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The Multi-Faceted Practice of Architectural Sustainability Found in the Regional Architecture of Vorarlberg, Austria

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Abstract: The biggest and increasingly more urgent challenge of the twenty-first century has become how a more sustainable level of development can be achieved. In order to bring about a better sustainable approach to 'development' it is necessary to address various different challenges of economy and society simultaneously. By examining the various aspects of sustainability found in the contemporary regional architecture of Vorarlberg, Austria, this paper attempts to highlight a more holistic and multi-faceted practice of architectural sustainability. The literature review on the definition of sustainable architecture and the architectural culture of Vorarlberg will be followed by the characteristic examination of four case studies. The common characteristics found from the evaluation were matched with some of the UN's 17 Sustainable Goals to illustrate the multi-layered and connected nature of the sustainability qualities. The results of the research is indicative of a more holistic notion of architectural sustainability that is beyond energy-oriented and the functional efficiency of a building. Rather, it would mean the sustainability of a region, as a whole, when it encompasses the continuation of heritage, the way of living as well as how a building should be responding to the environment throughout its life-cycle.

Keywords: sustainability; Vorarlberg architecture; architectural tradition

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1. Introduction

During the past few decades, the achievement of sustainability in many different fields has become a global goal, especially when the negative impact of climate changes are experienced all around the world. In order to better achieve a more sustainable level of development, new approaches are urgently needed to ensure that the development is much better aligned with the environmental, societal and economic challenges we are facing [1]. In the field of architecture, sustainable buildings are assumed to merely represent differently configured technical structures [2], with particular pathways of technological innovation viewed as objectively preferable to others, which tends to ignore the essentially social questions implicated in the practice of sustainable architecture [3]. So, most commonly, sustainable architecture is regarded as a conscious approach to energy and ecological conservation in the design of the built environment [4]. However, there had been a shift in the way sustainability was approached [5]. By examining the regional architectural culture of Vorarlberg and evaluating some of the contemporary architectural projects of the region, the main aim of this research is, therefore, to illustrate a diverse and broader notion of architectural sustainability.

The process of this study is outlined in the following parts. First, as the background to the research, the general concept of 'sustainability' in architecture will be outlined, as well as the concepts of social and economic sustainability, followed by the different aspects of Vorarlberg's regional architecture, covering the background of the use of timber, the timber industry, and traditional building types. The main body of research will contain the characteristic evaluation of the four architectural projects selected, in order to illustrate the multi-faceted practice of sustainability that can contribute towards the sustainability

of a region's cultural identity that also contribute towards the economical sustainability of the local area. The findings from the evaluation of the case projects will be compared to, and matched with, specific goals of UN's 17 Sustainability Development Goals to illustrate more specifically how the architectural culture of Vorarlberg works towards a 'sustainable development'.

The main research questions, therefore, for the current study are as shown below.

Q1. *How does regional architecture of Vorarlberg represent the multi-faceted practice of architectural sustainability?*

Q2. *How do the qualities found in the regional architecture of Vorarlberg meet some of the criterions of UN's Sustainable Development Goals?*

2. Concepts of Sustainability

The most widely understood definition of sustainability was founded in the 1987 'Brundtland Report' where a notion of 'development' is set within the environmental 'limits' [6]. Since then, the concept of sustainability has been developed into a more refined and applicable field and method that states that sustainability is a condition that is supported by the three pillars of environment, society and economy [7]. In order to illustrate the importance of the inter-connection of the three, the concepts of sustainability in architecture (as environment), society and economy will be outlined below.

2.1. Sustainable Architecture

When 'sustainable architecture' is described and understood, the common idea is that for an individual building to be sustainable it has to represent a healthy built environment, based on ecological principles and resource efficiency [8]. However, it is critical to make the distinction between green buildings and sustainable buildings. It is possible to agree that green buildings are environmentally friendly, which means they are designed to make minimum environmental impact. Furthermore, a green building is mainly ecologically oriented [9] with the added performance of minimum impact on the environment [10]. However, sustainable buildings play a further significant role in increasing social equity, cultural and heritage issues, traditions, human health, social infrastructure as well as safe and healthy environments [11]. Reflecting this confusion, for some time the sustainability assessment systems showed many limitations [12], including that the evaluation was limited to the physical boundaries of the building, and was mainly (or only) interpreted from the environmental perspective [13]. It is also true that the definition of sustainability has been dominantly 'quantitative' historically, relying on different technologies to measure and dataries the 'efficiency' of architecture as an object.

With the realization of the various limitations of assessment of sustainable building and conveying the definition of 'sustainable architecture', the 2002 World Summit on Sustainable Development in Johannesburg provided a shift in the perception of sustainable development towards a more comprehensive consideration of the social and economic dimensions of development [14]. From around 2013, it was possible to note the paradigm shift of 'sustainable architecture' from a more 'technical' aspect of a building to a broader cultural framework of the human interrelationship with nature [15]. It is also found that 'sustainability' and 'architecture' must be integrated and both positioned as a 'social practice' [16].

2.1.1. Social Sustainability

For the definition of social sustainability too, the involvement of the discipline of sociology has been invisible in professional circles as the public and policy discussions have mainly focused on climate change and sustainability [17,18]. According to the United Nation's Global Compact, social sustainability is defined as follows: social sustainability is about identifying and managing business impacts, both positive and negative, on people [19]. At the same time social sustainability also addresses human rights, women's

empowerment, gender equality and labor opportunities, among other key social issues. The social sustainability can also include issues such as education and health. More importantly, it is outlined that the businesses can take the following actions to achieve the sustainability goal: (a) businesses should contribute to improve lives and services, (b) make strategic social investments and promote public policies that support social sustainability, and (c) form a partnership with other businesses, pulling power to create a greater positive impact.

2.1.2. Economic Sustainability

Economic sustainability can be defined as a broad set of decision-making principles and business practices aimed at achieving economic growth without engaging in the harmful environmental trade-offs that historically accompany growth [20]. It can also be understood as a practice of conserving natural and financial resources to create long-term financial stability [21]. The regional and global economic sustainability is important and essential for many reasons, such as the preservation of human life.

2.2. Architecture Culture of Vorarlberg

2.2.1. Use of Timber

Timber, as a building material, is accepted and valued for its natural characteristics. Because it is a material which is readily available in many parts of the world, it is recognized as a universal building material [22]. Due to its natural characteristics, it is known to have positive psychological responses as well as a material that is closely tied to the place which arouses the awareness and critical assessment of the immediate environment [23]. Wood is widely regarded as a 'warm' natural material, due to its visual appearance as well as its tactile qualities. Furthermore, its excellent insulating properties, due to the fibrous composition which provide both heat-storage capacity and insulation value [24], makes timber the obvious choice of building material for a cold alpine region such as Vorarlberg.

Vorarlberg is located on the northwestern slopes of the Austrian Alps. It is the second smallest province surrounded by forests where timber has been the main locally sourced material for the construction of homes and other public buildings for centuries. One third of the region is still covered with forest [25] and the numerous creeks and rivers were perfect for setting water-powered mills [26]. Timber-framed houses, or any timber structures that are properly detailed, are extremely durable and can last an exceptionally long time; some buildings built in the 17th century are still being used in Vorarlberg.

2.2.2. Local Timber Industry and Craftsmanship

With the existence of the timber industry in Vorarlberg, it was the carpentry trade and the craft culture that formed the unique architectural culture of the region. As early as in the 17th century, there were guilds that regulated and authorized the profession. It also controlled the pricing of the work and how different members of the carpentry trade work together, preventing fraudulent activities and also over pricing and excessive competition [27] (p. 60). Only the carpenters and bricklayers were accepted in the guild, initially, but later other professions from the building industry, such as stonemasons, wood sculptors, plasterers and painters were also accepted. This guild is called 'Werkraum Bregenzwerwald' (Bregenz Forest Workshop) which connects different professionals as well as training the next generation of craftsman. The role of the guild is very significant as it ensures the sustainability and continuation of traditional skills by training the future qualified workforce.

With the revival of timber construction in the region from the 1960s, the high quality and tradition of local craftsmanship were recognized by a group of young architects such as Hans Purin and Rudolf Wagner, and gradually by the general public. Since then, the mutual respect and acknowledgement between the architect and craftsmen has contributed greatly towards the architecture culture of the area. Both professions have different expertise but with the common goal of preserving and advancing traditional skills.

2.2.3. Traditional Building Types

The word 'tradition' has the original Latin meaning which is 'delivery, surrender, handing down'. This can be understood in the contemporary context as the 'handing down of statement, beliefs, legends, customs and information, from generation to generation, especially by word of mouth or by practice'. Another definition of tradition refers to belief, principle or way of acting which people in a particular society or group have continued to follow for a long time [28].

In this regard, it is possible to recognize the four distinctive traditional farmhouse types which were developed in Vorarlberg region: "Bregenzerwalderhaus" (Bregenz Forest House: house type from Bregenz Forest region); "Walserhaus" (Walser House: house type from Walser region); "Rheintalhaus" (Rhein Valley House: house type from Dornbirn and the Vorarlberg Rhine Valley); and the "Montafonerhaus" (Montafon House: house type from Montafon valley in Vorarlberg). The typical form that is found is the pitched roof, which came about to provide more attic space as well as for shedding snow in the winter (Figure 1). The bands of windows, while the size may vary from one house to another, allowed plenty of daylight into the interior as there were many textile industries. The masonry plinth on the ground level was also a way of protecting the wood structure from the ground moisture as well as for containing the weaving chamber [29]. The most well-known building type, Bregenzerwaldhaus, is known for 'less' decorative detailing such as carvings or murals, and for the shingle cladding which protected the wooden structural timber from weathering [27] (p. 97). The other interesting architectural feature found in Bregenzerwaldhaus is a porch area on the ground level called 'Schopf'. This was an area that accommodated the extension of living area during the summer months [27] (pp. 303–310). The wooden shutters could be unfolded to make this a usable space for other times or weathers, of the year.

Figure 1. Traditional building types: Bregenzerwaldhaus; Walserhaus; Reintalhaus; Montafonerhaus. These houses appear quite similar, however, Bregenzerwaldhaus type has the large windows, while Walserhaus has the smallest openings. The Reintalhaus has the steeper pitch of all four types. (Copyright Bohringer Friedrich, Creative Commons (https://en.wikipedia.org/wiki/Creative_Commons, accessed on 1 November 2022), Attribution-Share Alike 3.0 Austria (https://creativecommons.org/licenses/by-sa/3.0/at/deed.en, accessed on 1 November 2022)).

3. Contemporary Building Culture and Regional Architecture of Vorarlberg

3.1. Contemporary Building Culture

While reviewing the contemporary buildings of Vorarlberg, it can be observed from the design that the local vernacular architectural tradition and craft has had a strong influence. From the exterior, the form of the structure is as simple as the traditional buildings, some even appearing similar to a farm building of the past (the house by the Fens by Barnardo Bader, for example). From the interior, there is a 'down to earth' simplicity where the layout of the floor plan is simple and straight forward. As a result, the regional architectural tradition is continued and re-interpreted and passed down to the next generations. This is a development that has settled as a resilient and socially constructive cultural phenomenon of the region [30], which has been developing in the last forty years and was coined as "Holz Baukunst" ("Art of Building").

Prior to this architectural cultural development, the readily available renewable material, timber that can be sourced locally, existed in the extensive forests that surround

Vorarlberg. There are many advantages of this material. Firstly, the material can be easily assembled on site without the use of heavy machinery. It is also possible to pre-fabricate timber modules that can be brought to the site which will further reduce the construction time. The use of timber, together with a hybrid use of concrete structural element, creates a pleasant interior environment as well as achieving a good energy balance. This unique combination of traditional and universal building materials and construction methods became the direction for the future of architecture and construction in the region [31].

Furthermore, there is a strict Passive House Regulations in Vorarlberg, where architects are continuously challenged to come up with better design solutions that comply to the tight regulations, which also means that the technologies involved will have to be more innovative in order to accommodate the different needs and performance, while keeping in line with the traditional aspects of materials or the appearance of the building. The level at which architectural cultural sustainability has been achieved during the last thirty years in Vorarlberg was made possible only by the strong collaborative culture between the craftsman, architect, client, industries and authorities with a common goal of building a 'good' building.

3.2. Case Projects

The following four projects in Vorarlberg have been chosen to illustrate the notion of 'sustainability' from different perspectives. These projects were built and completed in a range of a decade, 2003~2012. They are of different sizes and functions and designed by different architects. These projects have been selected from a very wide spectrum of projects, in terms of size and function, in order to illustrate that the unique architectural culture in Vorarlberg is apparent in so many of the buildings in the region, not limited to a particular type of buildings by particular architects. The case projects will be examined under the following topics, not only to address each of the topics' role towards achieving sustainability, but also to be able to compare between them.

1. Layout of the spatial programs on plan and the envelope of the facade: to relate to the distinct similarities of the planning (i.e., the usage of the space) and the exterior appearance with the traditional vernacular farm buildings, regardless of the actual function.
2. Construction method: to illustrate the use and the involvement of the local industry (timber forestry as well as constructions industry) as well as the continuation of regional heritage in terms of construction method.
3. Energy strategy: to illustrate the energy performance in terms of its efficiency and how the building continues to make a minimum impact on the environment.

3.2.1. Secondary School Klaus-Weiler-Fraxern (2003)

This project has a significance as the very first building in Austria to comply with Vorarlberg's strict Passive House Energy Standards. Designed by Dietrich Untertrifaller, this L-shaped building in the structural timber system was built in pre-fabricated box elements and was erected within eight months. Despite the tight schedule and the budget, the architect Dietrich Untertrifaller demonstrated through this project that it is possible to meet the high architectural standards with sustainable and ecological construction.

1. Layout of the spatial programs, on plan and the envelope of the facade:

First of all, the building is set back from the main street and the interior is organized in such way that the main school spaces are shielded from the noise from the street. The layout of different programs in the main school block is simple strips along the north-south axis (Figure 2). The classrooms are lined up along the two long elevations, and in between are the strips of services and circulation corridors. This simple, linear arrangement of programs is similar to that of the region's farm buildings. There is an atrium in north-south axis which is aligned with the main corridors (Figure 3). This open space allows all levels to be inter-connected and transforms the long corridors into a lively communicative spaces.

The skylight allows natural light to penetrate all the way down to the ground level. The two sides of the building, dissected by the atrium, are laterally connected by foot bridges which create rhythmical visual and physical connections.

Figure 2. 2nd Floor Plan, Secondary School Klaus-Weiler-Fraxern (Main School block) (Copyright Dietrich | Untertrifaller).

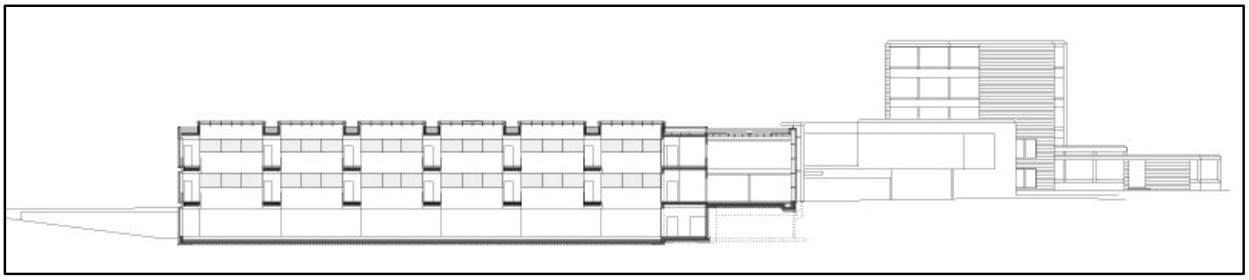

Figure 3. Section through the foot bridges; showing the locations of the skylights (Copyright Dietrich | Untertrifaller).

2. Construction Method

Despite the tight schedule in designing a compact volume, the architect was able to develop a sustainable building strategy and avoid building a conventional structure. The locally grown and harvested fir was used to pre-fabricate the light-weight timber box elements which was the key to reducing construction time and cost [32].

There is a unique treatment on the south facade, in corrugated and perforated copper which reduces the excessive solar gain but maintains the visibility of the outside during the day (Figure 4, right). Another element of interior environment control is the automated external blinds on the outer plane of the glazing of west and east facing classrooms. There is a horizontal strip of operable windows at the eyelevel of the students. These are actually set well back from the main facade line, constructed under a light-shelf, which retains the view of the outside even when the blind is down (Figure 4, left). All interior spaces are finished in birch wood panels that create a warm atmosphere. An extra added vibrancy through the use of bright red epoxy resin completes the interior.

Figure 4. Main facades; North-west (**left**), South (**right**) (Copyright Dietrich | Untertrifaller).

3. Energy Strategy

The energy strategy of this project starts from the design of the compact volume that is well-insulated with an airtight envelope, the installation of passive heating and ventilation, all of which is enhanced by the selection of environmentally friendly materials. The design process is then further supported and celebrated by the close collaborative work between all the parties involved: the architects, local authorities, construction firms and consulting engineers. As a result, it was anticipated through the simulation that the building's energy demand will be less than 15 kWh/m^{2}a. During the first two years, the building's performance was closely monitored and the actual performance was far better than anticipated, and the entire complex requires the heating energy of 11 kWh/m^{2}a.

There is extensive use of 'energy-saving' components that contribute towards reducing the building's energy consumption by approximately 75%. All the windows are triple-glazing and there is a ground heat exchanger that maintains the interior temperature at 18 °C throughout the year. The heat exchanger also recovers 85% heat in the exhaust air. It might be assumed that the construction cost would be much higher for a project such as this one; however, this project was only 3% more costly than a conventional project of similar size. This was a successful demonstration of the continuous commitment of the three local authorities, Klaus, Weiler and Fraxern, to conserving the environment in a sustainable way.

3.2.2. Community Centre Raggal (2006)

This is a winning entry design that proposed a single-storey structure which unites all the municipal services under one roof. This is a community center for a small community with a population of 900 inhabitants, designed by Johannes Kaufmann. A competition was held to seek a design that will unite all the municipal services under one roof. The winning entry proposed a single-storey structure that fronts the main village square. The building then rises up, making the use of the existing topography, to three-level volume on the north side of the building. As it is located on the mountain slope of the Great Walser Valley, the building makes the most of the views of surrounding nature, as well as maintaining the relationship with the existing surrounding buildings.

1. Layout of the spatial programs, on plan and the envelope of the facade:

The building is located on a sloping site, with the main facade facing due south-east. Similar to the local traditional farm buildings, the program layout in the interior is organized in a simple linear manner (Figure 5). Spaces that are occupied during the day are on the south-east side of the building, utilizing the daylight as the source of heat energy. Other programs such as storage (archives), meeting room, canteen and other services are positioned on the opposite end which also acts as a buffer zone from the north-west as well as the excavated ground of the slope.

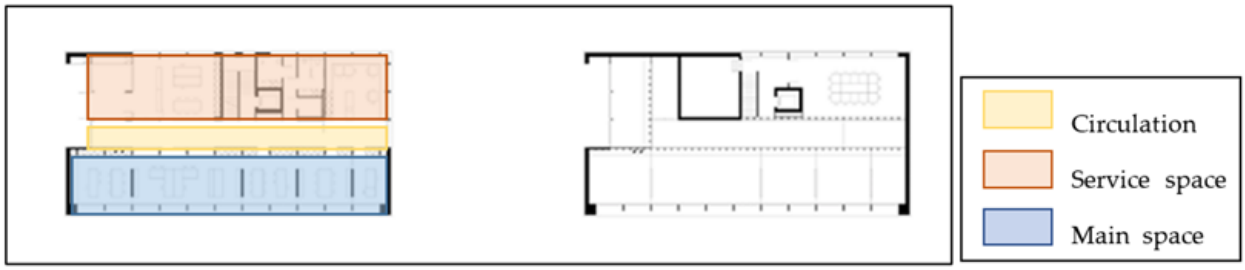

Figure 5. Ground and Upper Floor plans of Community Centre Raggal (Copyright Johannes Kaufmann).

2. Construction Method

It was the request of the clients to use locally grown and harvested fir and spruce from the forests which the community owns, within the UNESCO Biosphere Reserve of "Great Walser Valley". As a new public building for the small community, it was very important not only to use the locally grown material but also to employ local industries and people to retain and enhance the value of the region (Figure 6).

Figure 6. Exterior view of Community Centre at Raggal, seen from Northwest (**left**), and at entry level (**right**) (Copyright Johannes Kaufmann).

The building is located on a slope, which made it necessary to employ a structural system that consists of a reinforced concrete basement level, with pre-fabricated timber panels on top. An extensive use of engineered timber for the entire exterior and interior is observed to work with the different grid modules varying from 600 mm on the ground floor to 2400 mm on the first floor. The exposed roof rafters on a 600 mm module is based on the local regulations for the region's high snow fall. For the structure, spruce was used with silver fir cladding of the exterior. Silver fir boards are used to cover all the walls and ceilings of the interior, except for the bathrooms. All the components and furniture of the building are carefully custom made and pre-fabricated at the local carpenters. From the origin of the material to the building process, and the participation of the local community, the building has an extraordinary 'sense of belonging' to the region, thus maintaining and adding further value of the local tradition.

3. Energy Strategy

This small community center is compact in volume with a total usable floor area of 731 m^2 that consists of airtight envelope assembly and timber wall panels with 320 mm insulation, with triple glazing. It has been designed to maintain a good surface-area-to volume ratio which contributes towards lowering the heating energy demand at 23 kWh/m^2a that is well below the limit set for the Low-Energy House standard at 50 kWh/m^2a. Furthermore, within the building there is a mechanical ventilation system which also operates as a heat recovery from exhaust air. Even as a low energy building, there are large north-facing

windows that encompass the surrounding landscape as the main view from the interior. Wood chips from local saw mills run the biomass-powered heating plant which is in the basement, and generates enough energy for the community center as well as seven other buildings in the village. All in all, without going out of its way or beyond the budget that was available, the community center has adhered to many of the regulations outlined by the Austrian Passive House Energy Standards [33].

3.2.3. Community Centre St. Gerold (2009)

From 2000, the Walser Valley has been designated as a UNESCO Biosphere Reserve, which means that any building built within this area is of high interest in terms of sustainability and ecological considerations [34]. This is a small community center, located at the steep south facing slope. Designed by Cukrowicz Nachbaur Architecten, the community center is a compact structure surrounded by nature as well as historical buildings of the local area.

1. Layout of the spatial programs, on plan, and the envelope of the facade

The building sits within the sloping site, consisting two levels that are embedded on the north side. By opting to embed the structure there was a minimum amount of excavation or flattening of the land for a new building. It is also apparent that the orientation of the building makes maximum use of the sunlight, making the use of solar gain from the south. The spatial layout of the interior program is simple, similar to one of the old farm buildings where circulation (stairs) is located on the north side, service area in the middle, and the main useable space on the south side of the layout (Figure 7).

Figure 7. Four floor plans of St. Gerold (Copyright CUKROWICZ NACHBAUR ARCHITEKTEN).

2. Construction Method

This is the very first four-storey timber building built in Vorarlberg. Due to the sloping site, there is a retaining wall within the structure built with reinforced concrete. Other than this retaining wall, the entire structure is built of solid lumber which was harvested from the local forest and also sawn locally. It was mutually agreed upon by the community to avoid using materials that might contain toxic substances. Therefore, all the materials that were selected for use were tested for the following: embodied energy levels, acidification and any potential for global warming. Furthermore, the materials were examined for chlorofluorocarbons, fluorocarbons, PVC and hardwood from unsustainable sources in the tropics, so that the design guidelines were met. These rigorous examinations were conducted in order to minimize the CO^2 impact on the environment from the use of these materials. For the insulation of the entire building, instead of mineral wool products, sheep wool was used which is less hazardous during the handling of the material for construction. For the sheathing and insulation of all mechanical services, PVC-free materials were used.

All the different types of wood used for structure, facade and interior are harvested and fabricated locally. Opting to pre-fabricate almost all components off site resulted in

cost saving as well as shortening the construction time [31] (p. 99). Since all the exterior and interior finishes, including for the walls, ceilings and floors, are in untreated local silver fir, indoor air-quality is ensured to be excellent and the exterior materials cause no pollution to the environment (Figure 8).

Figure 8. St. Gerold Community Centre seen from the West: when built new (**left**) (Copyright HANSPETER SCHIESS FOR CUKROWICZ NACHBAUR ARCHITEKTEN); after weathering (**right**). The untreated silver fur has aged naturally without causing pollution to the environment (Copyright HANSPETER SCHIESS FOR CUKROWICZ NACHBAUR ARCHITEKTEN).

3. Energy Strategy

The energy-saving strategy of this project starts by making the entire building extremely air tight, as it enhances the performance of the envelope and improving the U-value. Currently, the building meets the Passive House Standards in Austria which was set up in 1980. The building standard requirement states that a building of this size should need heating energy less than 15 kWh/m^2a. Due to the compact design of the building which incorporates the careful design of individual components, the building's need for heating energy is as low as 10.7 kWh/m^2a.

The ventilation and heating systems have been carefully considered and designed to suit the needs of the users. The fresh air is continuously supplied via mechanical ventilation that is controlled by the use of CO^2 sensors, while heating is supplied by a geothermal heat pump. As much as 87% of the heat energy that is normally lost through ventilation is recovered through the heat exchanger system [27] (p. 63). Even the heat produced by the refrigeration units in the community store is fed back to the building's energy system, so that not a bit of energy is wasted. There is a daylight sensor which controls and modulates the external blinds that prevent over heating by excessive solar gain. Although it was not installed during the original construction phase, provisions have been made for the future installation of PV panels on the south facade. When these extra provisions are installed and operational, it is expected that the building is almost completely self-sufficient, in terms of energy needs.

3.2.4. House by the Fens (2012)

House by the Fens was designed by Bernardo Bader, who is a local architect from Bregenz, Vorarlberg. This house is located at the western edge of the existing settlement of the Krumbach community, and sits at the border with the forest. From the outside the form of the house is deceivingly simple, similar to the vernacular farm buildings of the region, but there is a play of single- and double-height spaces that create a rich array of spatial experiences [35]. The simple volume with a large void that dissects the long space into two appears to take the nature right into the house (Figure 9).

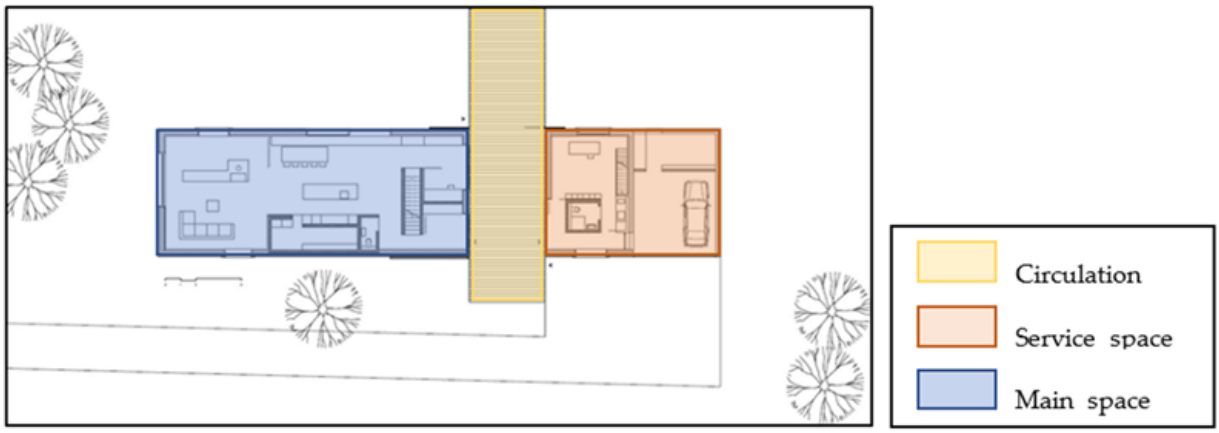

Figure 9. Ground Floor Plan, house by the Fens, Krumbach, 2013 (Copyright Bernardo Bader Architekt).

1. Layout of the spatial programs, on plan and the envelope of the facade:

From the outside, a long rectangular volume with a gabled roof appears similar to the regional farm building. However, there is a large opening which dissects the rectangular volume. The wooden terrace that traverses the house acts as the entrance, a semi-outdoor space which becomes an extension of the living space and then finally a route to the nature beyond the house (Figure 9). This semi-outdoor space, which might have a reference to the traditional 'schopf' that was also a semi-outdoor space accommodating the extension of the living space, can be closed off by using the sliding louver screens. On either side of the opening are the two main living spaces that resemble the old layout of living space and a stable in a farm house; now, where once was a stable now is a garage with a studio space (Figure 9). A total of 60 spruce, elm and silver fir trees were sourced from the local forests in Schwarzenberg which is only 15 km from the construction site. By sourcing the material from a close distance, the project reduces the CO^2 footprint of the material dramatically. All cuts from the wood were used for the components that make up the house, from structure to walls, floors, doors, furniture and kitchen, hence reducing the waste to the bare minimum [36].

2. Construction Method

The house is in a pre-fabricated structural system with pre-fabricated concrete parts for the core zone. By opting to utilize pre-fabricated units, the decision minimizes the waste of construction material and shortens the on-site construction period, which is an ideal way to reduce the construction budget as well as remain environmentally friendly. All timber structural elements are highly insulated, making the envelope of the house as airtight as possible. The exterior is finished with larch board-and-batten siding and fir paneling on the interior. The roof is constructed in the same way, with standard seam copper sheet cladding that will continue the vertical lines on the exterior envelope (Figure 10).

During the excavation for the construction of the house, a large quantity of brick clay was found. This was sent to a local brick manufacturer where it was pressed into bricks for the floor. These were custom made with grooves that will hold the underfloor heating pipes for retaining a better thermal mass. The floor is then covered with fir flooring panels.

3. Energy Strategy

There is a ground source heat pump (geothermal heat pump) which provides warmth in the winter and coolth in the summer. The ground floor is heated by the underfloor heating pipes, while radiators provide heat in the upper level. During the winter the house is mechanically ventilated; however, in the summer a combination of natural cross and stack ventilation keeps the interior cooler. This is further enhanced by double-height volumes of the interior. The overall heating energy needs is 25 kWh/m^2a, which is well within the strict regulations of Vorarlberg [37].

Figure 10. Seen from North-east; house by the Fens, Krumbach, 2013 (Copyright Bernardo Bader Architekt).

4. Findings

By analyzing the case projects, the following common findings became apparent.

- *Use of local materials* that has the following consequences: timber itself is already a sustainable material with may positive effects; since it is sourced locally the need for excessive transportation is not necessary, thus making a minimum CO^2 footprint during transport;
- *Active involvement of local industries, communities and authorities*: there is a symbiotic relationship between the timber industry and craftsmanship which supports the local economy and the economic growth of the region; local authorities that set up the Passive House Standards as well as promoting the strategy; and local communities (clients) who decide to use the local timber and follow the stringent standards of local authorities;
- *Continuation of local vernacular regional architectural language*: providing training and education of traditional skills as well as new innovative technologies to meet the contemporary needs and requirements.
- *Clean energy source and reduction of energy needs*: by following the strict regulations of the region, most buildings are extremely energy efficient, particularly passive buildings. There is a conscious awareness of reducing the waste of construction materials.
- *Collaboration between all parties involved*: architects, craftsmen, clients and the local authorities work together to achieve the common goal of building a new building that will contribute towards making a better environment as a whole.
- *Awareness and appreciation of values*: both architectural cultural value as well as the importance of being environmentally friendly and sustainable.

The above findings can be categorized and summarized as below in Table 1.

Table 1. This shows how the four projects address the three types of sustainability.

Project Title (Year of Completion) Architect <Program/Function>	Architectural/ Environmental Sustainability	Social Sustainability	Economic Sustainability
Secondary school Klaus-Weiler-Fraxern (2003) Dietrich Untertrifaller <Education>	- Compact volume; well insulated and air tight - Heating energy demand of 11 kWh/m^2a - Use of triple glazing - Geothermal heat exchanger recovers heat from exhaust air	- Automated exterior blind for interior envrionment control - Use of birchwood for interior finish creating a warm atmosphere - Collaboration between all parties involved - Employment from timber industry and construction	- Use of pre-fabrication - Locally sourced timber as the main material - Timber processed locally
Community Centre Raggal (2006) Johanes Kaufmann <Public space for the locals>	- Use of orientation for maximizing heat gain - Minimizing CO^2 impact heating energy demand of 23 kWh/m^2a - Air-tight construction (highly insulated) - Geothermal heat exchanger recovers heat from exhaust air	- Use of daylight as the heat source for daytime use - Collaboration between local industries and craftsmen - Involvement of the local community	- Use of locally grown fir and spruce - Pre-fabrication of construction elements
Community Centre St. Gerold (2009) Cukrowicz Nachbaur <Public space for the locals>	- Materials were tested against toxic substances - Minimizing CO^2 impact - Heating energy demand 10.7 kWh/m^2a - Use of sheep wool/PVC-free materials were used	- Use of untreated fir as interior/exterior - Fresh air supply/heat supply through geothermal pumps - Employment from timber industry and construction	- Solid lumber from local forest - Sawn in local industry - Pre-fabrication of construction elements
House by the Fens (20120) Bernardo Bader <Private Residence>	- Brick clay, found during excavation, was re-used - Air-tight construction (highly insulated) - Heating energy demand 25 kWh/m^2a - Minimizing CO^2 impact	- Fresh air supply/heat supply through geothermal pumps - Employment from timber industry and construction	- Locally sourced timber - Pre-fabricated structural system - Use of all cuts from the wood for doors and furniture (reducing waste)

The above findings can be also be matched with seven of the UN's Sustainable Development Goals.

- *The use of local materials* work towards achieving the following SDG: 12. Reasonable Consumption and Production: 12.2 By 2030, achieve the sustainable management and efficient use of natural resources.
- *Active involvement of local industries, communities and authorities work* towards achieving the most numerous SDGS: 4. Quality Education: 4.4 By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship. 8. Decent work with economic growth: 8.3 Promote development-oriented policies that support productive activities, decent job creation, creativity and innovation and encourage the formalization and growth of micro-, small- and medium-sized enterprises. 9. Industry innovation and infrastructure: 9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets.
- *Continuation of local vernacular regional architectural language and the awareness and appreciation of cultural values* by the local people and all involved, to achieve SDG 11

which is: 11. Sustainable cities and communities: 11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage.

- *Clean energy source* that is enforced further by the stringent regulations of Vorarlberg, to work towards achieving the following SDGs: 7. Affordable and clean energy: 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix. 13. Climate Action: 13.2 Integrate climate change measures into national policies, strategies and planning. The findings of this research also indicate that the continuation of tradition and heritage, meaning how the region has lived and worked, is a critical element of the architectural sustainability of a region. The sustainability of a region does not only mean the existence or survival but also sustaining its unique identity during this era of rapid developments and globalization.

5. Discussion

From reviewing the background of Vorarlberg's architectural culture, and the more detailed examination of case projects, it became clear that there is a unique cultural element in this region that enables the 'sustainability' of architecture to exist in a multi-layered manner.

It is the common general understanding that, when sustainable architecture is concerned, there is a strong focus and an emphasis on the functional and efficiency of the building as if it is a machine. While a 'conventional' green building responds to the environment with a focus on how much CO^2 is reduced or how much solar power is captured and used by the building, many buildings in Vorarlberg go on to illustrate further the deeply embedded appreciation of the tradition of the region in both the aesthetic and functional, which makes it 'sustainable' as a whole.

The multi-layers that influence how the building is designed and constructed can be considered to work collectively towards achieving up to seven of the UN's 17 SDGs, which is a clear illustration that the notions of sustainability in architecture are not only about the building as an operational and functioning entity, but also as an organism that has a life span as well as a cycle at the physical, social, cultural and environmental level.

In the UN's 17 Sustainability Development Goals 2015, 4 of the 17 goals are related to culture. This is a distinct improvement from The Millennium Development Goals (2000) which went before, where there was no mentioning of culture [38]. It is proof that the role of 'culture' has become more important and significant for meeting the aims of sustainability. This change reflects the increasing ecological, social and economic challenges that are being faced.

From the findings of case projects and the background research of Vorarlberg's unique regional architecture culture (Figure 11), was drawn. Figure 11 illustrates the particularly unique relationship of different community groups, such as local government authorities, who make architectural guidelines; those in timber industries, who process timber and manufacture pre-fabricated units for timber construction; local architects and local craftsman are closely connected, working towards the common goal of making and maintaining a better environment, which is the core of the value of sustainable development. With this close collaborative relationship come the education and training of the next generation, the development of new technologies and skills that will better accommodate the current users, and continue to promote local employment and generate economy.

It has taken many decades to establish this closely-knit symbiotic relationship between the architect, local industries and craftsmen, clients and communities, which brought about a continuous development in the use of innovative sustainable technologies and skills while promoting economy, employment and providing pleasant and safe environment for the community. This way, Vorarlberg has been able to maintain and find a way of sustaining its regional cultural identity as well as making a continuous development in the architectural culture, which is globally appreciated and renowned now. It would be worthwhile, in the age of globalization, to note how this unique way of executing an architectural project could be the key to maintaining sustainability of a community. It would be interesting to further develop this study by conducting future studies into how the current findings can

be modified and applied to other communities as a way of establishing a new sustainable cycle of architecture culture.

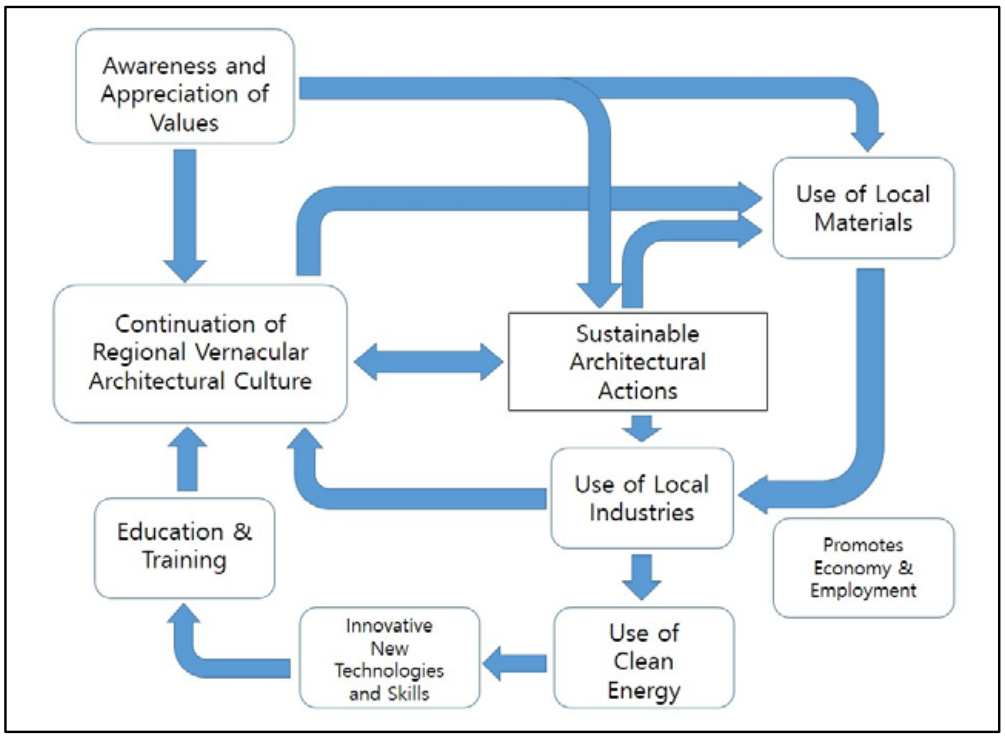

Figure 11. Sustainable cycle found in the regional architecture culture of Vorarlberg.

6. Conclusions

In the fast developing and changing environments of today, it is becoming more critical to maintain the unique identities of different regions and countries. Through modernization, the identity of history, heritage and tradition is often diluted if not erased all together. It is therefore very important to maintain the cultural identity on one hand, while developing architectural ideas and technologies on the other. This is to say that any architectural design actions should consider its role and how it can promote the social and economic sustainability as well as environmental sustainability. There should be more discussions between an act of architecture and social and economic sustainability concerns.

The aim of this paper had been to heighten the role of architecture which extends to the social and economic cycle of a region. Hence, by illustrating a multi-faceted practice of the sustainability of architecture through reviewing the unique architectural culture of Vorarlberg, Austria, a holistic concept of architectural sustainability could be understood. The emphasis of the argument is that the 'sustainability of architecture' is not only on the sustainable functional building as an independent object, but also how it is situated within the context of the regional tradition/history as well as an entity that generates social and economic growth and sustainability.

It is also further expected that through taking the case of Vorarlberg, Austria, the concept of sustainable architecture is differentiated from green architecture. It would be particularly applicable for those in architecture education where the importance and the existence of the multi-faceted practice of sustainability must be incorporated as a role of architecture which will achieve the sustainability of the cultural identity and tradition while promoting the local economy.

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