UBC LIVING LAB: INNOVATION IN ACCELERATING THE ADOPTION OF SUSTAINABLE TECHNOLOGIES FOR CAMPUS INFRASTRUCTURE

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ABSTRACT: Any group that creates challenging goals also requires a strategy to achieve them. In the University of British Columbia's (UBC) case, the goals are to reduce greenhouse gas emissions to 33% below 2007 levels by 2015, and 100% by 2050. A part of the strategy is a *Campus as a Living Lab* program to simultaneously meet increasing infrastructure capacity requirements while achieving sustainability goals. The Campus as Living Lab collaborates with industry partners, operations, and researchers to utilize the campus as a test bed for commercialization of sustainable technologies. This paper explores this program and its replicability to other institutions. This exploration involved developing business process models for current practices at UBC, and an ethnographic study to extract key transferable characteristics for replicability. The research culminates in a series of generic business process models that illustrate what is required to create a Campus as a Living Lab program.

Keywords: Sustainability, Living Lab, Infrastructure, Technology Demonstration, Technology Commercialization

1 INTRODUCTION

1.1 Background

Many technical solutions have emerged to make developments—buildings and infrastructure systems—more sustainable. Technologies to retrofit buildings to become more energy efficient are an example. In most cases, however, building owners do not take full advantage of the technical solutions that are available to them. This clearly demonstrates that the solutions to improving buildings' sustainability are not technical alone. The challenge can be viewed as one of technology transfer—how to successfully transition new technical solutions from nascent inventions to common practice. One particular mechanism that can aid the technology transfer process is the provision of a test bed; a facility that can implement emerging technologies at full scale to demonstrate their potential and help convince others to follow suit.

The University of British Columbia has adopted a program to use its own campus as such a test bed: the UBC Campus as a Living Laboratory (CLL) program. The program has been successfully implemented in response to aggressive University sustainability targets and it has initiated several substantial projects. Apparently

successful, an opportunity exists to replicate the program with other large institutional organizations such as universities or municipalities. Yet it has been difficult for those that have not been directly involved in the program (and even those that have) to clearly define the processes and practices that make up the CLL program in a way that would allow it to be replicated elsewhere.

This paper reports on a research project to examine the UBC CLL program in detail, formalize and map its major processes, examine opportunities for improving its practices, and document it in a way that would make it easier to replicate elsewhere.

1.2 Research Outline

The objective of the research was to create the foundation of a "roadmap" for other institutions to adopt a UBC CLL-like strategy. The sub objectives were to: 1) document and model the processes, 2) reconcile the models with emerging processes, and 3) create improvements.

The research built on several bodies of knowledge as its primary points of departure, included literature relating to technology transfer and knowledge diffusion processes. The CLL processes—both as-followed for the few major projects that it undertook as it was being formed as a major campus initiative, and as currently established within the University—were formally modelled and mapped using a combination of spider charts to assess the individual characteristics of candidate CLL projects, and business process modeling (BPM) techniques for charting the CLL processes. The methodology also involved an ethnographic approach where the lead researcher (the first author) attended numerous CLL meetings in both participant and data collection roles. The contents of these meetings was encoded against a classification system derived for the purpose to identify the correlation between committee discussions and CLL processes. Further, the researcher conducted numerous interviews to uncover the history leading up to the current CLL implementation, the processes followed for its major initiatives to date, and the current state of its basic processes.

The final step in the research methodology was to analyze the "as-is" CLL program, based on both the researcher's personal assessment and on interviews with CLL participants, to produce a generalized, proposed version of a CLL program, and to present this as a program that could be implemented elsewhere.

2 POINTS OF DEPARTURE

2.1 Technology Transfer

Sustainability—an inherently multi-faceted issue—can be viewed through many lenses. This research views the sustainability challenge through the lens of technology transfer: what issues impact the adoption of emerging "greener" technologies?; what are the barriers?; how might these barriers be breached?

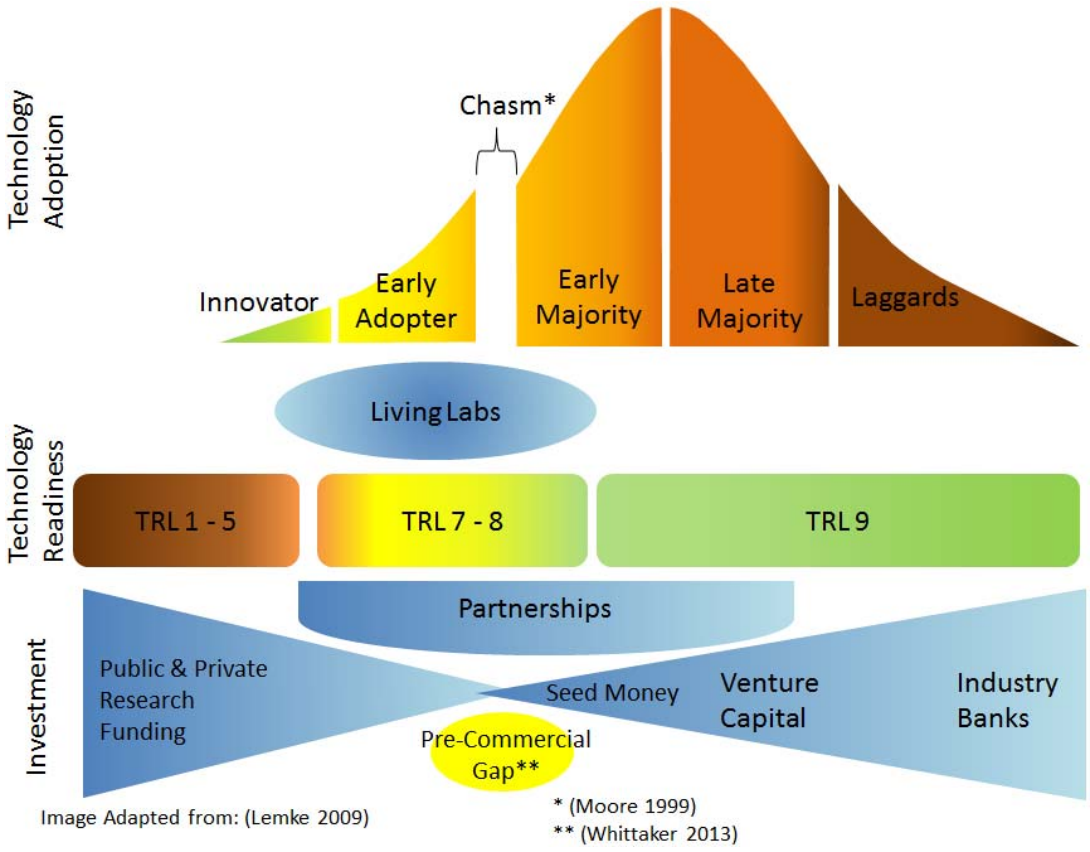

Figure 1: Intersection of Living Labs with technology adoption, technology readiness, partnerships, and investment

As one of its foundational points of departure, this research included a review of literature describing models of technology transfer. These models of technology transfer provide valuable insight into the challenges facing emerging technical solutions, and the barriers that stand between the spark of a new technical idea and the furnace of improved standard practices. A full discussion is beyond the scope of this paper, but Figure 1 illustrates how the mechanism of living laboratories can be positions relative to several of these technology transfer models.

Relative to the model of technology adoption curves [1] and Moore's chasm between early adopters and the early majority [2], living laboratories can provide a test bed to resolve minor issues associated with growing technologies to full-scale, provides data for innovations' effectiveness and efficiencies, and provide awareness within professional communities—all of which help to span the technology adoption chasm.

Relative to the technology readiness levels developed by NASA [3] and adapted for University environments by Blank [4], living laboratories provide support of level 7—system prototype demonstration at full scale in a similar environment—and level 8—system operating successfully as per specifications for one year in non-local campus/municipalities.

Relative to the changing investment regimes throughout a technology development life cycle, living laboratories help to bridge the "pre-commercial gap" between public research funding and early new venture investments [5].

Not shown in Figure 1 are models exploring various technology transfer processes [6], the roles of economic clusters [7], and value chains [8].

2.2 Knowledge Diffusion

Another major point of departure for this research is the literature describing knowledge diffusion processes. This literature identifies different categories of knowledge (e.g., tacit vs. explicit), modes of knowledge growth [9], and barriers to new knowledge growth. Of particular relevance to this research are four organizational barriers identified by Von Krogh [10]. Table 1 lists these four organizational barriers and ways that the business process models developed in this research could help to overcome these barriers.

Table 1 Potential methods of reducing organizational barriers to new knowledge creation integrated into this research

Organizational Barriers	Potential Methods of Barrier Reduction
The need for formalized language	A formalized language base is presented for talking about CLL
Organizational Precedents	A story is built with the UBC CLL as an organizational precedent
Procedures	The procedures provided are meant to be adapted to meet the needs of other organizations and should be continuously improved, this could reduce the notion that they cannot change
Company Vision	The notion that the vision should be grand and allow for

3 UBC'S CAMPUS AS A LIVING LABORATORY PROGRAM

3.1 History of the UBC CLL

The first spark of sustainability at UBC began with signing the Talloires Declaration in 1990 [11]. This declaration arose from the convening of "twenty-two university presidents and chancellors in Talloires, France, to voice their concerns about the state of the world and create a document that spelled out key actions institutions of higher education must take to create a sustainable future" [12]. In 1997 "UBC became the first university in Canada to adopt a sustainable development policy" [11]. This policy directed UBC to create Canada's first sustainability office in 1998 [13], [14]. Sustainability activities accelerated in 2006 when UBC developed a four year "Sustainability Strategy" and, a year later, became "one of six founding signatories to the University and College Presidents' Climate Statement of Action for Canada" [15]. Sustainability then became part of UBC's core mandate with several sustainability-related goals incorporated into the University's overall strategic plan, including the goal to "make UBC a living laboratory in environmental and social sustainability by

integrating research, learning, operations, and industrial and community partners“ [16].

Having established sustainability as a core value and goal through these activities, UBC began the process of developing plans and initiatives to pursue this goal, beginning with the development of a “Sustainability Academic Strategy” in 2009. This strategy lead to the creation of an organizational focus for sustainability at UBC, the University Sustainability Initiative (USI), with the objective to integrate campus-wide academic and operational sustainability efforts. The USI started with two major initiatives: the “Campus as a Living Laboratory” (CLL) program and the “Agent of Change” initiative (aimed at effective change primarily through the campus’s procurement and supply chain mechanisms) [17]. The USI also developed recommended goals to reduce the university’s green house gasses emissions to 33% below 2007 levels by 2015, 66% by 2020, and 100% by 2050, and these goals were then included in UBC’s climate action plan [18].

The USI had its first formal meeting in March, 2010 and it was able to pass a budget for the program by the following April to support the initiatives [19]. This budget also supported the CLL in starting to reduce GHG emissions. The first two projects to be completed were the Centre for Interactive Research on Sustainability (CIRS) in 2011, followed by the bio-energy research and diversification centre in 2012.

3.2 Current Status of the UBC CLL

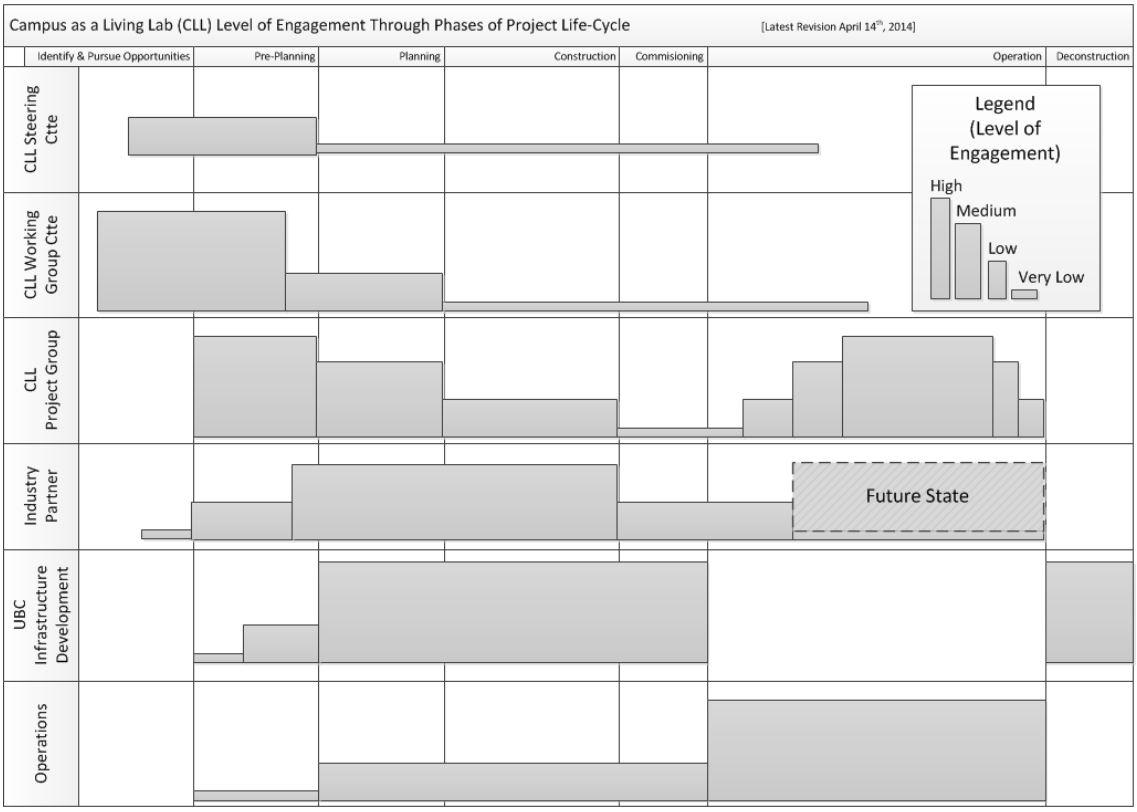

Figure 2: Campus as a Living Lab level of engagement through phases of project life cycle

From its beginnings as a loosely-defined initiative, the CLL program has grown to involve a dozens of individuals participating in several different committees. The major activity of the CLL is centered on projects—usually major building or infrastructure developments on campus. The CLL program works to identify opportunities for CLL projects, to review project proposals and select which should proceed, and to participate in the development and completion of the CLL projects. Some of the main organizational groups involved are a high-level steering committee, and working committee (the focus of the majority of CLL effort), and CLL project groups for each project that goes forward. Figure 2 provides an overview of some of the major CLL project participants and their relative level of involvement during the various life cycle phases of a typical CLL project. The CLL business processes followed, initially quite ad-hoc in reaction to the demands of the early CLL projects, have started to be formalized and clarified. As part of this research, extensive effort went into to identifying, formalizing, and documenting the CLL processes. It is beyond the scope of this paper to present the resulting business process models here (see [20]).

3.3 Representative Projects of the UBC CLL

As part of this research, several existing CLL projects were studied in detail, and the CLL-related business processes that were followed were identified and mapped. These projects are summarized as follows:

- The Centre for Interactive Research on Sustainability (CIRS): The CIRS is a $36.9 million project to create a building that is, itself, a "living laboratory" to test the ability to meet aggressive, net positive goals (that is, the building creates net benefits to its surroundings in these areas rather than net detriments) in the areas of energy, embodied carbon emissions, operational carbon emissions, and water quality [21]. Some of the technologies incorporated into the building to achieve these goals include heat capture from a neighboring building, a geo-exchange system, a reclaimed water system for sewage, a rainwater harvesting system for potable water and fire suppression, a green roof and living wall, natural ventilation, solar hot water and photovoltaic cells.

- The Academic District Energy System emerged from a larger initiative to review alternative energy sources at UBC. In addition to an initial feasibility study, a local "Energy X Contest" was also created for people at UBC to pitch their ideas for additional options for UBC to pursue. Key drivers for the project included ageing infrastructure, sky rocketing natural gas prices, newly implemented carbon taxes, public sector offset requirements and the campus looking for ways to reduce the carbon footprint. The result was an $88 million project to convert the campus district heating system from steam to hot water [22], [23], [24]. The project entails the conversion of 131 buildings from steam to hot water, 14 kilometers of hot water distribution piping and a new 60 MW hot water Thermal Energy Centre. This will result in "$5.5 million in annual savings including the cost investment for not reinvesting the aging steam system", and a reduction of GHG emissions by 22 percent [25] [23].

- The Bioenergy Research and Demonstration Facility is a $27 million investment in using a renewable resource for fuel and reducing the demand for imported power on campus [26]. In its full operating mode, the facility was designed to produce heat in the form of steam at the rate of 20,000 pounds per hour. This would reduce

UBC's base requirement on natural gas heating, and reduce UBC's GHGs by 9,000 tonnes per year [27].

4 ANALYSIS OF THE UBC CLL

4.1 Business Process Modelling

As part of this research, the business processes used within the UBC CLL program were studied and formally represented using business process modeling techniques—in particular, flow charts and data flow diagrams. These business process models provide clear, detailed representations of the sequence of tasks associated with the CLL activities of identifying new project opportunities, evaluating project proposals, obtaining the institutional commitments for selected CLL projects, and the oversight of these projects as they move through their life cycle phases. They identify the task sequencing, the parties involved in each task, and some of the key documents or artifacts associated with the tasks. However, the models consume more space than is available in this paper.

A few CLL processes had been formally modeling prior to this research by other CLL participants (e.g., the process for receiving and reviewing unsolicited requests for capital projects greater than $2.5 million). Other CLL business processes were less clearly defined, and this research involved the identification and clarification of these processes through document review and interviews with the CLL participants, resulting in a family of "As-Is" CLL business process models. In addition, the CLL-related processes followed for each of the three representative CLL projects described above were to determined and modelled. Since each of these projects was initiated at different points in time during the formation of the CLL program, each followed somewhat different processes to get established and carried out. The existing project business process models were compared with the current As-Is business process models to develop an understanding of the emergence of the CLL practices over time.

In addition to the business process models developed prior to and during this research, two important documents that have emerged from the CLL process to aid in the evaluation of project proposals are standardized format for summarizing new project proposals (in the form of a 12 slide powerpoint document), and an assessment of each project proposals against a standardized set of decision criteria (represented in the form of a spider chart, as illustrated in Figure 3)

As a result of the business process models created in this research, the CLL business processes could be more easily understood and discussed by both researchers and participants. Through a processes of evaluation by the researcher and discussions about these processes with CLL participants, the research developed recommendations for improvements to the CLL processes and identified the key characteristics of these processes that are believed to be important and transferable to other CLL initiatives that may be attempted elsewhere. These transferable characteristics were embodies in the proposed generic CLL processes described in Section 5 of this paper.

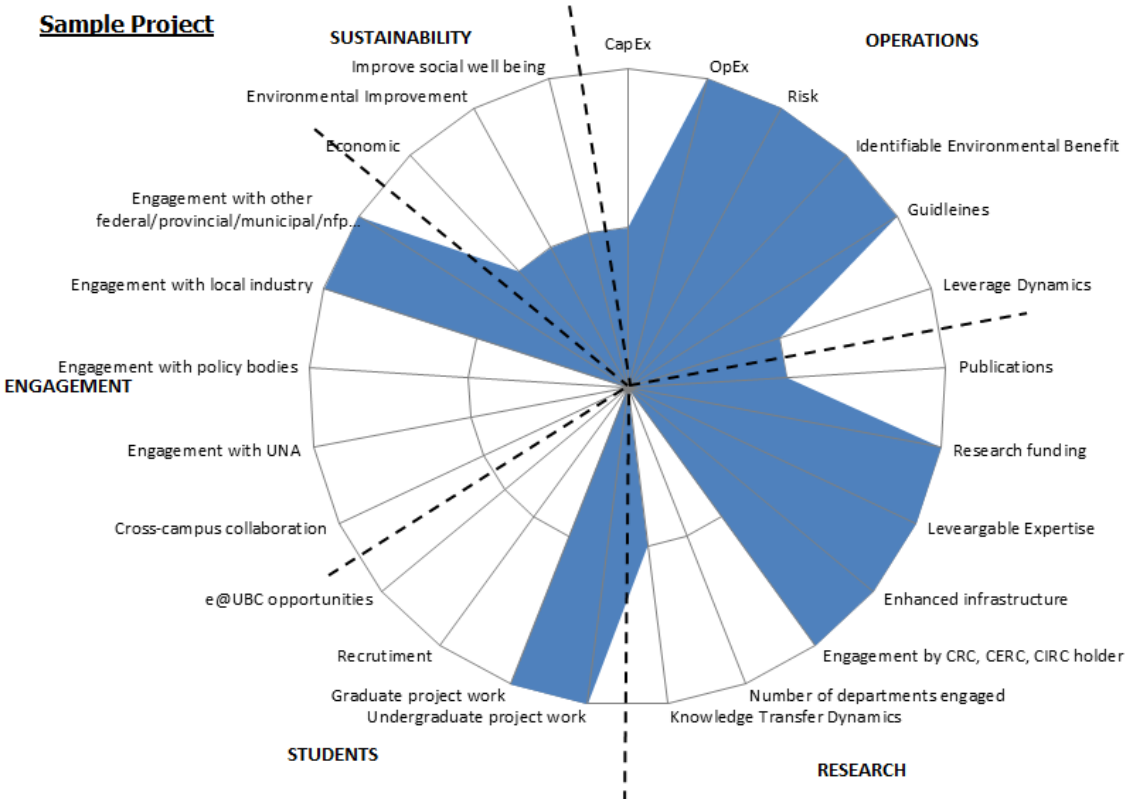

Figure 3: Visualization from spider chart analysis identifying potential project strengths and weaknesses

4.2 Ethnographic Research

In addition to the task of identifying, formalizing, and mapping the CLL business processes, this research undertook a task of assessing the relative importance of CLL processes by studying the degree to which CLL meeting time was spent dealing with various business issues and processes. To pursue this, the lead researcher (the first author of this paper) reviewed all available documents regarding the CLL program, interviewed most of its major participants, and gained access to some of the CLL committee meetings as an observer. Over time, the researcher made presentations to the CLL committee and increasingly took on an "observer-as-participant" role. In total, the research reviewed the minutes and associated documentation for 98 weekly CLL Working Group and 20 monthly Steering Committee meetings prior to attending the meetings as an observer, and then participated in 36 CLL Working Group and four Steering Committee meetings over a period of 16 months from December 6th, 2012 through March 27th 2014. Based on the meeting minutes and the researchers' field notes, the items discussed in the meetings were coded to classify the topics and business processes that were consuming the CLL participants discussion time.

The objective of the task of coding the meeting content was to classify the meeting items with respect to various business processes. It was therefore necessary to identify a coding system to that identified a range of possible business processes that could be the subject of the meeting discussions. Initially, two international standards that define a range of business processes were adopted to provide a framework

against which the meeting contents could be coded. These standards were version 6.0.0 of the Cross Industry Process Classification Framework from the American Productivity and Quality Centre [28] and the fourth edition of the Project Management Body of Knowledge from the Project Management Institute [29]. Based on an initial test of using this framework for coding meeting contents, this framework was further refined by excluding processes that were found to be irrelevant to the CLL discussions, and adding some processes that were not adequately defined in the APQC/PMI standards.

Each item discussed in the observed meetings was then coded against this final framework. An example is shown in **Figure 4**, which shows a sample of the business processes defined in the coding framework in the matrix rows, and three columns representing three CLL meetings. The number of instances of a particular type of business process discussed in each meeting is then represented as a number in the matrix cells, with the total number of instances summed in the right-hand column.

	N162-14	N162-15	N162-16	TOTALS
Develop Vision, Strategy and Assessment Tools (1.0)				**148**
Develop, evaluate, establish, and re-evaluate vision and mission				**5**
Develop, evaluate, establish, and re-evaluate high level goals				**13**
Develop, evaluate, establish, and re-evaluate objectives				**14**
Develop, evaluate, establish and re-evaluate organizational structure, reporting, and governance				**21**
Develop, evaluate, establish and re-evaluate methods and tools for assessing projects				**41**
Learn from others and develop ideas for improvement				**54**
Develop and Manage Business Capabilities (2.0)				**61**
Develop, evaluate, establish, and re-evaluate human resource management, planning, policies, and strategies				**7**
Manage departments financial resources				**1**
Develop, evaluate, establish, publish, and re-evaluate process management				**10**
Develop, evaluate, establish, and re-evaluate knowledge management practices				**8**
Develop, evaluate, establish and re-evaluate metrics for post-implementation of projects				**4**
Plan meetings				**31**
Develop Opportunities (3.0)				**257**
Develop, and evaluate opportunities			1	**63**
Evaluate risk, determine and implement risk mitigation strategies	1	1		**32**
Evaluate opportunity allignment with vision, mission, goals, and objectives				**28**
Identify requirements, objectives and resources for opportunities	1	1	1	**54**
Develop, and evaluate, and present business case(s)				**18**
Develop requests for information/proposals; negotiate, establish, and manage contracts				**26**
Develop, evaluate, and obtain funding				**36**
Assess the Environment (4.0)				**161**
Assess internal needs, capabilities, and opportunities				**89**
Evaluate the internal economic, environmental, and social landscape				**26**
Assess external needs, capabilities, and opportunities				**29**
Evaluate the external economic, environmental, and social landscape				**17**

Figure 4: Example of plotting data Points across Campus as a Living Lab Process Framework

Figure 5 shows a high-level summary of quantity of attention given for each major category of business process. Further analysis (not shown here) decomposed this summary into finer detail within each process category, and also assessed how the relative focus changed over time as the CLL program was initiated and became increasingly established.

The results of this analysis allowed the researcher to identify a series of business processes that were demonstrably important for the CLL program, some degree of their relative importance, and the general sequencing of how these processes develop during the creation of a CLL program. As with the business process modeling analysis,

this resulted in a set of key characteristics that could be transferred to other institutions in the form of proposed generic CLL processes, as described in Section 5.

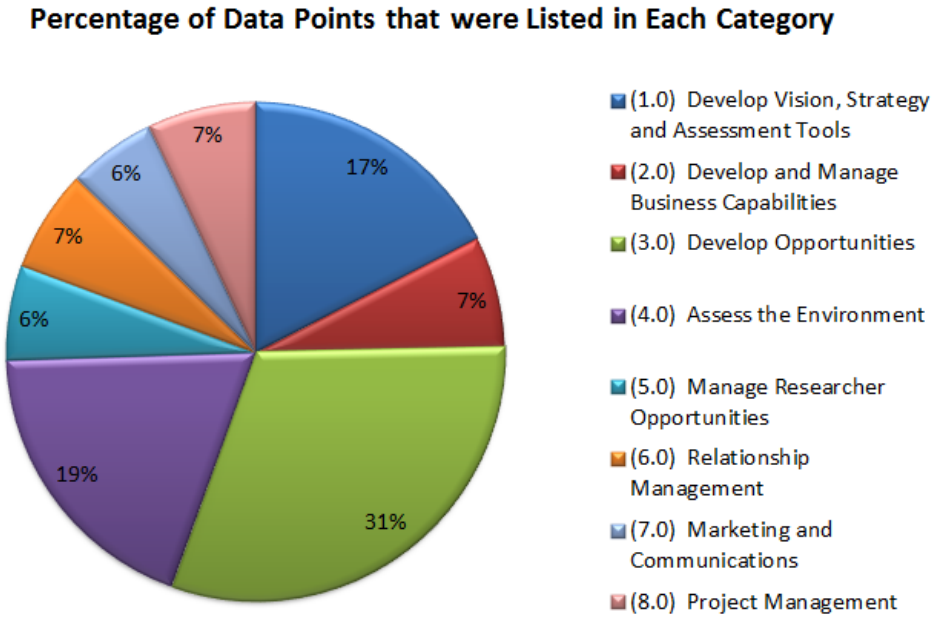

Figure 5: Percentage of data points that were listed in each category

5 PROPOSED GENERIC LIVING LAB PROCESSES

As described, the analysis of the UBC CLL conducted in this research resulted in key elements, characteristics, and principles for generalized CLL process.

5.1 Key Transferable Characteristics from the Business Process Modeling Analysis

A summary of the key transferable elements and characteristics identified from the business process modelling analysis is as follows:

1. An organizational structure for the USI and the CLL,
2. A diverse multi-stakeholder committee membership structure,
3. A process of categorizing projects based on size (high-level view),
4. A process of project evaluation (due diligence) and approval (mid-level view),
5. Tools for project evaluation: slide deck and spider chart,
6. A process for selection of a research champion,
7. A process for selecting strategic partners,
8. Design goals and charrettes for high performance buildings,
9. An approach of linking funding to sustainable technologies so that they are not value engineered out the equation,
10. Contests to solicit ideas for alternative energy or otherwise,
11. The linking of feasibility studies to contests for the wider community to contribute ideas.

5.2 Key Transferable Characteristics from the Ethnographic Analysis

The summary of key transferable elements and characteristics obtained by ethnographic study is provided as follows:

- Develop strategic documents:
  - Continually optimise strategic documents
  - Terms of reference
  - Project selection principals
  - Metrics for success
  - Processes to follow
    - Continual optimization of CLL processes
    - Integration of new technical guidelines for campus
- Administration:
  - Implement a governance model to capture all groups who may potentially work on CLL projects
  - Ensure adequate human resources are available
  - Develop a database of researchers ready to work on projects, and projects ready for researchers
  - Ensure the committee has technologically savvy members
  - Create a strategic marketing and communications plan
  - Establish a CLL identity
  - Have a marketing and communications budget
  - Identify research potential research champions early
  - Create relationships with other groups within the campus who are interested in CLL projects
- Knowledge transfer:
  - Share general challenges
  - Share successes and failures
  - Cultivate relationships with other institutions to share information about new technologies
- Being strategic:
  - Review proposals side-by-side to reduce stretching of resources and select most viable options
  - Have an inter-disciplinary business case review team on hand
  - Develop list of technology items ready to be integrated
  - Develop a presentation schedule for committee learning
  - Forecast potentially major campus issues and work on a plan early
- Integration with campus:
  - Link construction and operating cost into building budget
  - Incentivise deans to improve operational efficiency of buildings
  - Monitor energy usage of buildings and ensure equipment installed to monitor energy usage is installed and connected

5.3 Overview of Proposed Generic Living Lab Processes

The final element of this research is that some of the UBC CLL documents and business processes were generalized, adapted based on the key transferrable characteristics summarized previously, and assembled into a proposal for a set of generalized CLL processes that might be implemented by other institutions interested

in pursuing a CLL initiative. The items that make up this proposal are either documents (represented by a “D”) or processes (represented by a “P”). An outline of these elements is provided here and illustrated in **Figure 6**:

- Documents
    - Model Overview (D-1)
    - Organizational Chart (D-2)
    - Terms of Reference (D-3)
    - Slide Deck for Preliminary Project Evaluation (D-4)
    - Spider Chart for In-depth Project Evaluation (D-5)
- CLL Processes
    - CLL Committee Evolution (P-1.0)
        - CLL Committee Development Phase (P-1.2)
            - Infrastructure Analysis (P-1.2.1)
                - Infrastructure Analysis Contest (P-1.2.1.1)
            - CLL Project Selection and Development (P-1.2.2)
                - Unsolicited Request Evaluation (P-1.2.2.1)
                    - Initial Review (P-1.2.2.1.1)
                    - Request < $2.5M (P-1.2.2.1.2)
                    - Request > $2.5M (P-1.2.2.1.3)
                - Solicited Request (P-1.2.2.2)
            - CLL Improvement (P-1.2.3)
                - Continuous Improvement of Buildings (P-1.2.3.1)
- High Performance Buildings
    - High Performance Buildings (P-2)
        - Continuous Improvement of Buildings (P-1.2.3.1)

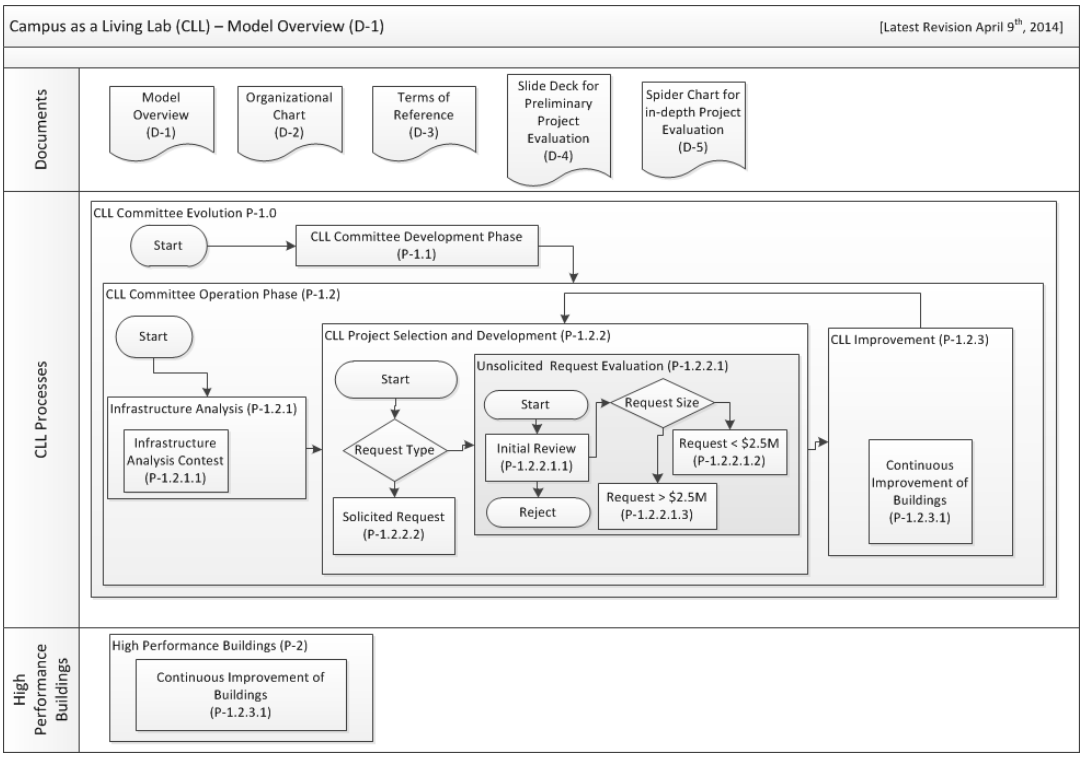

Figure 6: Campus as a Living Lab - model overview

6 CONCLUSIONS

The goal of this research was to develop a roadmap to assist with implementing a CLL concept. It was meant provide insight into the practices at UBC and to assist in shortening the learning curve that is involved with developing a CLL. In order to apply these to a new organization, the generalized processes provided would need to be adapted to conform to various organizational structures and to the human and financial resources available. It is a long process to develop a CLL, as can be noted by the many changes that the lead author witnessed during a 16 month long ethnographic study, but the process can be worthwhile as it provides another avenue for collaboration within a university and can assist with reducing the ever-present silos in institutions

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