step (4): Filling the data gaps:

We have concluded UBC influence in driving suppliers and manufacturers to declare their material hazard contents. As we found the promising potential of material declaration systems like Declare®, Hazard screen and LEED declaration framework, we propose paths for UBC to fill the gaps in the "Red-List" framework to be both reliable and valuable source of information to designers and development partners. We identified the pros and cons of each path for UBC feasibility evaluation. The options are as follows.

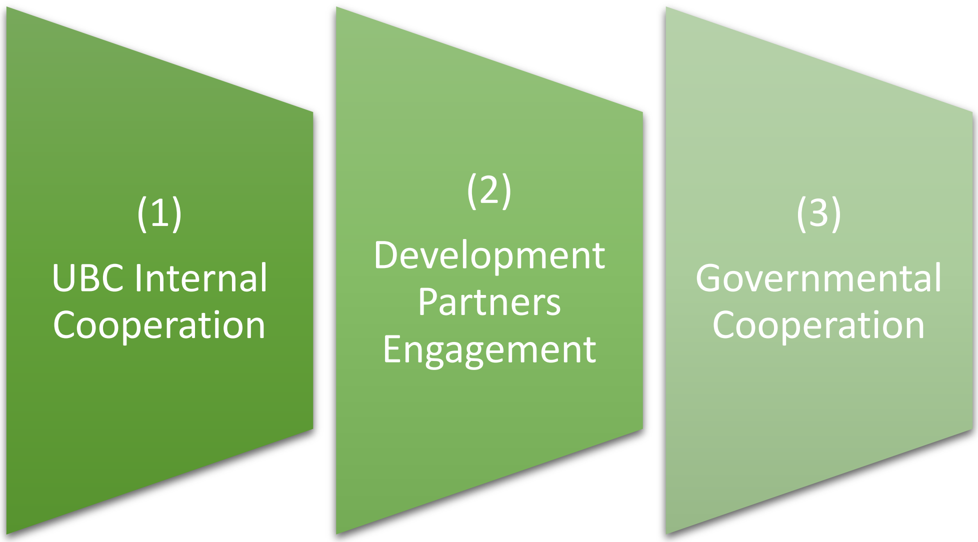


Figure 11: Options for filling the data gaps

5.4.1. UBC internal cooperation:

UBC sustainable can divert its projects to tackle precise material identifications at a time with the planned schedule to cover all the material segments through its staff and researchers.

Pros	Cons
- In-house driven data. - Automatically verified for clarity and authenticity. - Assessing materials at the existing building sector alongside the new building sector.	- Requires substantial research and outreach investment. - Will consume a considerable portion of research projects. - Selected teams for these tasks must have the material market knowledge to succeed in this endeavor.

5.4.2. Development partners engagement:

Contractors and/or designers must be involved in the completion of data by filling blanked sections of their used material as a part of their material-proposing phase. Their filled sections must be verified and endorsed by the UBC team before permanently adding its value in the red list.

Pros	Cons
- Accurately targeting materials in new construction/renovation projects. - Trade-off expensive research investment capital. - Allocating smaller team of professionals to verify the filled material lists. - Using the UBC power of influence on its development partners.	- The buy-in inability of some designers and contractors as additional work upon their normal type of contracts. - The difficulty faced by the designers and contractors to obtain origin and manufacturing phase data from relevant parties. - Dedicating a team of professionals to assess and verify the submitted data.

5.4.3. Governmental Cooperation:

UBC can promote the list benefits as a beneficial addition in selecting material on a municipal level. By that, UBC can acquire governmental buy-in which will lead to a systematic collection of data from manufacturers.

Pros	Cons
- Strong drive that will ensure the completion of red list data in a faster time. - Verified data with no risk of misleading information. - The potential increase of adoption by other municipalities.	- Challenges in acquiring the interest of governmental bodies. - More resistance from designers, contractors and manufacturer's side. - Challenges in promoting awareness of material toxicity on a larger scale.

5.5. Step (5): Material Selection Capability:

Dissecting the benefits, the material selection methodologies summarized in table (4), showed that imitating material selection tool can be distracting since it relies on bases differs from the material declaration framework criteria. So, a tailored material selection tool has to be formulated as an external item from the "Red-List" itself. Yet, it shall be based on the same principles of the "Red-List" framework.

The tailored tool shall have the following functions to be useful:

1- Calculate the evaluation score.
2- Compare between materials.
3- Show material advantageous comparisons in detail.
4- Provide insights to raise the accepted material threshold.
5- Can be relied on in setting a maximum and minimum score for any product type.

These guided functions provided a clear path to provide the material selection tool (MST) which is demonstrated as follows.

Material Selection Tool (MST)								
Product information columns	Category	Phase (1): Sourcing	Phase (2): Manufacturing	Phase (3): Installation	Phase (4): Occupancy	Phase (5): Recycling	Category Sub-score	Total Score
Material (A)	Priority Multiplier	10%	15%	20%	35%	20%	100%	-0.8
	Hazard	-2	-3	-1	-1	-1	-1.4	
	Exposure	0	1	0	0	0	0.15	
	Renewable	0						
	Durability				1		0.35	
	Origin	1					0.1	
Material (B)	Priority Multiplier	10%	15%	20%	35%	20%	100%	2.05
	Hazard	2	1	1	2	1	1.45	
	Exposure	0	1	0	0	0	0.15	
	Renewable	0						
	Durability				1		0.35	
	Origin	1					0.1	
Material (C)	Priority Multiplier	10%	15%	20%	35%	20%	100%	1.45
	Hazard	1	2	1	1	-1	0.75	
	Exposure	0	1	0	0	1	0.35	
	Renewable	0					0	
	Durability				1		0.35	
	Origin	0					0	
Selected Material		**Material (B)**						
Notes / Recommendations		**Material (A) shall be marked as not selectable**						

Table 15: Material Selection Tool (MST)

5.5.1. How to use the MST:

- User will refer to the "Red-List" and collect verified material data (all categories).
- The data will be filled in the MST for the selected materials.
- The user will calculate the overall evaluation score for each material.
- The outcome of selection will be pointed at the bottom and recommendations for further improvement shall be noted.

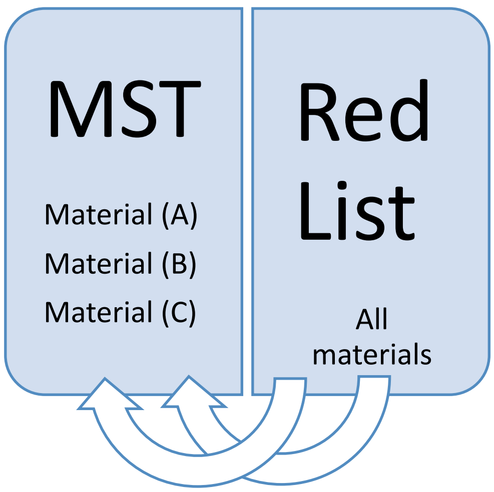


Figure 12: Preparation of MST keeping Red List as a base

Users interaction with the MST will make it more efficient and beneficial for the whole process. Below is a sample of the useful feedback that shall be given in the MST Notes / Recommendation section.

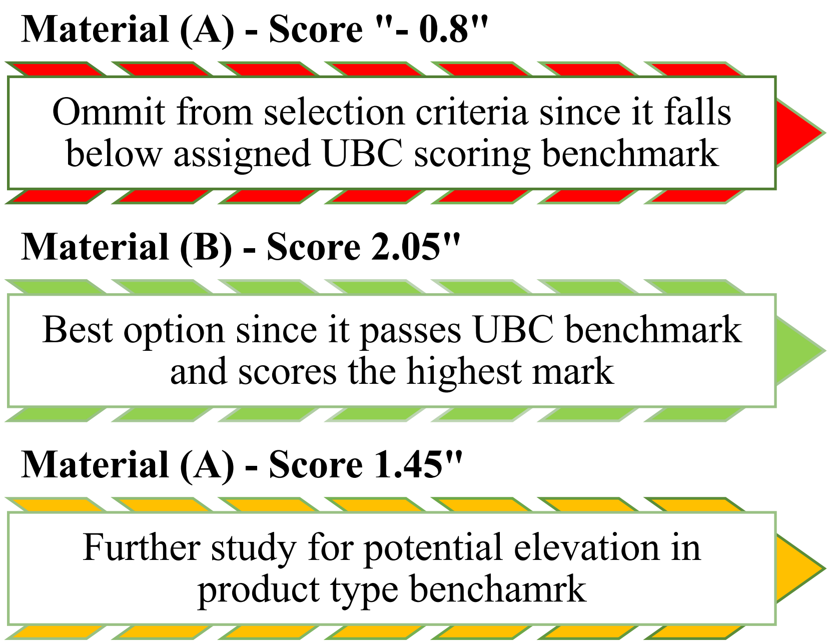


Figure 13: Material Selection Conclusions

5.5.2. Potential Area of Extending The Framework Usefulness:

It was intriguing the LEED approach to segregate material hazard content by a percentage of the whole product. That gave us an insight into assessing the extended ability that the MST can achieve. We concluded that it can be used to evaluate a whole building based on its hazard potential. The potential of such can be used funneled into two paths:

a. Setting a maximum hazard level for newly designed buildings.
b. Can accurately evaluate the hazard level of an existing building for future renovation plans.

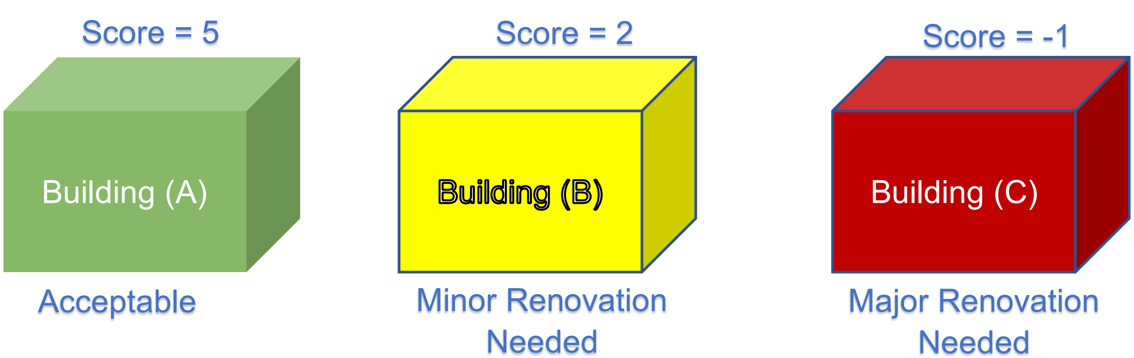


Figure 14: Existing Buildings Evaluation

5.5.3. Potential Usage of Building Evaluation Sheet:

a. Reduce new building hazard level in new designs.
b. Set a hazard effect score for designers and contractors to meet in any development.
c. Assessing holistic hazard level of collective of buildings or even districts on campus.
d. Monitoring hazard elimination plans progress.
e. Base hazard mitigation plans on for existing building through renovation plans as targeted goals.
f. Being a mandatory analysis criterion in UBC building design guidelines.

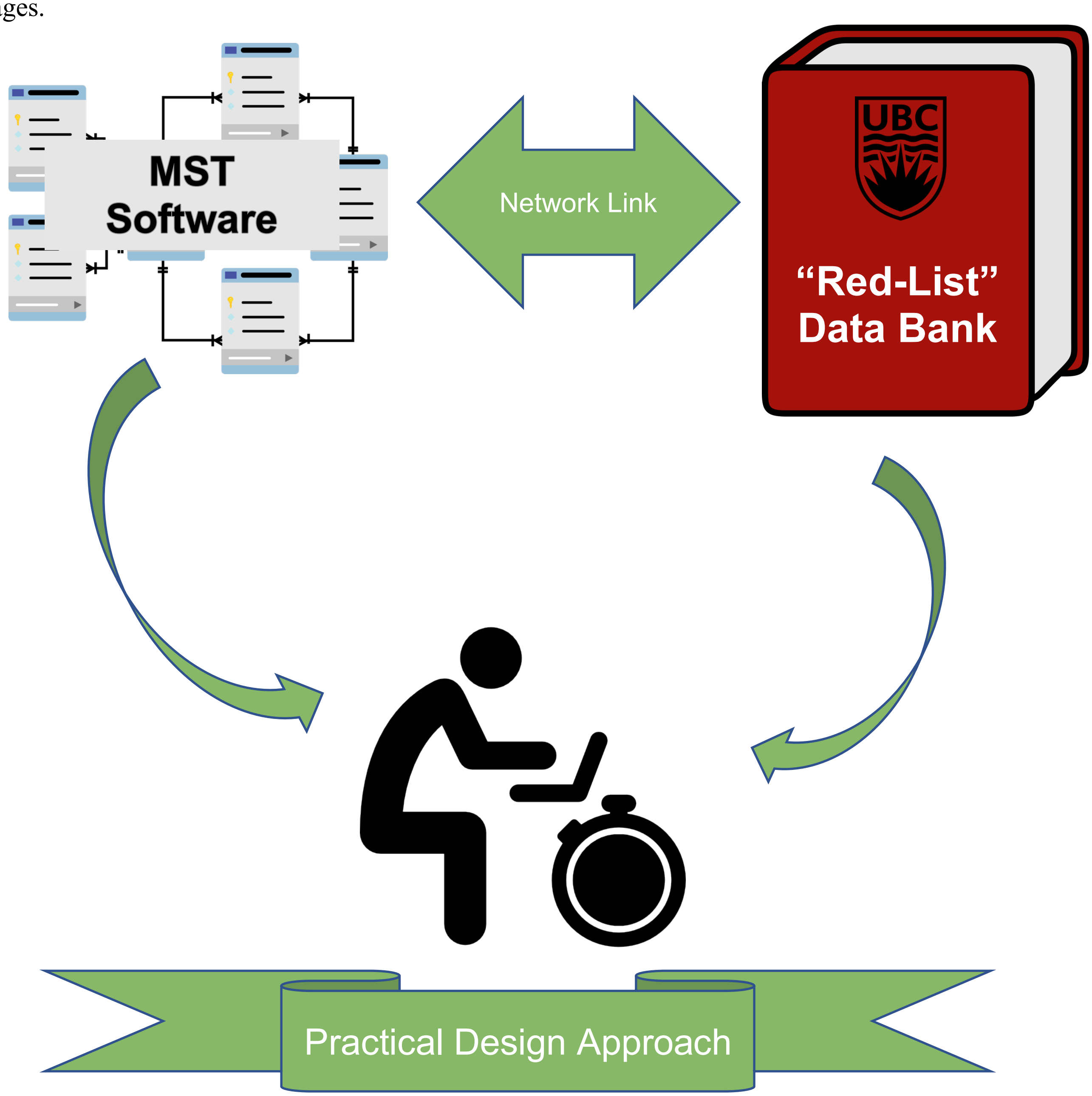
Material Segment	Selected Material	Toxicity Score	Percentage of the Building	Toxicity score by the percentage	Total Toxicity Score of Building
1	Material (A)	1	15%	0.15	1.72
	Material (B)	2.5	10%	0.25	
	Material (C)	1.6	7%	0.112	
2	Material (D)	1	12%	0.12	
	Material (E)	2.5	9%	0.225	
	Material (F)	1.6	5%	0.08	
3	Material (G)	1	3%	0.03	
	Material (H)	2.5	5%	0.125	
	Material (I)	1.6	8%	0.128	
4	Material (J)	1	4%	0.04	
	Material (K)	2.5	12%	0.3	
	Material (L)	1.6	10%	0.16	

Table 16: Building Evaluation Sheet Sample

5.6. Step (5): Searching Easiness:

We have noticed that The Pharos project by HBN (Health Building Network), Precaution List by the transparency initiative and Portico are using interactive data updating capability. Also, Materials shall be periodically tracked, updated and enhanced in quality for reliability and to build trust in using the framework.

We believe that UBC's evolved "Red-List" framework must have the same features. The continuous market technology advances constitute such feature to be available. Furthermore, this platform shall have searching capabilities to enable designers to easily assess their design toxicity level in the early design stages.



6. Conclusion:

- To make guideline/policy improvements which support the reduction in the use of hazardous building materials in UBC buildings, the first step was to identify the gaps between some of the best policy guidelines such as LEED and UBC content.
- The key takeaway was UBC should focus on reducing the four toxic chemicals in material such as mercury, lead cadmium, and copper.
- A credit scoring system was developed and integrated into the red list framework improvement.
- When taking the entire life cycle of the material life into consideration, we understand that all phases of the life cycle have contributions to the environment and human health.
- However, UBC should put more emphasize on occupancy phase and finishing material due to the long-life span of UBC buildings.
- The finishing materials are mostly inside of the building and exposed to the occupants, and also the impacts are long term.
- UBC's power of influence and priority level to UBC at each life cycle stage are also identified as key findings to further integrate into the red list framework.
- Furthermore, more intensive literature review and background study of living building challenge and Perkins + Will case study were conducted to develop the foundations for our final findings.
- Finally, in order to develop a practical tool for UBC for material selection to reduce the use of harmful material, we converted the color-coding system from the previously developed framework by Lorena Polovina's and turned them into an actual scoring system with different weighting impacts on different phases of the life cycle.
- Some additional consideration from LEED guideline study and life cycle analysis are also added into the selection system such as credit weighting, the origin of the product, the durability of the products.
- These findings and the red list scoring framework together will help UBC to enhance the GBAP and will reduce the use of hazardous materials as well as mitigate the impacts of the harmful materials.

7. Recommendations:

7.1. Recommendations for Action Plan:

- During the development of UBC red list, and also to mitigate the backlash from contractor and material manufactures, UBC could first require contractors to submit a material checklist.
- This checklist should include all the critical harmful material UBC has identified so far from the red list.
- The contractor or manufacturers need to ensure their products do not contain any harmful material identified on the checklist in order to get contracts from UBC.
- The checklist should also send to architect designers as they have more power of influence on material selection.
- This action period is in the next 3-5 years. After 5 years, UBC starts to ask the manufactures the submit the complete ingredient list for the material product, alternatively, they could submit it through Declare®.
- This will help to develop a database to assist the designers to make a "better" material selection.
- By 2035, UBC should require the contractors to submit the full life cycle report in order to mitigate the impacts of the full material life cycle.

7.2. Recommendations for Further Study:

- Assessing the most suitable approach to collect authentic material data.
- Evaluating the proposed scoring criteria and weighting to be more realistic, robust and effective according to UBC objective in the short and long terms.
- Plotting a realistic existing building toxicity level and assess the current hazard effects on UBC occupants.
- Which UBC building standards and guidelines are the most suitable fit for the proposed updated framework, tools and analysis to be implemented in.
- Where shall the proposed methods documents fit in the already used design documents between designers and the UBC. And if it shall be submitted during the early stages of design only or throughout the project construction phase.
- The ability to modify these methods/tools to operational tools during building occupancy phase for toxicity mitigation assurance.
- This will help to develop a database to assist the designers to make a "better" material selection.
- By 2035, UBC should require the contractors to submit the full life cycle report in order to mitigate the impacts of the full material life cycle.

8. References:

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