

## Article

# System Approach in Complex Integral Design Methodology and Its Application in New Zealand

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**Abstract:** Many New Zealand houses are energy-inefficient, unhealthy, cold, mouldy, and damp. Therefore, a new approach to building design is imminent. This article proposes a framework for the transformation of housing that integrates construction planning and design, optimization, and control tools at strategic, tactical, and operational levels. The introduced Complex Integral Design New Zealand (CIDNZ) represents a comprehensive and balanced system-based design and delivery process that facilitates and accelerates cross-disciplinary and trans-disciplinary expertise and knowledge. CIDNZ delineates a new way of designing the process based on integral, complex, and systems thinking. The emerging novel understanding of sustainability, which guides the transformation process, might lead to a balance between individuals, groups, society, and existing ecosystems. CIDNZ comprises all stages in the life cycle of buildings and all significant factors in the architecture, engineering, and construction industry, particularly, people, processes, technology, and the environment. Therefore, the entire construction process that implements a system approach to buildings as a vital part of environmental systems, goes from the environment to humans and vice versa and offers unlimited possibilities. The consequent practical application of these principles might eliminate or reduce the design defects and lead accordingly to the reduction of costs involved in their rectification.

**Keywords:** complex integral design; system approach; sustainability in buildings; transformation of housing



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## 1. Introduction

During the last two decades, it has become evident that the human race has entered a global age where diverse worldviews, cultures, religions, and science branches are in the midst of a deep transformation [1,2]. Increasing incidences of loss/loss business outcomes due to dysfunctional multistakeholder relations pinpoint the ramifications of the problematic business thinking and practice in many business activities [3]. Simultaneously, a new evolutionary stage of consciousness, called “integral” is emerging [4]. Annals in Social Responsibility described integral business as follows: “A future vision is of integral business where a currency of well-being is the main focus. Work would be undertaken in a mindful culture directed at encouraging an achievement of harmony across all eight well-being components. The value thrown off by such companies would be in the form of well-being creation for society” [5] (p. 21). Therefore, a new system approach to radically improve the architecture, engineering, and construction (AEC) industry is emerging [6,7]. Despite the development of integral architecture [8,9], a gap in the literature exists because a description of the complex integral system in the AEC industry is missing.

A large portion of the New Zealand (NZ) housing stock is energy-inefficient, unhealthy, cold, mouldy, and damp [10,11]. About 50% of NZ residential houses are affected by mould [12]. These problems are complex, and therefore cannot be determined with the same attitude as they were generated. Improvements in tools have to be a part of an

innovative approach. A radical change in thinking is necessary, as Albert Einstein said: “We cannot solve our problems with the same thinking we used when we created them” (as cited in [13]). Therefore, this article focuses on the development of a new concept waking up a paradigm shift in the architectural design process. Taking a system approach means thinking about the relationship between design process management and the social, environmental, and economic systems or structures that encompass the built environment. The first two paragraphs of this article consist of defining the integrative and holistic system approach—named Complex Integral Design New Zealand (CIDNZ), the applied methodology, and discussing the transformation phase of the paradigm shift. The proposed framework introduces alternative perspectives on how to design warmer, drier, and healthier houses for the NZ context. Consequently, the research suggests tools for the evaluation of CIDNZ and discusses the integration of diverse standpoints in the system approach. In the concluding paragraph, the vital contributions of this article are summarized.

## 2. Methodology

Consideration of philosophical position and methodology represents a crucial segment of this research because of the search for a new way to address the existing problem. The ontological position of this research is objectivism and epistemological perspective is based on integral theory. To develop a new concept in the architectural design process, this study utilizes empirical research design and causal reasoning, which are fundamentally qualitative [14,15]. This research is based on an extensive literature review, experience, and observations.

The topic of this research is a framework for the transformation of housing. The question on how to change the concept of architectural design process to improve the energy efficiency and human comfort in housing in NZ is addressed. The subsequent aim is a specification of steps integrating construction planning and design, optimization, and control tools at strategic, tactical, and operational levels.

The project started with a literature review on evaluation of sustainable buildings, indoor environment, system theory, integral theory, architectural design process, and building information modelling (BIM) with a focus on the implementation of BIM into the construction process. Simultaneously, an analysis was carried out of the current situation in the architectural design process in NZ and worldwide. For this purpose, industry related documentation and personal discussions with experts in the field of design, construction, and facility management have been conducted. Particularly, the social, environmental, and economic systems in the AEC industry have been considered.

Further, an essential part of the research was a critical review of existing knowledge about complex sustainability assessment including energy and hygrothermal modelling, life cycle assessment, and costing. The theoretical knowledge applied and further developed in the study led to the development of the innovative framework for designers.

## 3. Complex Integral Design New Zealand (CIDNZ)

Since the energy crisis in the 1970s and forthcoming climate change, energy-related issues are influencing the whole world. The building industry has contributed significantly to this situation [16]. Consequently, changes towards sustainability and resilient building design and construction are necessary to minimize the negative impact of buildings on the environment [17]. However, most improvements so far have been targeted to specific problem solving without any consideration of the whole. For example, in NZ, the incentive of warming up the existing houses led to insulation retrofits [18]. The insulation has been typically installed to some elements of the house only, like walls, floors, or ceilings but rarely to the whole building envelope [19]. As a result of these enhancements, the energy balance has been improved. However, the retrofits-related shifts in the position of the dew point have ramifications. Interstitial condensation, mould growth, and rotting of construction materials represent possible consequences of partial improvements in the thermal resistance of building envelopes [20,21].

From the system's definition point of view [22], every building might be seen as a complex system that interacts with the environment and humans. Therefore, the researchers propose a comprehension of the word "building" as an obscured system. From the system theory perspective [23], a building includes all of the used materials, equipment, location, shape, functions, and relations to the environment and occupants. What makes each building a system are the links and dependencies of one part on another and the environment. Any change of some element, function, behaviour of occupants, or climate has an influence on the whole system—the building. This approach represents a piece of new knowledge. In theory, BIM is a dynamic process accompanying the whole life cycle of a building. However, the praxis is still far away from this potential. A necessary transition process, therefore, might enable changes in the AEC industry, leading to the integration of the fourth industrial revolution [24].

Additionally, there is undeniable evidence that humans reached a radically new level of consciousness and stepped into an era of globalization [25]. Therefore, a minimalization of the negative impact of buildings on the environment and climate is not sufficient. The expanded consciousness recognizes the need for a harmonization of the man-made world with the life on the planet Earth. This corresponds to the United Nations Interactive Dialogue of the General Assembly on Harmony with Nature which invites to promote "... the balanced integration of the economic, social and environmental dimensions of sustainable development through harmony with nature" [26] (p. 5). Consequently, a definition of a new set of operations is necessary. We need to set a benchmark, or in other words, identify the need for certain considerations. From this point of view, the proposed approach of CIDNZ aims to radically improve the performance of NZ houses.

### *3.1. The Definition and Methodology of CIDNZ*

Complex Integral Design New Zealand (CIDNZ) represents a comprehensive and balanced system-based design and delivery process that facilitates and accelerates cross-disciplinary and trans-disciplinary expertise and knowledge to create buildings in balance with nature, environment, and human needs.

CIDNZ is based on comprehensive engineering and other disciplines, including but not limited to architecture, engineering, building physics, indoor air quality, environmental science, information technology, computer sciences, building services, building biology, meteorology, human physiology, and psychology. The system approach used in CIDNZ represents the ability to look at influencing factors and elements, tasks, goals, and functions from a "distance", which allows for different points of view. CIDNZ implements a new modality of thinking, called integral thinking, which rests upon the holistic consciousness and goes wider than "integrated" because it contains concepts of inclusivity, pluralism, and reverence [27]. Every building, inhabitant, stakeholder, or a group of people (for example, a family) are seen in CIDNZ as holons and examined in their whole/part relationships during the life cycle of the building. The theory of holons has been introduced by Koestler [28]. Holons are organized in hierarchies and heterarchies, called holarchy [29]. Therefore, the analysis of the holarchy and relationships between holons and holarchy allows for the integral examination of multifaceted, cross-disciplinary, human-, and nature-centred problems in the CIDNZ process. In this sense, the CIDNZ forms a holon as well.

CIDNZ uses the integral examination, which executes in four dimensions: transcendence, communion, agency, and immanence [30]. The transcendence demonstrates the ability of the holon to change and evolve. Therefore, it allows for the evolution of the whole system [30]. For example, the integration of the hygrothermal modelling into the design process enables improvements and the optimization of the hygrothermal performance of the building. The communion allows for relationships with other holons. This sometimes happens through indirect ways, such as government regulations, human priorities, and values [30]. Therefore, CIDNZ will encourage dynamic relations with building authorities and research to improve the design process and in general, the quality of NZ housing. The agency represents the ability of the holon to project the internal structure and

transform or influence the environment [30]. The agency will carry out an essential role in CIDNZ because the AEC industry might benefit from the cooperation and integration of diverse fields of knowledge. The immanence is the holon's tendency to preserve the status quo, repeat the past, and therefore, add to the stability of the system [30]. In CIDNZ, the immanence means the ability of the system to use reliable, proven, and tested methods, technology, and materials while encouraging the transcendence and evolution.

The design and delivery process and the end-result/building, when seen as systems, offer a paradigm shift in the way buildings are constructed and used. The system approach in CIDNZ, for example, interpolates questions and examples from natural systems. What does it need to create a zero-energy sustainable building? How can it be done? What are the conditions to eliminate harmful effects on nature and people? How could it be done so that the design and construction process go more smoothly, with minimal losses and delays, but not for the costs of the whole? The aim of the CIDNZ approach is the harmonization and optimization of processes, resources (humans and materials), and building performance (thermal, hygrothermal, environmental). For the operations and progression, CIDNZ adopted the integral operating system (IOS)—an integral model that includes four quadrants of growth, development, and evolution [4,31,32]. The description of the four quadrants in CIDNZ forms the content of the following section.

### 3.2. The Four Quadrants in CIDNZ

The CIDNZ system accommodated Wilber's four quadrants [33] to form four different views on the entire design process. Therefore, CIDNZ divides the design of sustainable and low-energy houses into four quadrants along two axes, as shown in Figure 1 which is an adaptation of Wilber's four quadrants [34]. The horizontal axis, connecting the interior on the left side and the exterior on the right side, depicts a viewpoint related to the subject of evaluation. On the right side of the axis, the subject is objectively examined from "outside", and therefore, it becomes an object. The vertical axis connects the collective perspective on the bottom with the individual perspective on the top.

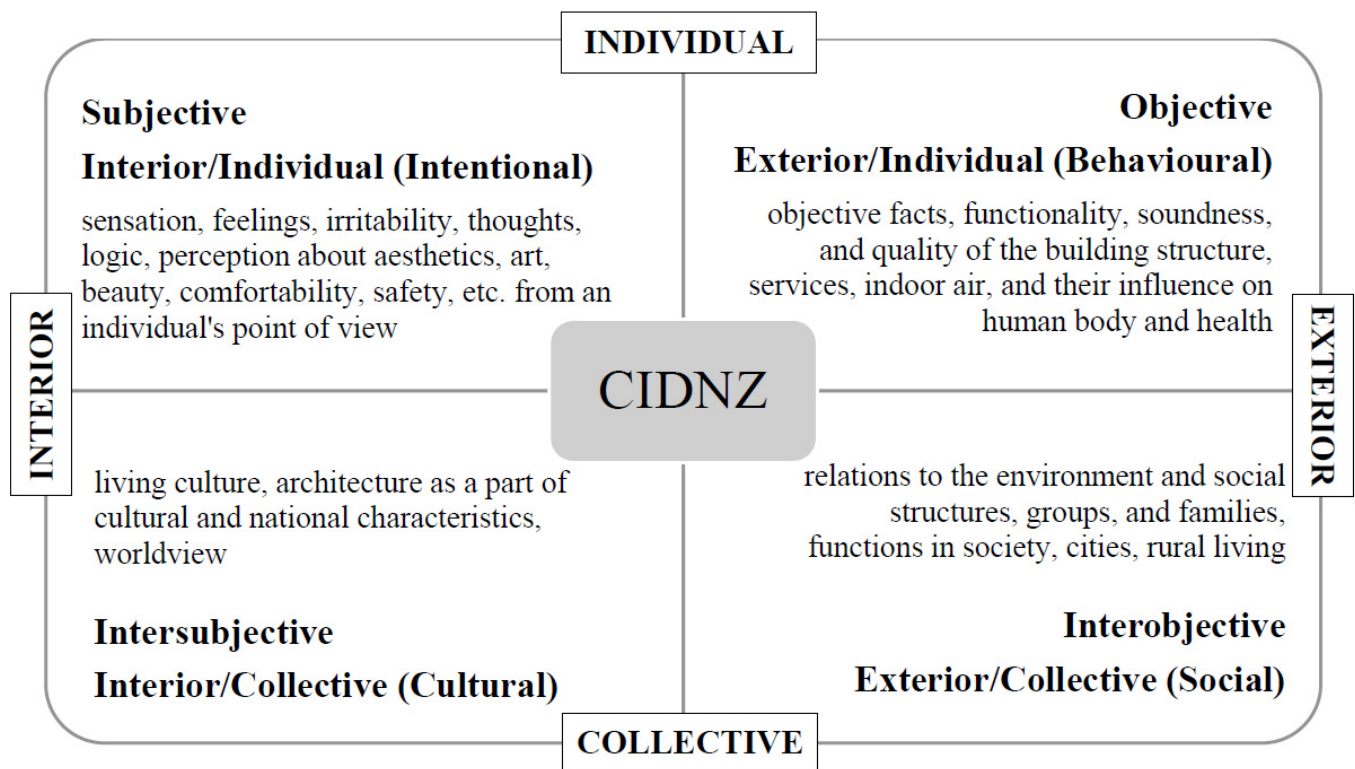


Figure 1. The Four quadrants in the complex integral design.



The subjective quadrant (upper left) describes the influence of the house on the perceptions and sensations of a person, such as the designer or the future inhabitant. The objective quadrant (upper right) depicts all objective, measurable facts about the building. In this phase, the designer team evaluates building performance, functionality, indoor air quality, etc. and their influence on the human body and health. In this phase, designers ask questions related to the impact of the building on the physical body. The intersubjective quadrant (lower left) relates to culture and nation: how the building influences or reflects the existing worldview and cultural values, inclusive corporate culture. The interobjective quadrant (lower right) reflects the relations to the environment, ecology, economics, and social systems and structures (groups in which people live or work). Due to the world's major problems, such as climate change, pollution of earth, water and air, and depletion of resources, the thinking in this quadrant and acting sustainably gained in importance.

Nevertheless, the balance between all quadrants is decisive for future well-being [35]. The quadrants in CIDNZ offer four different practical ways to formulate questions leading to integrally balanced solution concepts. Consequently, the application of the proposed innovative system approach requires a necessary transformation process.

#### 4. A Process of Transformation

The development and implementation of CIDNZ involve a process of transformation. The core of the transformation is located in the stakeholder's values. Therefore, a question emerges how to shift the values towards higher stages of individual and collective development: from personal to trans-personal and from rational to pluralistic and integral. The housing and the associated design and construction remain not a set of static things but rather an open system in which evolution depends on the human values and market conditions [36]. Consequently, the state of knowledge and value system determine the places where people live and work. For example, the materialistic self-centred values of the modern age, "... the values of accomplishing and getting, having and possessing" [37] (p. 150) brought in addition to wealth, innovations, and comfort exploitation of natural resources and massive pollution of the environment [38].

For a framework, the following section shall present the design process in its complexity and the rapidly changing human values conveying radically different ways of thinking. A new set of values based on humanistic, systems, holistic, and integral views is developing [39]. The CIDNZ, therefore, proposes a novel understanding of sustainability in the housing and construction industry in general. In this sense, CIDNZ transformation process values the undistorted acceptance of human nature as it is and problem-solving, which leads to a balance between individuals, groups, society, and the existing ecosystems.

Consequently, the shift in value system is visible in recognition of concepts of consciousness and attention in cognitive psychology and other scientific fields [40] and the birth of global culture and consciousness [25]. According to Beddoe et al., "A culture can be viewed as an interdependent set of worldviews, institutions, and technologies (WIT)" [38] (p. 2484). In this context, the researchers note that the global culture forms while each nation is developing its own unique culture. "As seen in an organic body, for the whole to become one, each part must develop itself. For each part to develop itself, the whole must become one" [41] (p. 308).

The stages of the individual and collective development might be followed in the spiral dynamic, which represents a human development theory, based on Graves [37] and first introduced by Beck and Cowan [42]. The spiral dynamic proposed eight levels of development to which Wilber later added the rainbow colours [43]. Consequently, the human development system depicts a map of evolving personality and worldviews. A worldview might be defined "... as a combination of a person's value orientation and his or her view on how to understand the world and the capabilities it offers, the lens through which the world is seen" [44] (p. 855). The historical process of frequently repeated destabilization of worldviews together with the present domination of the extreme postmodernist worldview led to the sustainability problem and ecological crisis [44].

Nevertheless, the emerging climate change and the need for sustainability transformations are bringing radical shifts in worldviews, innovative strategies, and the role of sustainability assessments [45].

Consequently, the CIDNZ transformation process involves a movement of values toward the integral worldview domain. The integral worldview constitutes transformed relationships to the environment, eco-social evolution, and unity and flourishing of all beings [46]. Simultaneously, it accepts and understands all major typologies of worldviews, such as premodern, modern, and postmodern. The integral worldview, therefore, offers an ethical framework that operates within a circle consisting of the four quadrants, eliminating one-sided identifications and defining “human dignity” [44]. Integral thinking is particularly useful in complex fields that require comprehensive approaches, such as housing design and construction. Integral thinking includes traits of advanced ways of thinking, such as ecological, systems, holistic, postformal, and metaphysical [30].

Therefore, CIDNZ implements integral thinking which is an inclusive thinking in systems. Inclusive thinking is based on a notion of cross-sector and multidisciplinary collaboration and shared values [47]. The transformation process to integral thinking happens not as DeKay and Bennett write as “... a shift from behaviors to system” [48] (p. 256), but as a complex system that includes all quadrants and all levels [49]. Particularly, the CIDNZ ecological thinking aims to achieve a balance between the upper right and the lower right quadrant: in other words, a balance between behaviours/functions and environmental, societal, and ecological systems. Therefore, the transformation process represents an ever-expanding perception that reflects “... the need to change the legal anthropocentric paradigm and replace it with biocentric thinking which recognizes Nature’s intrinsic value and advances the interconnectedness between human beings and Nature” [50] (p. 4).

The transformation process depicts an entirely new quality of perceptions that are based on the second tier of human consciousness development. This is because this level of consciousness is profoundly different from all previous levels. It is the first time in known human history when the shift happens not by fighting and denying the previous levels [51]. In this level, the worldview is based on recognition and acceptance of all the progress done in the past, learning from mistakes, and integration of the knowledge for the well-being of all [39]. Through this process, holistic views of construction are developing. The holistic views include “... integrated, collaborative processes, enhanced technical and social skills, and interoperable technologies to support integrated information and automation systems and knowledge management” [52] (p. 227).

CIDNZ comprises all stages in the life cycle of buildings. Therefore, the transformation addresses relations to the environment, stakeholders, technologies, and processes involved in the design, delivery, usage, and decommissioning of buildings. Simultaneously, the process of transformation needs support from research and education. CIDNZ recognizes four significant aspects in the AEC industry: people, processes, technology, and environment. Figure 2 schematically visualizes the four fundamental aspects of CIDNZ and the conceptual framework for transformation.

The conceptual framework for transformation contains collaborative processes across all project phases, enhanced skills, integrated information and automation systems, and knowledge management. These are the four elements of the Integrated Design and Delivery Solutions (IDDS) [53]. IDDS is the CIB (International Council for Research and Innovation in Building and Construction) vision for a more holistic future transformation of the construction sector. Additionally, CIDNZ recognizes two crucial elements, such as human needs and environmental systems. Any change/improvement in one of the industry elements has a direct or indirect influence on the industry foundations [54]. Differences between IDDS and the complex integral design might be recognized in the fact that the former aims to enhance the efficiency and value of projects. The later goes a step further. CIDNZ as a process includes all previous stages of integrated, collaborative processes in personal and objective levels by a new integral cross-paradigmatic approach. Therefore, CIDNZ transformation process influences all fundamental aspects as described in the following sections.

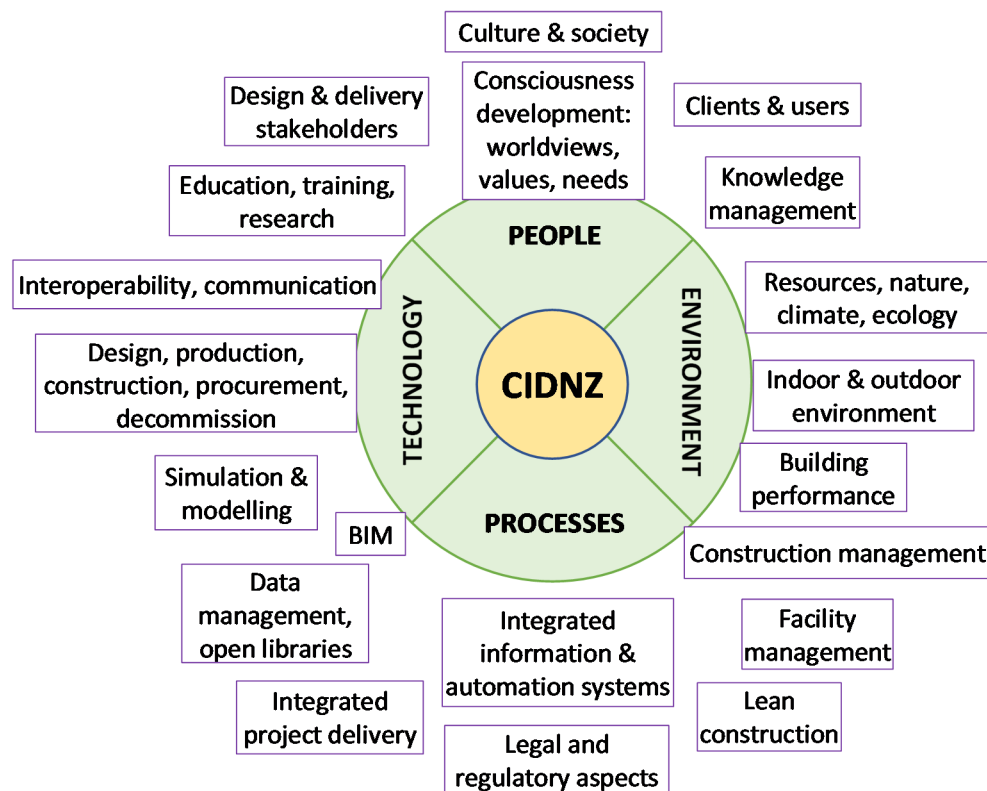


Figure 2. Fundamental aspects of CIDNZ and the conceptual framework for transformation.

#### 4.1. People

The people involved in CIDNZ consist of two major groups: the users/inhabitants and the design and delivery stakeholders. Both of these groups will undergo a process of change and transformation. As Dent wrote more than 20 years ago: “Our reality changes as our ability to detect phenomena changes” [55] (p. 16). Human needs and values, and individual worldviews, therefore, form a crucial element of the transformation process. Consequently, CIDNZ includes the identification of contemporary and future physical, psychological, and sociological needs and values, as well as aesthetics, health, safety, and functionality. The recognition of the human needs and values in CIDNZ proceeds across four directions: individual, collective, interior, and exterior.

On the side of design and delivery, the enhancement of skills and knowledge management throughout the industry foundations are decisive for the successful transformation. CIDNZ team members work in cooperation through the whole supply chain and continuously improve the level of knowledge. The involved processes require new/advanced skills in technology applications, multitasking, and the ability to think integrally in a cross-disciplinary way [24]. Therefore, people with joint degrees, such as architecture/engineering, will be in demand [54]. Some professions, such as construction or architectural managers and mediators, might gain importance [56]. The collaboration and shared knowledge about past projects will improve the skills of tradespeople who will participate in integrated work processes [7]. Consequently, the educational system will require changes towards integral thinking and inter-disciplinary approach [30], especially in combination with environmental and human sciences. It will not be enough to build technically advanced low or zero energy buildings; there will be an expectation to harmonize the built environment with nature, health, and wellbeing of people.

#### 4.2. Processes across All Project Phases

The AEC industry is already undergoing a transformation process due to the new technologies and collaboration with BIM [57], Integrated Project Delivery [58], and Lean

Construction and Procurement [59]. However, the reality of the processes across all project phases is that very few firms are able to collaborate effectively [7,60]. Interoperability issues between diverse BIM tools and design systems still exist [61]. A prerequisite to the successful development of collaborative processes across all project phases is, however, the interoperability of diverse software. Therefore, stakeholders in a supply chain would benefit from interoperability considerations by the acquisition of new technology [62].

The process of transformation to achieve CIDNZ will require a thorough analysis of supply chain and team members for each project to ensure the optimal transition. The analysis will serve in setting up a new organizational structure based on cooperation, collaboration, acceptance, and respect. The professions of the team members should correspond to the overall aim of the project, enabling a cross-disciplinary approach in all of the four quadrants. The team members might belong to scientific fields of architecture, building physics/science, engineering, design, psychology, environmental sciences, project management, sociology, information technology, etc. Besides the importance of technical equipment and organizational structure, communication, conflict management, negotiation, and teamwork represent the essential factors of successful collaboration [57]. Consequently, CIDNZ as a system should improve the value of housing, not only in economic terms of delivering better value in a shorter time and lower costs but relating to human needs and environment. The latter two attributes also include architectural and aesthetical values, supporting the well-being of occupants and the integration of buildings into the environment in a sustainable manner. CIDNZ, therefore, requires a paradigm shift in values of all involved stakeholders, inclusive users, developers, designers, and members of the supply chain.

The CIDNZ processes include principles of Integrated Project Delivery (IPD) and Lean design and construction. IPD is based on a contractual agreement between main project parties (client, designer, and contractor) about collaboration, use of BIM, and improvement of value for money by minimizing waste, inefficiency, and conflictual relationships [58]. However, despite a growing interest in IPD, the reality is that “... only few institutions are able to adapt their programs to meet this need” [56] (p. 2041). In the 1990s, Koskela applied a new production philosophy, which started in Japan in the 1950s, to construction [63]. Since then, a continual evolution of reconceptualization of construction as a production process and the Lean design and construction movement are changing the AEC sector [59]. Lean represents improvements in the management and production and is associated with just-in-time and implementation of information technology to minimize excess labour or stock of goods [64]. Consequently, the transformation in the AEC industry requires full integration of information and automation systems. The necessary free flow of information is discussed in the following section.

#### 4.3. Interoperable Technologies

To successfully transform complex systems, such as the AEC sector in the 21st century, implemented technologies in all stages have to be interoperable. Therefore, one of the imperatives of the process of transformation to CIDNZ consists of the interoperability analysis of the construction technology to achieve optimized solutions and higher value levels in the AEC sector.

Shirowzhan et al. describe construction technology as “... tools, systems, mechanisms, computers, electronic boards and components, equipment and any combination of resources used for carrying out physical construction activities in the process of construction from design to demolition” [65] (p. 2). Consequently, the compatibility measures influence the building performance and the impact of the construction process on the environment and economics. Improvements of compatibility measures require changes in the information systems (BIM), business processes, and management of business relationships to move “... from traditional red ocean strategies, i.e., efficiency and differentiation, and aim at blue ocean strategies, i.e., value innovation” [66] (p. 530).



However, the current information management is still limited (with some exceptions) to a complete model exchange, which leads to poor semantic integrity and loss of information [53]. Although many studies acknowledge the compatibility and interoperability issues in software architecture [67], they “... have not been directly discussed in recent BIM standard investigations” [65] (p. 13). According to some researchers, the future of interoperable technologies lies in semantic BIM and Semantic Web Services [68]. Other examples of semantic systems are intelligent management of energy and security in buildings [69] or real-world semantics for acquisition, processing, and analysis of large volumes of data [70]. From the practical point of view, CIDNZ recommends including in the team an information manager, an interoperability specialist responsible for determination of the optimal software and information flow which suit the project the best. Additionally, free information exchange between all stakeholders in all directions is crucial for CIDNZ for several reasons. Communication of values, balance between built environment and nature, optimization of a design in all quadrants, energy efficiency, and performance are some examples.

To achieve this, further development of semantic interoperability and information science but the transformation of professionals' education in the construction industry are necessary. Data management and the interlink between machines—objects—people and processes represent essential attributes of the fourth industry revolution [60]. Therefore, to enable the optimization and further analysis of an architectural project relevant, coherent, complete, interoperable, and open data libraries must be available [71,72]. Additionally, a precise semantic definition of data exchange between implemented software will enable conflict-free data transfer and minimize errors [73]. A significant transformation will happen in information management by using sophisticated models: view- and rule-based approaches [69]. Simultaneously, companies will need to solve problems related to software innovations and accommodation of new technology together with the existing [62]. Therefore, CIDNZ suggests an independent examination of compatibility and interoperability in the construction technology context as a part of the transformation process.

#### 4.4. Environmental Systems

The CIDNZ approach is of transformation with a transition towards the balance of environmental systems. The explanation of interactions and processes in environmental systems is, therefore, vital to the understanding of this transition. From the integral view, the holarchy of environmental systems includes interconnected natural and man-made holarchies with complex relations, processes, and impacts. Natural systems are open and dependent on other systems, which are often of anthropogenic origin [74].

Therefore, CIDNZ comprehends the term “environmental systems” as an integration of indoor and outdoor environments, ecology, resources, transport, climate, weather, humans, and natural systems. Ferguson described an environmental system (ecosystem) as follows: “An ecosystem is a community of interacting organisms and the physical environment in which they live. Humans and their buildings and settlements are part of this community, which can include birds, plants and insects, as well as inorganic matter (such as rock and metals) and natural forces (such as the flow of water, fire, or the chemistry of photosynthesis). All of these link together and interact as a complex web of life” [75] (p. 11).

This holistic approach to the environment has deep roots in many indigenous traditions. For example, Māori worldview, *mātauranga Māori*, is based on a belief in the deep spiritual connection between people and the environment (all living and non-living things) [76]. This means that the relationships between humans and environmental systems determine decisions, rather than their effects. In this sense, CIDNZ might learn about the interconnectedness of all things from the Māori theory of the origin of the universe. Māori people believe that “... any actions that change or degrade the mauri of one thing will have a corresponding impact on the form or integrity of another” [75] (p. 15). Mauri represents “... life principle, life force, vital essence, special nature, a material symbol of a life principle, source of emotions—the essential quality and vitality of a being or

entity. Also used for a physical object, individual, ecosystem or social group in which this essence is located" [77]. Therefore, for many Māori, the respect for the physical environment coincides with the obligatory protection and safeguarding of mauri as an essence located inside of each entity. Māori people see humans "... as an integral part of the ecosystem" [76] (p. 2). On the contrary, the prevailing worldview sees nature (ecosystem) and humans (human activities) as separated. However, the indigenous collective leadership principles might be beneficial to all complex adaptive systems that are resilient, non-linear, and interdependent, such as shared leadership in teams engaged in a creative task [78]. The core of the Māori collective leadership as a multidimensional paradigm forms the knowledge code, which is "... a way of tapping into and releasing collective intelligence that is transmitted from one generation to the next" [79] (p. 531). Therefore, a leader, a rangatira represents the ability to being a paradigm warrior, working on its potential, supporting and leading people toward a state of belonging and flourishing. However, these principles are not about any individual leader but a complex of roles and responsibilities [79]. Rangatira means "... chief (male or female), chieftain, chieftainess, master, mistress, boss, supervisor, employer, landlord, owner, proprietor—qualities of a leader is a concern for the integrity and prosperity of the people, the land, the language and other cultural treasures (e.g., oratory and song poetry), and an aggressive and sustained response to outside forces that may threaten these" [80].

Therefore, understanding what the environmental systems represent and how they are formed, interconnected, and interdependent is vital to the CIDNZ transformation process. The buildings and built environment configure a subset of environmental systems, which include natural systems and people. Consequently, the researchers believe that the built environment has to fit into the environmental systems if humanity is to survive in the long term. The system approach requires a more sophisticated way of thinking about environmental systems. Simultaneously, a question arises about the flexibility and balance of these systems. Therefore, the strong transition involves the integration of science in diverse fields, identification of problems, adaptation and redesign of critical systems in the AEC industry, and management of the transformation process.

## 5. Framework for Designers

This study is concerned with improvements in housing quality. However, the problem of built environment sustainability is of such complexity and interconnectedness that the real and long-lasting improvements require a system approach. The complexity of the built environment might be demonstrated in hygrothermal relations in buildings. Although buildings without a vapour barrier can have satisfying moisture performance by fluctuations of relative humidity (RH) [81], the probability of uncontrolled in-wall condensation, mould growth, or rotting is very high [82]. Therefore, several researchers suggest an airtight but vapour permeable building envelope [83,84]. Nevertheless, as already mentioned, the design and construction of sustainable and energy efficient buildings require consideration of multiple factors, including but not limited to hygrothermal relations. The authors selected the NZ prevalent moisture related issues for showing one of the topics connected with the improvements in housing quality. During the process, designers of sustainable buildings need to answer many questions. The following questions depict an application of the methodology to a specific theoretical example. How high are the moisture loads into the wall? Is the drying process possible? How long would the drying out take? Is the wall construction diffusion open? If yes, how does such construction perform in the long term? Is there any risk of additional wetting of the building envelope from driving rain, melting of frozen water, or excessive indoor RH? How could the building adjust to future usage needs?

The design process that follows an integral approach might eliminate most of the problems described in this research. Therefore, this research proposes a new framework for designers to improve the sustainability of housing. The elements of the framework are not new, but the concept of the design process is. The basic idea behind this concept is to

create habitable spaces for people in harmony with nature and natural forces, not against it. The holistic architecture is copying nature in its function, as several researchers emphasize [84,85]. The integral sustainable design takes natural systems as a model for design and develops an ecological literacy that understands and applies the principles of ecosystem structure, process, and organization [48]. For example, the concept of integrated environmental approach stresses the necessity of simultaneous consideration of the building structure, energy efficiency, indoor environmental quality, and moisture management during the whole design process [86,87]. This does not mean that the design has to be simple or boring. This means that the design process implements a system approach to buildings as a vital part of the environmental systems, goes from the environment to humans, and offers unlimited possibilities.

“Nature is no longer just a thing” (p. 3), as Justice Antonio Herman Benjamin of the High Court of Brazil stated: “Granting rights to Nature reflects a profound change from the traditional legal wisdom which once considered Nature just a collection of elements and now sees Nature as the meaning and foundation of all life. This shift in paradigm, once the topic of philosophical and ethical circles, now reveals itself as a legal paradigm” [50] (p. 3).

Therefore, future housing and the related design and construction process need radical changes. The concerns are not limited to energy efficiency, CO<sub>2</sub> reduction, or moisture but include issues related to environmental systems, humans, and Nature. To radically improve the quality of housing in NZ, the AEC industry has to consider customer requirements and needs at early construction planning stages. Simultaneously, the designer team needs to manage the increased complexity of buildings and their construction. This research introduces a complex integral framework that integrates construction planning and design, optimization, and control tools at strategic, tactical, and operational levels. The framework offers stakeholders the possibility to actively engage in the design process, influence the impact of the building on the environment, and be informed about concurrent design variants. Figure 3 depicts the structural relationship model of the framework with the influencing factors and design defects. With the paradigm shift in mind, the following sections briefly describe four steps in the CIDNZ framework for designers.

### 5.1. Step 1—Construction Planning

Construction planning is in its role similar to product planning which is considered to be the crucial stage in the decision-making process in the design [88]. This step in CIDNZ involves the identification of values and functions, customer/user needs, resources, and analysis of construction site, climate, ecological, social, and cultural environment. The outcome of construction planning encompasses preliminary design decisions, building performance objectives, time schedule, design resources, knowledge, and technology. At this stage, designers aim to eliminate functional defects in the design [89]. The preliminary design contains fundamental decisions about solar gains, thermal mass, and ventilation. The designing process in the first step follows the recommendations for the high-quality environment buildings [87]. It is based on the principles of climate specific design [90] and climate-responsive design [91]. The origin of the latter two design philosophies might be tracked from the early 1950s when Olgyay first introduced the term bioclimatic design. The original publication of Olgyay’s *Design with Climate* book (1963) laid the foundation for an architecture based on outdoor climate [92].

Different outdoor conditions and the intended use of the building require divergent construction concepts to achieve energy efficiency, healthy indoor environment, and durability of the building. Architectural designers decide in the early design stage about the size, position and orientation of the building, insulation, fenestration, air-tightness, zoning, need for heating and cooling, mechanical or natural ventilation, shading, and thermal mass. Therefore, preliminary design, as a result of this stage, is based on the multidisciplinary holistic approach to the creation of new spatial objects in the existing environment. The successful applications of bioclimatic factors into BIM sustainable architectural design require an extensive knowledge in biology, climatology, and building physics [93]. Therefore, a cru-

cial part of the suggested framework for designers consists of the further education of the team members. The interdisciplinary knowledge might enhance the ability to understand and adequately interpret the relations between the indoor and outdoor climate conditions and the involved environmental systems.

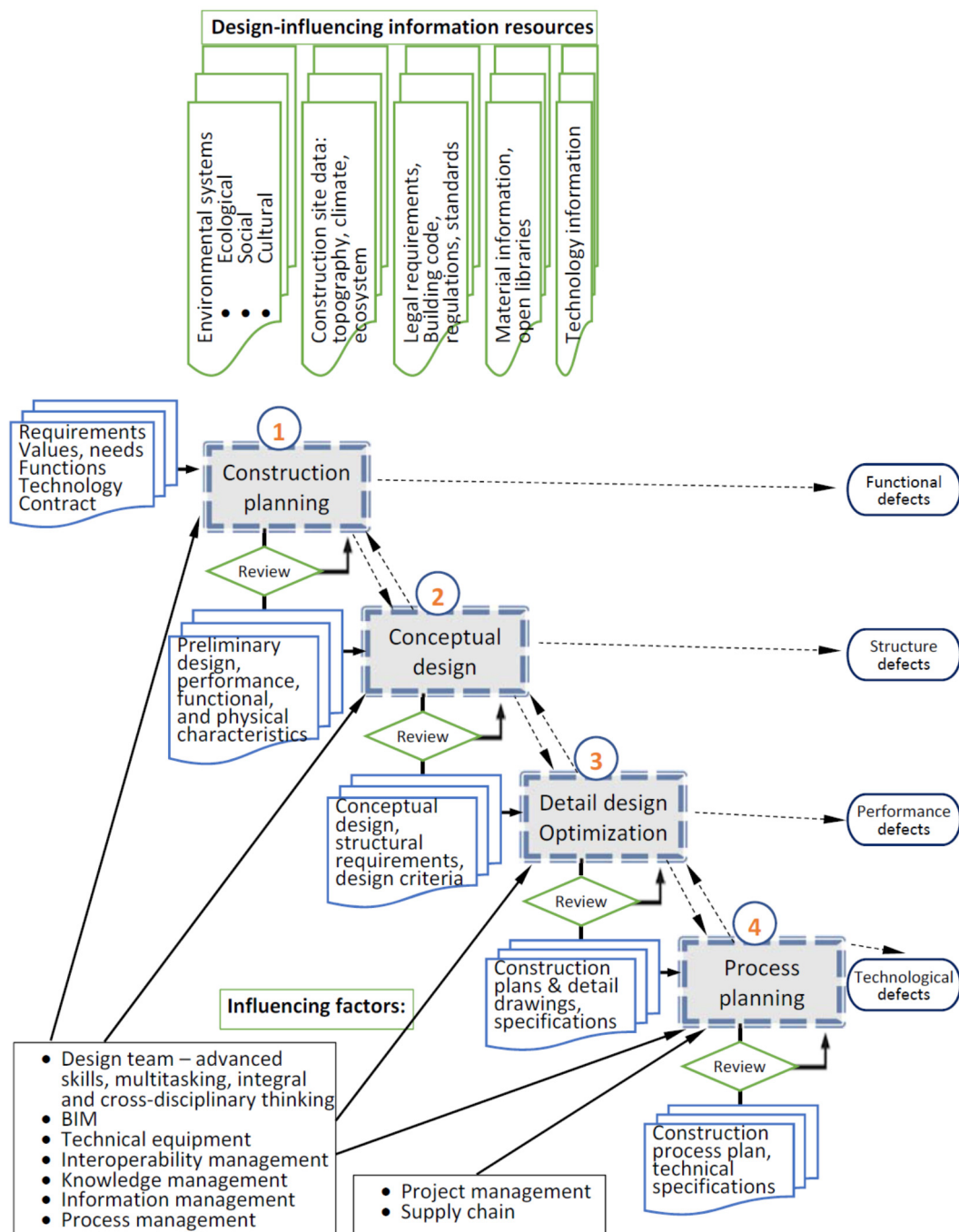


Figure 3. The structural relationship model of the CIDNZ framework, influencing factors, and design defects.

### 5.2. Step 2—Conceptual Design

At the conceptual design stage, demands, functions, and values need to be prioritized and identified from the perspective of all four quadrants. Therefore, CIDNZ adds to the technical system and human use perspectives [94], which represent the behavioural view (the upper right quadrant), intentional, social, and cultural perspectives.

At this stage, decisions are made that have an influence on the final carbon emissions [94], thermal and hygrothermal performance, indoor air quality, and the impact on the environment and human well-being. Designers aim to eliminate structure defects in the design [89]. The second step in the proposed design framework is comprised, therefore, of the determination of building structure, materials, assemblies, and technical systems. The objective of this stage is to optimize the thermal and hygrothermal performance of the building and minimize negative impacts on the environment and humans. The designer considers diverse factors, such as the energy demand of the building (in-build and operational), durability and quality of materials, risk of surface and interstitial condensation, and permanent wetting of the construction (wind-driven rain). Therefore, the composition of the roof and exterior walls should respect the outdoor and indoor situation to achieve a high energy efficiency and good hygrothermal performance of the building envelope.

Additionally, interior walls and ceilings provide a valuable area for moisture and thermal buffering. This research suggests distinguishing between the hygrothermal functions of interior elements and building envelope. This is new knowledge of this research, which allows for enhanced moisture management in buildings without affecting the primary functions of the building envelope. Practical moisture buffering (sorption and desorption of water) on a regular basis is according to the effective moisture penetration depth (EMPD) model only possible in a thin surface layer of interior material [95–97]. Accordingly, for every hygroscopic material there might be set an optimal moisture buffering thickness [98]. For some materials, such as the earth, there is only a thin layer (4 mm) sufficient to effectively manage the indoor RH amplitude [99]. Therefore, the selection of building materials and their purposeful placement represent an active approach to passive regulation of indoor RH [100].

### 5.3. Step 3—Detail Design and Optimization

The third step in the proposed framework by using BIM contains the incorporation of whole building energy simulation tools, such as DOE-2 or EnergyPlus [101–103] and whole building hygrothermal simulation tools, such as WUFI Plus into the design process [104–106]. The choice of building simulation programs depends on the personal experience of the designer, available hardware, and the frequency of usage [107]. Due to the fact that the sophisticated hygrothermal analysis by numerical simulation assesses building hygrothermal performance under real climatic conditions, diverse design options might be tested. The computer modelling WUFI Plus, which is fully compatible with BS EN 15026 [108], simulates the interactions between the building envelope, building services, outdoor conditions, and the proposed use of the building.

At this stage, designers aim to eliminate performance defects in the design [89]. Therefore, during the third stage of the design process, designers should consider the physical properties of the construction, humidity generated by occupancy, and external climate. The considerations include thoughts about the shape and orientation of the building in relation to the site topography, prevailing winds, sunlight, shade from the surroundings, and possible water intrusions (driving rain). The tasks in this design stage are in accordance with the recommendations of BS 5250:2011+A1:2016 Code of Practice for Control of Condensation in Buildings [109]. The assessment of the risk of surface and interstitial condensation and mould growth should follow the methods described in BS EN ISO 13788 [110]. Consequently, the incorporation of moisture transport mechanisms into the decision process might prevent the underestimation of heating and cooling energy [106]. Research shows that energy consumption by consideration of moisture effects might be significantly higher than by thermal simulation only [111,112]. Consequently, the employment of both thermal and hygrothermal simulation enables the evaluation of proposed construction and building materials. It supports decisions during the early stages of the design process when the costs for changes are the lowest [101].

Since the design defects are the prevalent causes of future costs during the construction process and building usage [113,114], it is vital to incorporate simulation as a means of



design check and optimization. The causes of the design defects are multiple, such as a lack of knowledge, time and costs pressure, or lack of motivation [115,116]. However, design defects are rarely mentioned in NZ, where most studies are concentrating on the defects caused by substandard workmanship or low quality of building materials [117,118]. Nevertheless, CIDNZ recognizes the value of defect-free housing design, and therefore introduces the concept of concurrent engineering into the construction industry in NZ. Concurrent engineering is based on the integration and concurrency as two fundamental design principles [119]. Integrated concurrent design considers information from all lifecycle issues and uses a multidisciplinary approach to the optimization of the end-product/building. Therefore, designers concentrate on functionality and performance design in the process of construction modelling [89]. Stakeholders, particularly supply chain members and users, are integrated into the design process in the early phases, which potentially benefits the project.

The steps described in the proposed framework might need to be repeated during the design process to achieve optimal thermal and hygrothermal performance of the building. For example, simulation results reveal that the decisions about fenestration in the preliminary design (first step) might cause overheating in summer. Therefore, the design needs changes to reduce solar radiation into the building. However, every decision requires thoughts about the impact of such changes on the whole system, particularly future users. In this example, thoughts need to be given concerning daylight, shading, energy balance during winter and summer, etc. Therefore, designers should include building performance analysis into the design process. Building performance analysis enables ensuring that buildings meet the minimum performance thresholds as required by law; furthermore, the quality of indoor environment, sustainability, and energy savings might be optimized. This requires the incorporation of other building performance domains, such as lighting, sound, ventilation, indoor air quality, and others [120].

#### 5.4. Step 4—Process Planning

The fourth step in the proposed framework is the final stage of the design process, which simultaneously constitutes the first part of the construction process. Process planning connects (in any manufacturing system) product design to manufacturing [121]. The construction process is a manufacturing process with several specific characteristics [122]. Therefore, the integration of process planning into CIDNZ might enhance the efficiency of the construction process, saving time and costs. During this stage, the designer team finalizes the building design and specifications as the result of the optimization process of the previous three stages. Designers aim at this stage to eliminate technological defects in the design [89]. The outcome of process planning includes construction process plan and the technical documentation, such as drawings for construction, design specifications, and other necessary documentation.

Construction process planning and control in CIDNZ might implement diverse activity, location, or objects-based methodologies, such as critical path method (CPM), earned value analysis (EVA), last planner system (LPS), line of balance (LOB), Flow-line, location based management system (LBMS), and building information modelling (BIM) [122]. The choice of the project-specific and suitable methodology or their combination depends on the project planning, scheduling, and monitoring perspective of the project execution team.

The proposed framework for designers requires an integration process of the system approach addressed by the following section.

## 6. Integration of the System Approach

CIDNZ seeks to complement the construction process with a complex integral system through integration spanning from design intent to successful commissioning, operation, maintenance, and decommissioning in balance with nature and well-being of humans. Civilization resilience, expressed as the relationship between environmental systems (inclusive

social, political, economic, and ecological structure) and well-being, relies on knowledge, institutions, and infrastructure [123].

ISO/IEC/IEEE International Standard defines system integration as “... progressive assembling of system components into the whole system” [22] (p. 454). The integration process of the system approach, therefore, depicts three significant features: knowing, doing, and inhabiting. CIDNZ is an interdisciplinary, multilevel, and evolving knowledge system that integrates building physics, systems and integral thinking, modelling, energy calculations, design and architecture, comfort analysis, building services design, management, and other academic fields. However, some knowledge is only possible by learning-by-doing [124]. Therefore, CIDNZ encourages creativity, curiosity, innovative thinking, and testing results. Especially, finding new ways to look at things and new collaborations which might bring diversity and improve solutions to existing problems. As DeKay and Bennett wrote: “... An Integral Design Theory has to be not only explanatory but also analytic, generative and evaluative” [48] (p. 433). Equally crucial to innovative thinking is sharing knowledge. Therefore, life-long education and communication of what we know supports the integration process.

CIDNZ is contemporaneously an action system. By “doing”, CIDNZ integration provides a platform for change. The goal is to raise standards by framing the cross-disciplinary problem in zero-energy sustainable housing. All homes in NZ have to be built to the minimum legal standards. However, the NZ Building Code is behind the international standards for comparable climate [125,126]. Consequently, the costs over the whole life cycle of the houses built to the minimum legal standards are much higher than by houses built to a higher standard [127]. Therefore, CIDNZ advocates for code changes to promote better results.

The inhabiting of the evolving knowledge and action brings clear communication about the integral meaning of sustainability and leadership in times of change. Therefore, CIDNZ might improve on our understanding of housing design, mobilize and activate creativity, and bring innovations. The complex integral approach to design is a new way to adapt the built environment to the changing world. The integration of the system approach might follow a spiral development of thinking which Hokoï employed by his hygrothermal research and described as: “Understand an issue through simplification, complicate the issue by looking at it in a complicated manner or extending the issue, and simplify the complicated issue again by looking at it with a more advanced and clearer understanding” [128] (p. 5). Consequently, with the look of an advanced and more precise understanding, the following section evaluates the process of transformation and integration of the system approach.

### *6.1. Evaluation of CIDNZ*

Radical changes are necessary to achieve cost-effectiveness, waste and energy reduction, health enhancement of people, and harmonization of the built environment with the natural system on Earth. CIDNZ expresses a proposal on how to achieve these changes. This section addresses thoughts and questions about the evaluation of the integration process. How does one evaluate a complex process which embodies non-quantifiable measures? Another question accrues when we consider the value of the well-being of people. How might we measure the success of a project in these dimensions? The researchers suggest the evaluation of CIDNZ as a system that can be measured, refined, and optimized.

However, the CIDNZ evaluation is not based on a points system because values of a multilevel and complex system may not be interchangeable or attainable due to their diverse qualitative and quantitative measures [129]. Additionally, composite finite sums are markedly different from simple finite sums where the defining properties of simple finite sums and their fundamental recurrence identity are no longer valid [130]. The assessment of complex system changes needs to account for time, as effects of feedback loops emerge over time [129]. Therefore, the CIDNZ system inhabits a feedback loop, which leads inescapably to improvements. The feedback is supported by a sense of internal conviction

that the design team is willing to find the optimal design solution. The system is based on the integral and critical thinking which seeks adversity and willingness to change not only the opinion but the rules as well. This system is supporting the belief that it exists in multiple ways to reach the goal. Therefore, the evaluation of this system forms holistic and perspectival answers to the question of how well the system serves the goal towards the well-being of people and balance with nature.

#### 6.1.1. System Definition and Structure

Systems and Software Engineering Vocabulary defines a system as:

1. Combination of interacting elements organized to achieve one or more stated purposes;
2. Product of an acquisition process that is delivered to the user;
3. Something of interest as a whole or as comprised of parts;
4. Interacting combination of elements to accomplish a defined objective;
5. Set of interrelated or interacting elements [22] (p. 453).

The integration of the system approach will, therefore, require more research and detailed system description and analysis to determine the organization, information, hardware and software requirements, and processes of the CIDNZ system. Simultaneously, it will identify relations inside of the system and to other systems. Therefore, the following section delineates the evaluation characteristics of the CIDNZ elements, which will need further development.

#### 6.1.2. System Elements

This research proposes an evaluation of the system based on the four elements described in Section 4: people, processes across all project phases, interoperable technologies, and environmental systems. The system elements are evaluated by using the integral approach with an application of perspectival mindsets. This means that the evaluation aims at a multiperspectival and holistic characteristic. This section suggests the broad characteristics of the evaluation process, which will need further development and specification in detail.

The evaluation of the people-element involves the identification and evaluation of values related to individuals, such as team members and stakeholders (inclusive users/inhabitants and supply chain members), and collectives, such as cultures and societies. Table 1 depicts some of the suggested values.

**Table 1.** Evaluation characteristics of the people-element.

Individual Values	Collective Values
Qualification of team members, multitasking, integral and holistic thinking, life-long learning	Sharing of knowledge, education programs on all levels, praxis-oriented, management and cross-disciplinary education
Communication, collaboration, acceptance, respect, motivation, conflict management, negotiation	Financial and social benefits of cooperation, learning from past experiences
Willingness to experiment, innovate, change, ability to adapt, listen to others	Peer-review, recognition, learning by doing, new career development
Users/inhabitants values and needs reflected in the project	Cultural, aesthetical, societal values and needs reflected in the project
Stakeholders' cooperation, free information flow in all directions	Savings in time, costs, and material; realization of whole-life value

The involvement of stakeholders into the CIDNZ process might bring multiple values that are only partly measurable, for example, waste reduction, savings in time, costs, and materials, or improvements in the indoor environment, quality and performance of the building. However, the benefits of the complex integral system approach are often hidden in non-quantifiable values, such as enhanced well-being of inhabitants,

company reputation, knowledge of team members, or non-disturbance of the natural habitat. Therefore, a complex evaluation of the processes-element belongs to the delivered values of the CIDNZ integration. Table 2 delineates evaluation characteristics for the processes across all project phases.

**Table 2.** Evaluation characteristics of processes across all project phases.

Processes across All Project Phases	Values
Organizational structure	Level of integration of information and automation systems enabling a free flow of information
Analysis of processes	Holistic, modular, procurement models, identification of best practices, flexible, configurable according to project information and needs
Analysis of supply chain and team members	Co-operation, collaboration, acceptance, respect
Involvement of stakeholders	Improvements in quality and performance of buildings, well-being of inhabitants
Professions of CIDNZ team members	Correspondence to the overall aim of the project; enabling of the cross-disciplinary approach in all of the four quadrants
Knowledge management	Enhancement of structural and process efficiency
BIM and analytical tools, such as hygrothermal modelling	Level of implementation and interoperability
Integrated Project Delivery (IPD)	Level of implementation
Lean design and construction	Improvements in the management and production, just-in-time and implementation of information technology to minimize excess labour or stock of goods
Process efficiency analysis	Influence on ROI, waste, CO <sub>2</sub> emissions, eco-systems, and reduction of design defects. Loop between evaluation—recognition of necessary changes—implementation of measures—evaluation

The evaluation of technologies is mainly oriented on interoperability analysis of the design and construction technology to achieve optimized solutions and higher value levels in the AEC sector. Examples of questions related to the evaluation of technologies and their interoperability are listed in Table 3.

**Table 3.** Evaluation characteristics of technologies and interoperability.

Do the Implemented Technologies Allow for ...
Experimentation and simulation of design variants over the full life-cycle?
Flexible processes and modular tools?
Interaction with users, flexible and adaptable to changing needs?
Development of interfaces to standards?
Optimization of thermal and hygrothermal performance, daylight, quality of indoor air, etc.?
Assessment of the impact on environmental systems?
Collaboration between stakeholders, sharing of models and information?
Reduction of functional, structure, performance, and technological defects?
Open BIM across all project phases and actualized as-built?
Open libraries and quality of data?

The evaluation of environmental systems aims to assess the influence of CIDNZ on all involved systems, flexibility, and balance between them. This evaluation is, therefore, complex and requires further research. Some examples of possible evaluation characteristics of environmental systems are listed in Table 4.

**Table 4.** Evaluation characteristics of environmental systems.

Questions in the Evaluation of Environmental Systems
What the involved environmental systems represent?
How are the environmental systems formed, interconnected, and interdependent?
What is the structure of the involved environmental systems?
Is the built-system flexible to allow balance of the whole eco-system?
What are the critical sub-systems and how might be adapted or redesigned not to harm other systems, such as natural systems or people?
What is the quality of the indoor environment?

### 6.1.3. System Effectiveness

CIDNZ assessments bring together evaluations between material and immaterial, and individual and collective values. The critical question is if the system brings some balance between these values and if the balance can be maintained during the whole life cycle. The system evaluation starts, therefore, with the system description “... defining the organization, essential characteristics and the hardware and software requirements of the system” [22] (p. 453).

The next step in the evaluation process represents the description of the system breakdown structure (SBS). ISO/IEC/IEEE 24748-4:2016 defines SBS (as cited in ISO/IEC/IEEE 24765:2017) as: “1. system hierarchy, with identified enabling systems, and personnel that is typically used to assign development teams, support technical reviews, and to partition the assigned work and associated resource allocations to each of the tasks necessary to accomplish the technical objectives of the project” [22] (p. 453).

SBS forms the basis for cost tracking and control and supports system effectiveness analysis to determine the level of the system’s performance in the intended environment [22]. In this point, a clear distinction between possible complementary effectiveness analyses should assist the interpretation of the analysis results. The CIDNZ evaluation and transformation include sustainability assessment, which “... always involves social systems that have their own perspectives, with meaning, values, and logics” [131] (p. 5).

Therefore, two kinds of complementary assessment tools should be developed. Each of these tools has different perspectives and values. An entire CIDNZ assessment tool, describing in detail and evaluating the implementation of the complex integral system approach to building industry, and a swift CIDNZ assessment tool, allowing for the fast overview, learning, and motivation. The swift CIDNZ assessment tool will constitute a set of criteria (Table 5). The analysis of these criteria will lead to an evaluation of multiple integration aspects but no quantification nor ranking. The purpose of this tool is to support the integration process and help to identify areas that need attention or more development. Therefore, coaching for appropriate tool use should accompany the integration process of the system approach and its evaluation.

The CIDNZ assessment tools include some aspects which are not used by Green Public Procurement (Green Public Procurement was developed by EU and is defined as “a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life-cycle when compared to goods, services and works with the same primary function that would otherwise be procured” (as cited in [132] p. 1)), such as nature and biodiversity, and passive building design strategies. Examples of passive building design strategies include the use of solar energy, thermal mass, and natural ventilation to limit energy demand and the utilization of roof overhang or vegetation for shading [133]. The passive measures for hygric indoor climate regulation, such as moisture buffering by hygroscopic materials, can help to minimize or eliminate energy use for air conditioning technology while maintaining indoor comfort [134].



**Table 5.** Swift CIDNZ assessment tool criteria.

Stage/Step	Indicator
Construction planning	Selection of design team—cross-disciplinary and multitasking, collaborative Environmental systems analysis—nature, biodiversity, and the impact of the planned construction on these systems Construction site analysis, position, and orientation of the building Knowledge and information management BIM Principles of IPD and Lean design and construction Process and interoperability management Functions, requirements, values, needs—based on all four quadrants A contract between major stakeholders (minimum between designer, owner/investor, and construction company)
Conceptual design	Performance requirements Materials information and selection, life cycle assessment (embodied CO <sub>2</sub> combined with durability assessment) Functional and physical characteristics specified
Detail design and optimization	Thermal and hygrothermal performance optimization (energy demand in kWh/m <sup>2</sup> , ventilation, heating, thermal mass, shading, passive solar, moisture buffering, mould prevention, etc.) Airtightness—diffusion open materials Building energy, HVAC, lighting, and data management Daylight and quality of lighting Acoustics—noise reduction Quality of indoor air—pollutants, temperature, humidity, ventilation—well-being aspects Design for durability and resilience—the quality of materials, evaluation of hygrothermal relations, emissivity Water saving measures—use of rainwater, dual waste water system allowing for recycling of water from sinks, washing machines, showers, and baths for watering the garden or flushing toilets after local treatment Energy sources—passive measures, renewable energy
Process planning	Project management—inter-disciplinary knowledge Supply chain optimization, just-in-time Waste management—reducing and recycling waste Testing of airtightness, energy performance, quality of indoor air, water and light, thermal and humidity comfort, acoustics, visual and aesthetic comfort BIM—as-built data actualization

The CIDNZ focusses on improving the housing quality in NZ. This research understands buildings as man-made environmental systems, and therefore, the changes go beyond technical and organizational issues. By viewing CIDNZ as a four-quadrant holon, the assessment of system effectiveness includes all aspects of the system phenomenon. Since the people aspect is primary, change must be built on the willingness, enthusiasm, and knowledge of stakeholders and end users. Therefore, CIDNZ system effectiveness depends on the ability to learn from existing theories and approaches, past experiences, scientific research, and nature.

## 7. Conclusions

The CIDNZ approach is of transformation, in which the first phase is of strong transition. The strong transition involves the integration of science in diverse fields, identification of problems, adaptation and redesign of critical systems in the AEC industry, and management of the transformation process.

The suggested integration of scientific achievements, available tools, and partial knowledge into the design process of houses in a holistic and integral way—named Complex Integral Design New Zealand (CIDNZ)—is likely to change the quality of houses. The proposed framework is introducing a new perspective on how to design warmer, drier, and healthier houses for the NZ context. CIDNZ encourages architectural and engineering

design to adopt a new way of thinking, which is based on integrative and interdisciplinary principles. The consequent practical application of these principles and integral thinking might eliminate or reduce the design defects and lead consequently to the reduction of costs involved in their rectification. The perspective of the design process transforms from originally cost-oriented view (cheap and fast built) to a complex system to create healthy, energy-efficient, zero-energy buildings without a negative influence on the environment and in harmony with life and nature.

The core of the transformation lies in the values and worldview which each stakeholder holds. Consequently, CIDNZ introduces a novel understanding of sustainability in housing. Sustainable system succours to establish and maintain a balance between individuals, groups, society, and existing ecosystems. Therefore, the future housing (created by the CIDNZ principles) will be durable, less disturbing to the natural habitat, less polluting the environment, constructed from high quality, recyclable or reusable materials, have a healthy indoor environment, and enhance quality of life. The proposed CIDNZ framework is flexible, allowing the addition of new perspectives. It focuses on people by respecting a broad spectrum of human needs, including physical, psychological, social, and spiritual. Therefore, the housing will enhance humans' individual and social lives, harmonize with larger environmental systems, and be adaptive to changing needs.

## 8. Summary

The problem of energy-inefficient, unhealthy, cold, mouldy, and damp housing in NZ is complex and therefore cannot be solved with the same methods as it was created. This article proposes CIDNZ, a comprehensive and balanced system-based design and delivery process that facilitates and accelerates cross-disciplinary and trans-disciplinary expertise and knowledge. The necessary CIDNZ transformation process involves a movement of values toward the integral worldview domain, that is based on humanistic, systems, and holistic views. Consequently, the emerging novel understanding of sustainability, which is accepting human nature as it is and leading to a balance between individuals, groups, society, and the existing ecosystems, guides the transformation process.

CIDNZ comprises all stages in the life cycle of buildings and all significant aspects in the AEC industry, particularly, people, processes, technology, and environment. Therefore, the process of transformation addresses relations to the environment, stakeholders, technologies, and processes involved in the design, delivery, usage, and decommissioning of buildings. Simultaneously, the process of transformation necessitates support from research and education. The proposed complex integral framework integrates in four steps construction planning and design, optimization, and control tools at strategic, tactical, and operational levels. The framework offers stakeholders the possibility to actively engage in the design and construction process, influence the impact of the building on the environment, and be informed about concurrent design variants. Consequently, the whole construction process implements a system approach to buildings as a vital part of the environmental systems, goes from the environment to humans and vice versa, and offers unlimited possibilities.

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