ISSN: 2008-5079 / EISSN: 2538-2365
DOI: 10.22034/AAUD.2020.183579.1862

The Role of Parametric System in the Analysis of Sim Van Der Ryn's Ecological Architecture Principles in Iranian Plateau*

Ali Ziaee[a]- Hamed Moztarzadeh[b]- Khosro Movahed[c]**

[a] Ph.D. Student in Architecture, Department of Architecture, Shiraz Branch, Islamic Azad University, Shiraz, Iran.
[b] Assistant Professor of Architecture, Department of Architecture, Shiraz Branch, Islamic Azad University, Shiraz, Iran (Corresponding Author).
[c] Associate Professor of Architecture, Department of Architecture, Shiraz Branch, Islamic Azad University, Shiraz, Iran.

Received 28 April 2019; Revised 22 December 2019; Accepted 18 February 2020; Available Online 20 June 2020

ABSTRACT

The present study focuses on the five principles of ecological architecture defined by Ryn and Cowan (2007) to analyze the contemporary architecture of Iranian plateau. In the present study, a parametric mechanism based on mathematical algorithms and the graph theory are applied to implement these principles to evaluate and design architectural projects. This study begins with the design of a decision tree search system as the agent of searching the concepts, then complements this system with the graph theory to implement the principles. The graph theory allows numerous iteration of the algorithm. Two vertices of the graph theory, extracted from the decision tree search system, are attributed to the concepts of architectural and ecological system. The five edges of the graph connect the vertices together bilaterally, each reflecting one of the five principles. Overall, using the algorithm and its derived graphs, the desired outputs can be cast into different independent diagrams. Gephi application is recommended and applied to analyze the graph in this study. To test our algorithms on Iran's contemporary architecture, the data are gathered based on the survey of the portfolios of leading architectural designers who currently work under Architectural Engineering System (AES) with license No. 352 in Pars Province in Iran. The expertise and the practical experience of the AES members are highly respected and often noted. These data enable us to employ a 'bipartite' approach whereby the desired, ideal, or optimum outcomes are set in contrast with the existing Iranian apartment buildings that are currently in use. We employ several social factors (structures) as selective concepts. First, the organization of this study is discussed and then, the data are applied to analyze the results.

Keywords: Parametric System, Ecological Architecture, Graph Theory, Social Structure.

* This article is derived from the first author's doctoral thesis entitled "An Analytical Study Using Parametric Design Basics in Contemporary World Architecture (Case Study of Impact in Iranian Contemporary Architecture)" in the field of architecture, under the supervision of the second author and consultant of the third author at the Department of Architecture, Shiraz Branch, Islamic Azad University, Shiraz, Iran.

** E_mail: hamed.moztarzadeh@gmail.com

1. INTRODUCTION

Today, we live in two interpenetrating worlds. The first world is the result of over four billion years of continuous evolution. The second is the world of roads and cities, created by people over the many years of their lives. Viewing these two worlds side by side, the thread of unsustainability and imbalance is apparent that 4 billion-year approach is proven to be sustainableof both of them! (Instance & Ackerman, 2014; Ceballos & Ehrlich, 2015; Cullen & Allwood, 2012; Einstein, 2013; Hanh, 2013; Hansen, 2010). There is also a lack of consensus, cohesion, and logical dialogue which, in turn, is exacerbated increasingly by multitude undesirable environmental problems (Ryn & Cowan, 2007; Duval, 2010; Hawken & Lovins, 2010; Kolbert, 2014; Klein, 2015).

Notable among the above research is the pioneering work of Ryn and Cowan (2007). They offer some ground-breaking theories on ecology. Specifically, they posit five ecological principles that identify contrasts between these worlds physically and socially. The ecological principles identify the link between living creatures and the environment (Curry, 2008; Lappe, 2011, 2001; Mann, 2016; Lappe, 2010).

We propose a parametric system within an algorithm to analyze Ryn and Cowan's (2007) five ecological principles. Accepting and relying on Ryn and Cowan's theories, our focus in this paper is to examine their applicability to special cases and their extension to critically evaluate architectural designs in special geographical setting.

The parametric system is a new approach in architecture. It relies on mathematical principles and has been increasingly recognized as a computer-based design tool. In the present study, the final parametric system is supplememted with the graph theory, which is an established means for categorizing proposed structures. The graph theory provides the final structure of the intended design and plays the role of the final model within the algorithm.

Due to their extensive practical background and field experience, the members of this organization are generally viewed as experts in the field. So, for implementation and practical test, the architectural designers, who currently work under Architectural Engineering System with license No. 352 in Pars Province in Iran (AES henceforth), are asked to test the final algorithm. One of the authors of this paper is a member of this organization. In particular, their positions on comparative analyses and their evaluation of 'desired' building designs algorithm, compared with 'actual' one, are valuable to this study. We have drawn heavily on their views and internal portfolios in defining, partitioning, and associating the architectural ecological factors of typical Iranian residential apartment buildings into two groups for evaluation under Ryn and Cowan's five theoretical principles. We follow a 'bipartite' approach whereby the optimum (= desired or ideal) outcomes are set in contrast with the existing actual (= status quo) Iranian apartment buildings that are currently in use.

In the mathematical field of graph theory, a bipartite graph (or bigraph) is a graph whose vertices can be divided into two disjoint and independent sets and such that every edge connects with one or more vertex.

The residential apartment buildings selected are very typical in the Iranian plateau. To this extent, our research may be considered wide in its scope even though it derives its parameters within the samples that are already defined within the program. Notwithstanding, the outcome of our algorithm may still be viewed as samples of a proposed larger algorithm. Designing and encoding of comprehensive algorithms to address a large population samples need a team consisting of several experts in the fields of architecture and computer programming.

2. RESEARCH QUESTIONS AND HYPOTHESIS

We draw upon Ryn and Cowan's (2007) five ecological principles. It is assumed that they are valid and informative enough to critically evaluate architectural ecological factors. The present study aims to: a) examine how the ecological architecture principles of Ryn and Cowan can be converted to a mechanism to design and evaluate a project via identifying and relying on a parametric system, and b) apply the algorithm of our research along with the analysis of Ryn and Cowan's principles to typical contemporary residential apartment buildings in the Iranian plateau.

We apply two hypotheses:

H_1 Relying on mathematical principles and a properly designed algorithm, and based on the graph theory, it is posited that a parametric system can be applied to use the five architectural principles of Ryn and Cowan (2007) to analyze and criticize the ecology of architectural work.

H_2 Within the context of H_1, it is posited that the final algorithm of this study can be used to design and criticize the various plans in the field of architecture. To demonstrate and test this hypothesis, an additional group consisting of eight principles is also employed and the relation between Iran's optimum (= desired or ideal) and actual (=status quo) contemporary ecological architecture is evaluated using the final algorithm of this study.

3. METHODOLOGY

The present study is qualitative research carried out using content analysis. The content analysis includes three phases: 1. Preparation and organization, 2. Investigation of materials and messages, including data encryption and their categorization, and 3. Processing the extracted data, and providing the final conclusion (Sarmad, Bazargan, & Hejazi, 2014, p. 132). These are shown in Figure 1.

Fig. 1. Content Analysis Process
(Sarmad, Bazargan, & Hejazi, 2014)

The qualitative research process is often drawn according to the subject and content of the study. It is not a unique process to be conducted in one format, but rather it is mostly designed based on the subject (Kreswell, 2017). Qualitative studies generally include six levels:

1. To organize and prepare the analysis, 2. To investigate data comprehensively and formulate hypotheses based on data, 3. To analyze the details within a data encryption process, 4. To apply encryption process to describe the data or themes for analysis, 5. To identify and explain the causality and trends, if any, in qualitative relations, and 6. To analyze, interpret, and extract results from data (Fig. 2).

The validity and reliability in a qualitative study is not same as in a quantitative one. These features mean that the researcher investigates the accuracy of findings using particular qualitative methods. In addition, the researcher is responsible for interpreting the various outcomes in the process of study (Kreswell, 2017).

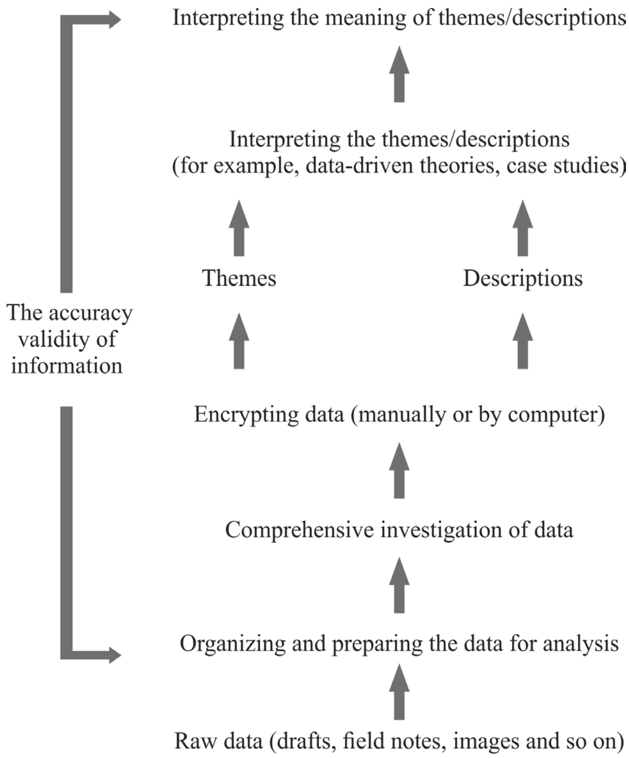


Fig. 2. Data Analysis in Qualitative Research
(Kreswell, 2017)

Given that the present study is primarily qualitative, the above six steps are applied to analyze the data. Next, the content analysis and the qualitative methodology are combined together (Purmaka, 2012; Kreswell, 2017). In other words, the above specified qualitative methodology (Fig. 2) can be used in the three separate processes of content analysis (Fig. 1). Thus, combining figures 1 and 2, the two methods can be used in parallel or sequentially.

3.1. Parametric System

Parametric systems are often based on algorithms (Bastian, Heymann, & Jacomy, 2009; Khabbazi, 2012). Irrespective of their complexity or nonlinearity, some degree of compatibility and accountability among the parameters are required to meet appropriate criteria and render a stable process (Abbaszadeh, Sadafian Shayesteh, & Kamelnia, 2014). Simply stated, an algorithm is a limited set of instructions completing a particular goal in limited steps, based on the inputs provided by one or more parameters. Therefore, parametric design may be regarded as a subgroup of an algorithmic design that is precisely defined in its structure (Abbaszadeh, Sadafian Shayesteh, & Kamelnia, 2014) (Fig. 3).

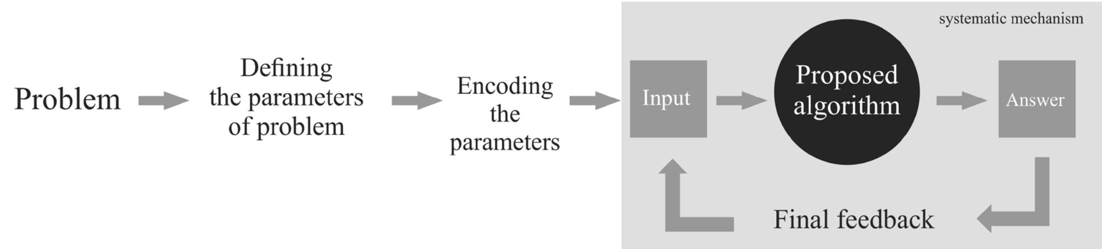


Fig. 3. The Parametric System Mechanism
(Abbaszadeh, Sadafian Shayesteh, & Kamelnia, 2014)

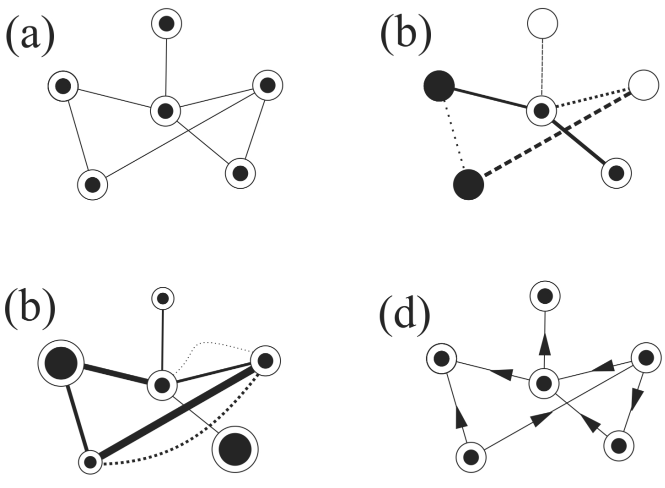
In simple linear design processes, evaluation and comparison of the outcome may be undertaken manually. But, simple linear designs cannot account for the complications that are present in today's designs and requirements. (Abbaszadeh, Sadafian Shayesteh, & Kamelnia, 2014).

4. ECOLOGICAL ARCHITECTURE

Ecology is the knowledge of investigating the interactions between living creatures and their ecosystem. It can be considered as the oldest human science (Yeang, 1995; Klaus, 1995; McKibben, 2010; Macy & Johnstone, 2012; McDonough, 2013). It tries to identify relevant factors and provide at leastbasic knowledge that human beings need to know to recognize their place and time on planet Earth (Lovins & Rocky Mountain Institute, 2013; Hertsgaard, 2012; Jey & Lester, 2001).
The first group of ecologists, who were pragmatists, tried to identify the dispersion and frequency of animals and use such knowledge for the collective benefits of mankind (Klaus, 1995). The theory of designing and directing the various dimensions of ecological system into architecture is well known as Sim Van der Ryn's ecological architecture. This theory includes those designs that minimize the destructive environmental effects through merging with life processes. This theory also well seeks to link the dispersed efforts of green architecture, sustainable agriculture, environmental engineering, environmental restoration, and interactions among related fields (Olanike, 2011; Pipher, 2013).
To posit the above theory fully, Ryn and Cowan (2007) propose five venues, known as the comprehensive five-step ecological theory of Ryn. In brief, these steps are: 1. Solutions Grow from Place, 2. Ecological Accounting Informs Design, 3. Design with Nature, 4. Everyone is a Designer, and 5. Make Nature Visible (Ryn & Cowan, 2007, p. 69).

5. THE GRAPH THEORY

The concept of graph was first proposed in 1736 by Leonard Euler through providing a solution for the problem of Konigsberg bridges. A graph is a set of vertices (nodes), edges, and the relations between them. A set of nodes that are connected by some lines is the simplest form of a graph. (Saberian, Mak, & Hamrah, 2012) (Fig. 4).



This figure includes a sample of four different graphs; a) a simple graph without direction with a type of edge or fixed node, b) a graph with different vertices and edges, c) a graph with different weights for its edges when there are more than one edges between two nodes, and d) a graph with directed edges

Fig. 4. Some Examples of Different Graphs
(Saberian, Mak, & Hamrah, 2012)

Many computer applications have been designed and marketed in this field, some at significant prices. In this regard, 'Gephi' is a notable example. It is exclusively dedicated to design, computation, and production of graphs. 'Gephi' enables the researcher to calculate and draw graphs for up to one million edges for various analyses (Bastian, Heymann, & Jacomy, 2009).

6. DATA AND CONTENT ANALYSES: APPLICATION TO IRANIAN PLATEAU

To test our algorithm on Iranian architectural designs, the data were gathered based on the survey of the portfolios of leading architectural designers that currently work under Architectural Engineering System (AES) with license No. 352 in Pars Province in Iran[1]. The expertise and the practical experience of the AES members are highly respected and often noted. Considering the current inventory of about 400 typical residential apartment buildings that these members had dealt with, or that they were aware of, we selected about 100 of them and sought their views as to what architectural designs they considered optimum (= ideal or desired) as compared with the existing apartment buildings. We delineated their responses into two groups: optimum (= ideal or desired) and actual outcomes. The input data are built upon information from the AES portfolios and focused on typical residential apartment buildings that AES accumulated during nearly the past 15 years or so as a byproduct of their professional activities. These data enable us to employ a 'bipartite' approach whereby the desired, ideal, or optimum outcomes are set in contrast with the existing Iranian apartment buildings that are currently in use. We employ several social factors (structures) as selective concepts. Below, we first establish and briefly discuss our general set-up. Then we move on to present our empirics.

6.1. Set-up of the Entire System: Qualitative Discussions

Ryn and Cowan's ecological architecture provides particular criteria for designing and criticizing architectural works through its five principles. Given the extensive amount of data that these principles require, and the need for iterating over them, the Graph theory was selected as an authentetic tool to achieve the research goal. This is because Graph theory is capable of organizing and portraying a huge volume of data via a cohesive and trustable method. We follow a parallel process whereby we take a combination of the three 'content analysis steps' and the six 'qualitative research stages'.

To start with, it was recognized that the data should be first categorized by the subject. We were privileged to have input data from the AES design portfolios. Thus, the collected data were organized and categorized accordingly. It was recognized that a mechanism is required in this study for controlling (=limiting) the numerous ranges of the data to a feasible set. This range is widely available based on today facilities on the internet. To retrieve and categorize our data from the reference networks, we resorted to a parametric mechanism as discussed earlier. A decision tree search and a sort-out algorithm with multiple (unlimited) sub-branches that form, in some sense, the edges or paths in our algorithm, were employedto consider this process to be relatively advanced in terms of searching, categorizing, and eliminating irrelevant or unrelated factors. This algorithm can then be used for the content search using specified keywords related to the subject of our study. In addition, the algorithm, as designed, is kept open to search all related keywords to the subject in the wide zone of internet before putting them in pre-determined categories.

In search of more data input, we consider simultaneously categorization by subject, relevance, feasibility, consistency, and fit to be captured within our proposed algorithm (Fig. 5).

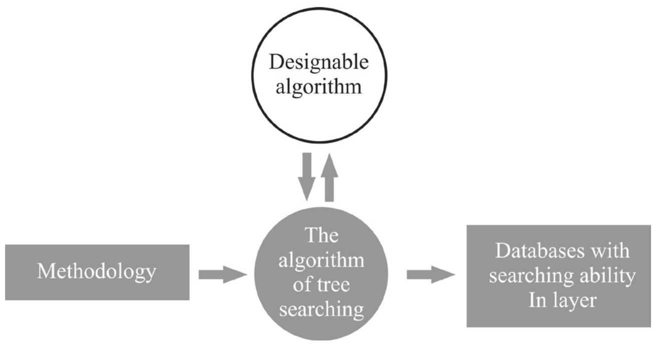


Fig. 5. Collecting Information Using Decision-tree Search Algorithm
(Ryn & Cowan, 2007)

As a mechanism for converting the five principles of Ryn and Cowan to an algorithmic mechanism, a parametric system was applied. The content analysis methodology, as discussed earlier, includes three general steps. These are already depicted in Diagram 1 in Section 3, i.e. methodology. Designers and critics of architecture may analyze the degree of the relationship between the work and its ecological context by choosing different contents, each in accordance with one or more of the five principles. The architectural work can then be designed, documented, analyzed, and rated based on the extent the work is compatible with these five principles. Each of the five principles is a criterion that can criticize various concepts extracted from each work. The contents involve all concepts and attitudes that somehow establish a relationship between architecture and ecology.

Choosing, categorizing, and encoding contents are conducted through a six-step 'qualitative' methodology. To identify the sources of concepts, we employ a systematic mechanism for qualitative extraction of information from the internet, as is summarized in Diagram 3. We embrace a great number of factors and venues in our list, including: behavioral models, performance models, social structures, spatial proportions, hierarchy, calmness, movement, dynamicity, and many other concepts. Then, Ryn and Cowan's five principles of ecology are applied as criteria to establish and analyze the rate of relationship between architecture and ecological context in terms of the concepts identified in our list (Fig. 6).

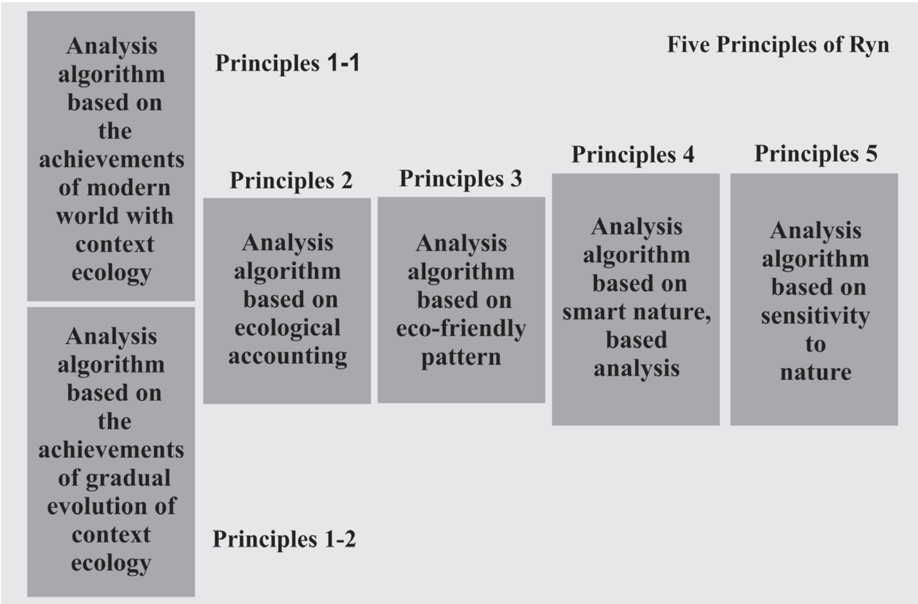


Fig. 6. First Phase of Our Content Analysis
(Ryn & Cowan, 2007)

In the second phase of content analysis, the parametric system is applied to investigate the intended design and criticize it in light of Ryn and Cowan's principles. At this point, we may use the principles either to design a new work or to critically examine an existing one. Given the views of the AES members, our analyses fall in the latter category.

We do some encoding in this phase and employ some preliminary levels of mathematical algorithm. In this phase, choosing each concept, relying on a particular aspect of the proposed algorithm, establishing the relationship of the concepts with Ryn's ecological criteria are investigated. Positive, negative, or middle range values are also determined (Fig. 7).

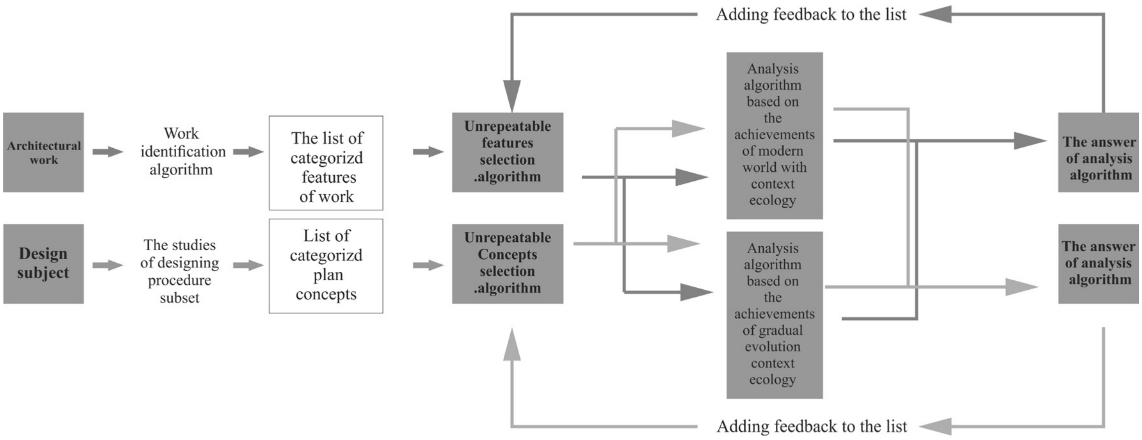


Fig. 7. Second Phase of Content Analysis
(i.e., Solutions Grow from Place)

The same steps presented in Figure 7 are applied for other principles. The brief algorithm of Ryn and Cowan's five architectural principles is shown in Figure 8.

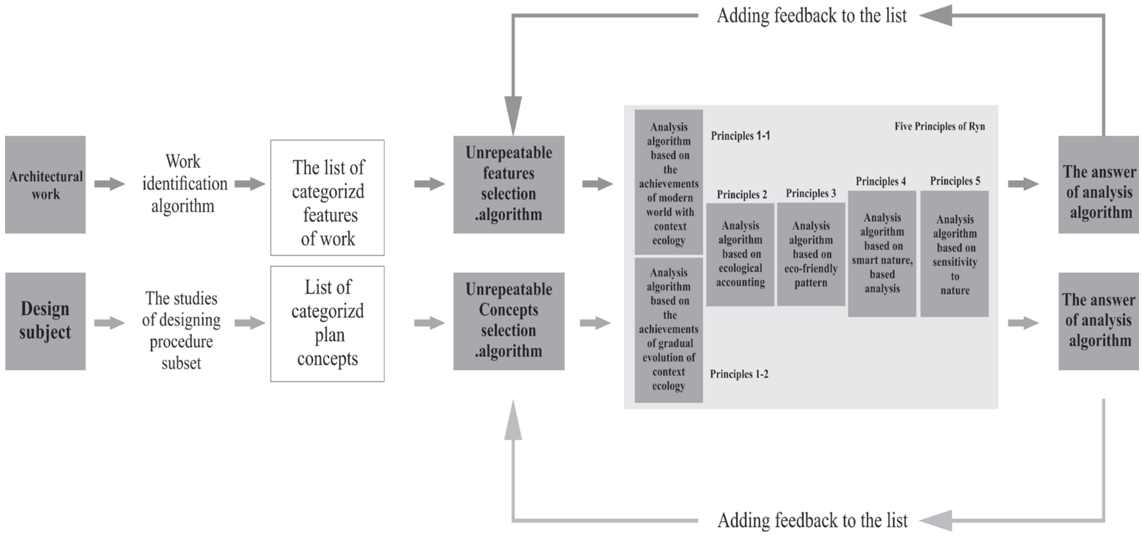


Fig. 8. Second Phase of Content Analysis

In the third step of content analysis, the extracted data are processed and finally some conclusions are drawn. Choosing different contents leads to different parametric mechanism, and this in turn leads to new data to be extracted. Then, relying on graph theory, the outcome is analyzed. In other words, the graph theory establishes a relationship between the extracted architectural and ecological concepts based on Ryn and Cowan's theory. Under this scenario, the outputs are obtained (Fig. 9). This process can also establish a relationship when we have two-sided vectors between two edges of architectural and ecological concepts.

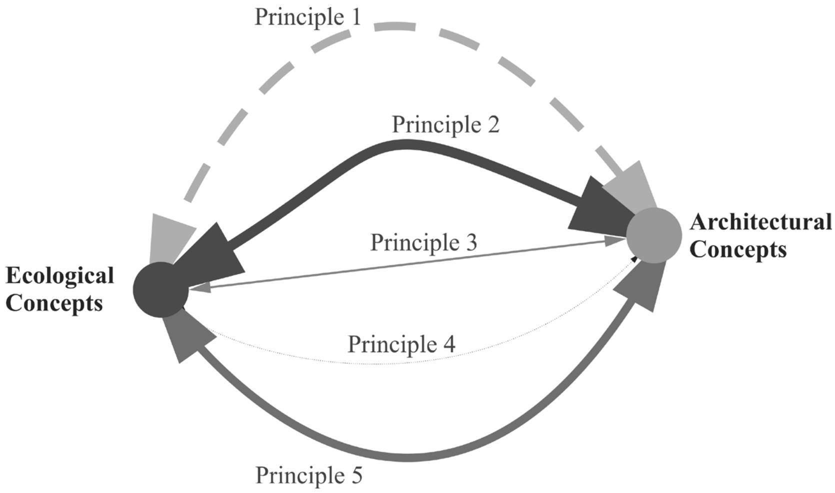


Fig. 9. The Five Principles of Ryn and Cowan Based on the Graph Theory

Replicating many concepts is feasible. The proposed mechanism will be able to divide or combine any number of concepts based on the graph theory. The advantage of graph theory is that it simplifies depicting solutions to complex problems by dividing the problem into groups and establishing directional linkages among them (see section 6 for more details).

For example, if the number of concepts are increased from one to two, the graph theory will then suggest a set of new relations based on the parametric algorithm. In other words, the designed parametric algorithm will calculate the spectrum of possibilities, including the cases of predicted two-sided relationships, if any, in the list. Finally, the graph theory will overtake and suggest the possibilities for analysis. Now the scope of the search is widened, some indicating the presence and some lack of the relationship between architecture and ecology, as the final output (Fig. 10).

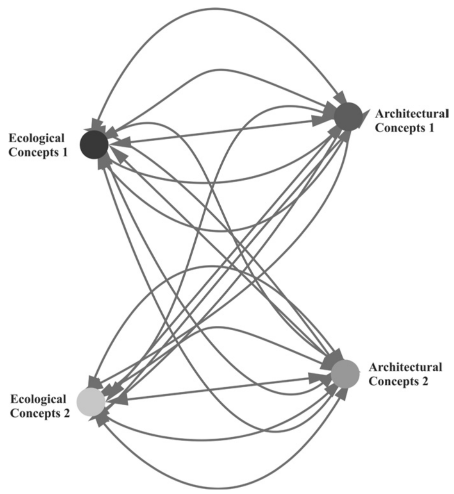


Fig. 10. Increasing the Number of Architectural and Ecological Concepts to Two Concepts for Ryn and Cowan's Five Ecological Principles

In the case of replicating the concepts more often, manual analysis will be very difficult. So, applying computational platforms will become necessary. A notable example is the Gephi software. Using Gephi software, the output of different analyses in different diagrams may be combined to draw a more formal and general conclusion. Therefore, given the high level of capability of this software, sometimes up to one million vertices, this software can analyze the concepts and contents required. Obviously, by increasing the number of vertices, the number of iterations within the parametric algorithm will increase, often at a rate that is non-linear.

Finally, according to what mentioned above, the final parametric algorithm was produced, as shown in Figure 8. This Figure represents the combination of the graph theory and the parametric system based on a mathematical algorithm. The algorithm starts with the choice of design and a critical review of it. Then, choosing the contents, the number of vertices and edges are determined and the graph is drawn. Finally, the graph theory takes over and suggests paths that are indicative of desired relationships, or lack of them in some instances.

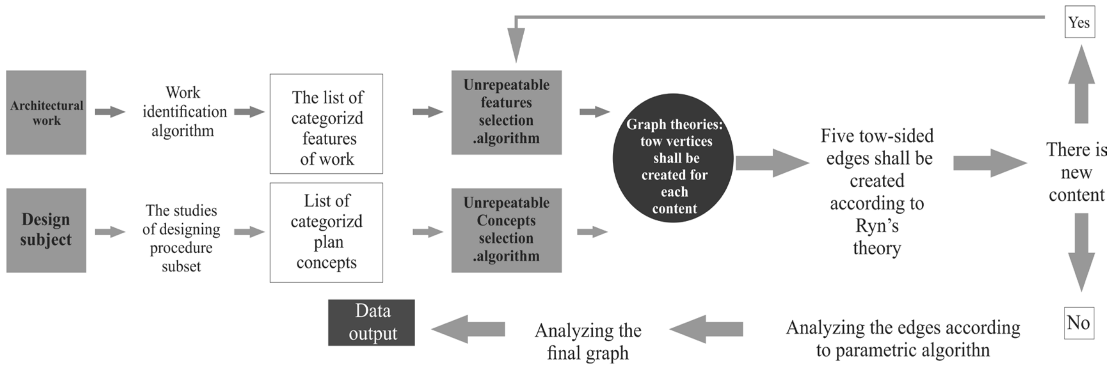


Fig. 11. The Final Research Algorithm

6.2. Application of the Final Redearch Algorithm to Real Case-study

In this section, the second question of this study is addressed: How our algorithm and its related parametric system and graph theory can contribute to the analysis of Ryn and Cowan's principles in the context of contemporary typical apartment buildings in the Iranian plateau? The purpose is also to evaluate how the algorithm simplifies explaining the ecological aspects of Iranian architecture.

To test the algorithm on contemporary Iranian architecture, we also sought the overall views of the AES members who were briefed on the structure and details of the final algorithm. Based on their views, a consensus was reached to follow a two-tier process for testing the algorithm on typical contemporary Iranian residential apartment buildings. First, the choice of apartment buildings yields a fairly large sample to select from them. Further, this choice offers a high potential that the AES members may know or have familiarity with several of them. Second, the two-tier process is selected because our approach can be analyzed in terms of the well-known bipartite graph (or bigraph), (see section 1). We requested the AES members to first consider the architectural principles of Jürgen Kurt Grotter's. These principles are presented in his book entitled "Aesthetics in Architecture" and related to eight principles of ecology that, in turn, are based on research at the University of Georgia. We attribute these 8 principles to Barrett et al. (1997) though others are known to have contributed to finalize the list at the University of Georgia. The earliest study that we can trace the eight principle is Næss (1973), though the principles have gone under substantial changes since Næss's article was released. Thus, the AES members first considered and critically evaluated these eight principles using the five principles of Ryn and Cowan, and then established the relationships between these two groups of principles. Within the bipartite graph structure, the five principles provide the edges of the graph, and the eight principles of architecture play the role of two groups of nodes in the bipartite graph structure. Using these data input, the Gephi graphs were drawn and some outcome were established in terms of data, graphs, and both data and graphs.

In the above experiment, typical residential apartment buildings provide ample number of choices to draw from. Based on their expertise, selection criteria, and analyses, the AES design members expressed their evaluation views into optimum (ideal or desired) expectations and actual status of the apartment buildings. These views would yield two separate graphs for comparison and analyses. Further details of this experiment will be presented with graphs and data in the next section.

7. APPLICATION OF THE ALGORITHM ON THE EACH OF THE FIVE ECOLOGICAL PRINCIPLES

We now consider each of Ryn and Cowan's five ecological principles in the application of our algorithm and its related processes to typical contemporary residential apartment buildings in Iran. First, the five principles were encoded, as shown in Table 1. These codes and labels were then used in the Gephi graphs. Also, the eight ecological principles were encoded and labled, as shown in Table 2. They were also used in the Gephi graphs. Presenting a brief history of the eight ecological principles is relevant at this point. Due to the lack of a broadly applicable list of environmental standards, the U.S. Department of Agriculture Forest Service asked the researchers to identify the most common general themes in all environmental studies. This led forest service social scientists, faculty members and graduate students of the University of Georgia to compile a list of eight general ecological principles, as summarized in Table 2 (Barrett, Peles, & Odum, 1997) for more details.

Table 1. Codes and Labels of Ryn and Cowan's Five Ecological Principles

No.	Label	Principle
1	1	Solutions Grow from Place
2	2	Ecological Accounting Informs Design
3	3	Design with Nature
4	4	Everyone Is a Designer
5	5	Make Nature Visible

(Authors and AES Office No. 352)

Table 2. Codes, Labels and Descriptions of the Eight Ecological Principles and their Associated Concepts

No.	Label	Principle	Description
1	A	Adaptation	The way a life system looks or behaves is not random or accidental; rather it is the result of changing to survive in a dynamic environment.
2	B	Behavior	Living systems evolve behavioral responses to stress and disturbances to enhance survival.
3	C	Diversity	Changes in environmental conditions over time have led to variety at each level of organization
4	D	Emergent Properties	When different levels of organization are functioning together, new properties are created that were not operational at lower levels
5	E	Energy Flow	Energy cannot be created nor destroyed but its form can be changed. Energy quality is always degraded through transformation.
6	F	Growth and Development	As organisms and systems increase in size, some changes occur that allow survival. Growth rate slows as maximum capacity is met.
7	G	Limits	There are limits to how much stress can be tolerated by living systems.
8	H	Regulation	Energy is consumed if a signal is sent to increase or decrease some functions to maintain balance.

(Barrett, Peles, & Odum, 1997)

Table 3 provides a list of 69 principles of architecture encoded based on the book "Aesthetics in Architecture". They were encoded to be used in the Gephi graphs. Setting the data input from Table 2 against those in Table 1, the AES members, based on defined criterion, suggest the best potential relations between the two groups, as shown in Table 4. Within bipartite graph theory, the eight principles of ecological architecture, shown in Table 2, form the first group of nodes, and the five principles presented by Ryn and Cowan have the role of connecting edges in the two-tier setting of the bipartite graph.

Table 3. Architectural Principles Selected Based on the Inputs from AES Office No. 352

ID	Label	ID	Label	ID	Label	ID	Label	ID	Label	ID	Label	ID	Label
1	Function	11	Culture	21	Symbol	31	Style	41	Night	51	Relationship	61	Materials
2	Form	12	Aesthetics	22	Part	32	Discipline	42	Devoid	52	Flexibility	62	Openings
3	Shell	13	Nature	23	Whole	33	Environment	43	Surface	53	Navigation	63	Hierarchy
4	Proportion	14	Earth	24	Ordering System	34	Place	44	Organization	54	Shape	64	Way
5	Economy	15	Structure	25	Social Interaction	35	Congruence	45	Coordination	55	Movement	65	Decoration
6	Design	16	Color	26	Sense of Belonging	36	Contrast	46	Balance	56	Dynamics	66	Plan
7	Light	17	Lighting	27	Social Participation	37	Indoor	47	Rhythm	57	Beat	67	Façade
8	Relaxation	18	Light Intensity	28	Transparency	38	Outdoor	48	Stress	58	Building	68	Radiation
9	Human	19	Ambient Light	29	Tradition	39	Space	49	Scale	59	Public	69	Access
10	Perception	20	Natural Lighting	30	Modernity	40	Day	50	Symmetry	60	Private		

(Grutter, 2004)

Table 4. Relationships between the Eight Ecological Principles and the Five Ryn and Cowan's Principles

Label	Eight General Ecological Principles	Five Principles of Ecological Architecture by Ryn and Cowan	Label
A	Adaptation	Solutions Grow from Place	1
B	Behavior	Everyone Is a Designer	4
C	Diversity	Design with Nature	3
D	Emergent Properties	Solutions Grow from Place	1
E	Energy Flow	Ecological Accounting Informs Design	2
F	Growth and Development	Ecological Accounting Informs Design	5
G	Limits	Make Nature Visible	5
H	Regulation	Design with Nature	3

Table 5. Ideal (= Desired or Optimum) Relationships between Sources and Targets Mapped with Vector Labels for the Iranian Plateau

Source	Source	Target	Label	Label	Weight	Source	Source	Target	Label	Label	Weight
1	Function	C	Design with Nature	3	7	5	Economy	F	Ecological Accounting Informs Design	2	9
1	Function	G	Make Nature Visible	5	3	5	Economy	G	Make Nature Visible	5	8
2	Form	A	Solutions Grow from Place	1	8	5	Economy	H	Design with Nature	3	7
2	Form	C	Design with Nature	3	9	6	Design	A	Solutions Grow from Place	1	5
3	Shell	A	Solutions Grow from Place	1	6	6	Design	B	Everyone is a Designer	4	2
3	Shell	C	Design with Nature	3	5	6	Design	C	Design with Nature	3	6
3	Shell	H	Design with Nature	3	2	6	Design	F	Ecological Accounting Informs Design	2	3
4	Proportion	A	Solutions Grow from Place	1	8	6	Design	G	Make Nature Visible	5	7
4	Proportion	C	Design with Nature	3	8						

Table 6. Actual (= Current Situation) Relationships between Sources and Targets Mapped with Vector Labels for the Iranian Plateau

Source	Source	Target	Label	Label	Weight	Source	Source	Target	Label	Label	Weight
6	Design	A	Solutions Grow from Place	1	1	15	Structure	G	Make Nature Visible	5	1
7	Light	E	Ecological Accounting Informs Design	2	1	16	Color	C	Design with Nature	3	1
8	Relaxation	A	Solutions Grow from Place	1	1	17	Ambient Light	B	Everyone is a Designer	4	1
9	Human	B	Everyone Is a Designer	4	1	18	Light Intensity	B	Everyone is a Designer	4	1
11	Culture	A	Solutions Grow from Place	1	1	19	Natural Lighting	B	Everyone is a Designer	4	1
11	Culture	B	Everyone Is a Designer	4	1	20	Signs	B	Everyone is a Designer	4	1
12	Aesthetics	C	Design with Nature	3	1	21	Symbol	B	Everyone is a Designer	4	1
13	Nature	A	Solutions Grow from Place	1	1	24	Ordering System	A	Solutions Grow from Place	1	1
14	Earth	G	Make Nature Visible	5	1						

Figures 12 and 13 depict the bipartite graphs produced using the Gephi graphs program. Figure 12 was produced under the optimum (= ideal or desired) situations, while Figure 13 was produced under the actual (=currently existing) situations. Both Figures are based on the data for typical contemporary residential apartment buildings in the Iranian plateau. In Figure 12, under the optimum situations, we observe the complexity of the relationships between the nodes of the five and eight principles. The dispersion and complexity of the relations represent the extent of the ideal relationships between the concepts. The larger display (trismot) of the nodes, the greater the weight of those nodes. Thus, in the first round of analyses, without relying much on the specifics of the graph theory, one can see the details and the complexity of the interconnections among ecological concepts and related factors.

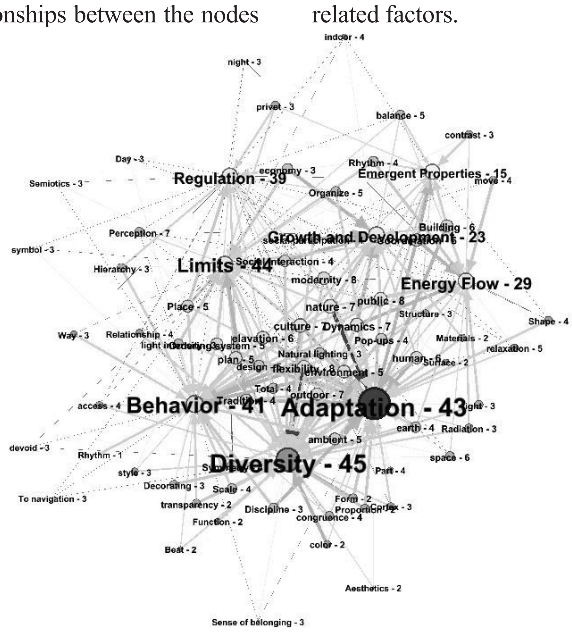


Fig. 12. Bipartite Graph Produced Using Gephi Graphs Under the Optimum (= Ideal or Desired) Situations for Typical Contemporary Residential Apartment Buildings in the Iranian Plateau

In Figure 13, under the actual (or status quo) situations, we observe a relatively different set of relationships when the nodes and the edges are compared with those in Figure 12. The identified relationships are relatively fewer and are far less complex. There is some imbalance between the nodes and the edges, reflecting a higher or a more degree of dispersion or gap between the relationships.

Comparing the two Gephi graphs shown in Figures 12 and 13, a direct and robust mechanism is provided to identify the ecological principles and concepts that are missing in the actual (or status quo) situations. Further, this comparison provides information on the potential actions required to achieve the optimum (= ideal or desired) situations.

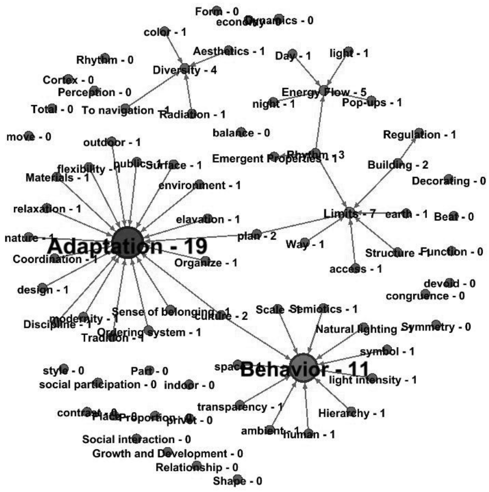


Fig. 13. Bipartite Graph Produced Using Gephi Graphs Under the Actual (= Currently Observed) Situations for Typical Contemporary Residential Apartment Buildings in the Iranian Plateau

Table 7 provides a set of statistical measures for comparison of the graph concepts. Two measures are provided for each group: simple mean values of node degrees and weighted mean values of the same measures. Considering the optimum (= ideal or desired) situations, the simple and the weighted mean values of node degrees are, respectively, 3.623 and 18.506. The corresponding measures for the actual (= status quo) situations are, respectively, 0.236 and 0.623. These computed measures clearly indicate the differences between the two groups. The superiority of the optimum situations versus the shortcomings of the actual situations are now vividly expressed relatively in average numbers. Given that the design node criterion has been the same for the two groups, these high differences reflect the relative amount of work that may be needed to reach the optimum situations. Finally, additional independent graphs of the differences can be produced based on the subsets of data, number of units used, and new specification of nodes. These runs of Gephi graphs program provide useful and measurablegraphs for rational comparison between the two graph alternatives.

Table 7. Mean Values and Weighted Mean Values of Node Degrees Under the Optimum (= Ideal or Desired) and Actual (= Status Quo) Situations, Computed from Gephi Graphs Program

Optimum (= Ideal or Desired) Situations		Actual (= Status Quo) Situations	
Network Overview		Network Overview	
Average Degree	3.623	Average Degree	0.236
Avg. Weighted Degree	18.506	Avg. Weighted Degree	0.623
Network Diameter	1	Network Diameter	1

8. CONCLUSIONS

In this study, we proposed a parametric mechanism, based on mathematical algorithms and the graph theory, to design and criticize architectural works according to Ryn and Cowan's five ecologicalprinciples and Barrett et al. (1997) eight ecological principles. We demonstrated in detail how our algorithm and its related processes could be applied in practice.

In this regard, we rely on the expertise, experience, and information on the inventory of apartment buildings in the past and present AES files of Design Office Number No. 352. The AES members of this office tried to define and establish a set of criterion to define, code, label, and map the relationships between the architectural and ecological principles based on Ryn and Cowan's five principles and Barrett, et al.'s eight principles. This led us to an analysis via bipartite graph. Throughly, information from AES inventory of typical contemporary residential apartment buildings in the Iranian plateau was applied.

We show with some details how each of the five principles is mappedto the eight principles and how they may be taken to analyze the relationship between the various architectural concepts and their ecological relationships.

We kept our examples simple in practical applications so that the first run of the algorithms could easily be traced and brought to some conclusion. In more detailed and complex practical applications, the number of concepts and quality factors are often greater. We showed that as the selected concepts and contents are expanded, the required number of iteration over the algorithm increases. Under this scenario, resorting to computer platforms becomes necessary. We used Gephi programs, a kind of computer platforms (software), to deliver our results.

We pursued, in general, two scenarios, one under optimal (= ideal or desired) situations, and the other under actual (= status que) situations. We found sharp difference between these two situations based on computed mean values and weighted mean values of node degrees for each alternative.

Obviously, complex computations may also sometime fail to reach convergence, i.e., fail to yield the necessary solution. In such cases some trial and errors often lead to a solution. Our proposed algorithm and its related processes may be subjected to more details to obtain more information and/or more precision.

We take several sequential steps in this study: 1. To set forth two hypotheses, 2. To discuss and examine their details, 3. To consider Ryn and Cowan's theory (= five hypotheses) and Barrett et al.'s theory (eight principles), 4. To identify as many as 69 ecological concepts and quality factors for inclusion in our analysis, 5. To propose an algorithm using a parametric system, 6. To draw upon the AES's information on typical contemporary residential apartment buildings in the Iranian plateau to run the algorithm, 7. To map the two groups of encoded data as a bipartite graph to identify and extract relationships between the architectural and ecological principles, 8. To employ the Gelhi software to provide two distinct bipartite graphs to portray the alternative optimal versus actual situations, and 9. To employ the information on node degree from the same software to compute statistical measures of node degree values and their differences across the two alternatives. All the abovementioned steps were undertaken according to ecological design theories presented by Ryne and Cowan and Barrett et al.

We provided Figure 8 as a prototype of our approach to answer our first hypothesis, i.e., how the ecological architectural principles of Ryn and Cowan, or similarly those of Barrett, et al., can be converted to a mechanism for designing and criticizing an architectural work and its surrounding ecology using a parametric system based on mathematical basics and the algorithms based on the graph theory. We achieve this objective via proposing an algorithm with parametric system, both with the help of the graph theory. Within this context, we also provided the answer to our second hypothesis, i.e., how to apply the five principles of Ryn and Cowan and the eight principles of Barrett, et al. to design and criticize Iran's contemporary architectural works. The details of our practical applications in this regard are provided in Section 7 of this study. We summarily finalize and present our empirical results in Figures 12 and 13. We complemented these Figures with some statistical measures in Table 7.

END NOTE

1. One of the authors of this paper is a member of this organization.

REFERENCES

- Abbaszadeh, V., Sadafian Shayesteh, S., & Kamelnia, H. (2014). The Position of Parametric Architecture Process in Linear and Non-Linear Approaches. The Proceedings of the First International Congress of New Horizons in Architecture and Urbanization, 6-7 Jan. Tehran.
- Ackerman, D. (2014). The Human Age: The World Shaped by Us, W.W. Norton and Company.
- Barrett, G.W., Peles, J.D., & Odum, E.P. (1997). Transcending Processes and the Levels-of- Organization Concept. Bioscience, 47(8), 531-535. https://doi.org/10.2307/1313121
- Bastian, M., Heymann, S., & Jacomy, M. (2009). Gephi: An Open Source Software for Exploring and Manipulating Networks. AAAI Publications, Third International AAAI Conference on Weblogs and Social Media, retrieved 2011-12-14. https://gephi.org/publications/gephi-bastian-feb09.pdf
- Ceballos, G., & Ehrlich, A.H. (2015). Annihilation of Nature: A Clarion Call for Engagement and Action to Stop the 6th Great Extinction, Johns Hopkins University Press.
- Cullen, J.M., & Allwood, J.M. (2012). Sustainable Materials with Both Eyes Open: Without the Hot Air, UIT Cambridge.
- Curry, P. (2008). Ecological Ethics: An Introduction, Polity Press.
- Duval, J. (2010). The Next Generation Democracy, Bloomsbury.
- Einstein, C. (2013). The More Beautiful World Our Hearts Know is Possible: Sacred Activism, North Atlantic Books.
- Grutter, J.K. (2004). Asthetik der Architektur. (J. Pakzad, & A. Homayun, Trans.). Translation and published by Shahid Beheshti University, Tehran, Iran.
- Hanh, T.N. (2013). Love Letter to the Earth, Parallax Press.
- Hansen, J. (2010). Storms of My Grandchildren: Descriptions of the Coming Climate Catastrophe and our Last Chance to Save Humanity, Bloomsbury USA.
- Hawken, P., & Lovins, A. (2010). Natural Capitalism: Creating the Next Industrial Revolution, Little, Brown and Co.
- Hertsgaard, M. (2012). Hot: Living through the Next Fifty Years on Earth, Mariner Books.
- Jey, T., & Lester, R. (2001). An Introduction to Cultural Geography. (S. Toullahi, & M. Soleimani, Trans.). Institute of Art and Communication Culture, Tehran.
- Khabbazi, Z. (2012). The Paradigm of Algorithmic Architecture. Mashhad. Ketabkadeh Kasra publication.
- Klaus, D. (1995). The Technology of Ecological Building: Basic Principles.
- Klein, N. (2015). This Changes Everything: Capitalism vs. the Climate, Simon and Schuster.
- Kolbert, E. (2014). The Sixth Extinction: An Unnatural History, Henry Holt & Co, February.
- Kreswell, J.W. (2017). The Research Plan of Qualitative, Quantitative and Mixed Approaches. (A. Kiamanesh, & M.D. Toosi, Trans.). Jahad University Allameh Tabatabaei Branch.
- Lappe, A. (2010). Diet for a Hot Planet: The Climate Crisis at the End of Your Fork and What You Can do About It, Bloomsbury.
- Lappe, F.M. (2011). EcoMind: Changing the Way We Think to Create the World We Want, Nation Books.
- Lovins, A., & Rocky Mountain Institute. (2013). Reinventing Fire: Bold Business Solutions for the New Energy Era, Chelsea Green Publishing.
- Macy, O., & Johnstone, C. (2012). Active Hope: How to Face the Mess we're in without Going Crazy, New World Library.
- Mann, H.L. (2016). Ocean of Insight: A Sailor's Voyage from Despair to Hope, Parallax Press.
- McDonough, W. (2013). Upcycle: Beyond Sustainability: Designing for Abundance, North Point Press.
- McKibben, B. (2010). Earth: Making a Life on a Tough New Planet, Times Books.
- Naess, A. (1973). The Shallow and the Deep, Long_range Ecology Movement. A Summary. Inquiry. 16 (1–4), 95–100. Doi: 10.1080/00201747308601682. ISSN 0020-174X
- Olanike, D. (2011). Gender and Rural Development. ISBN 9783643901033
- Pipher, M. (2013). The Green Boat: Reviving Ourselves in Our Capsized Culture, Riverhead Trade.
- Purmaka, C. (2012). An Introduction to Designing Methods. Translation by K. Bazrafkan, Islamic Azad University, Jordan Branch, Tehran.
- Ryn, S.V.D., & Cowan, S. (2007). Ecological Design, Tenth Anniversary Edition. Washington, DC: Island Press. ISBN 978-1-59726-1418

- Saberian, J., Malek, M., & Hamrah, M. (2012). Providing a classification of dual graph types and using them to improve the routing analysis. *Journal of Transportation Engineering*, 4(2), 137-150. https://www.researchgate.net/publication/258521565_Providing_a_classification_of_dual_graph_types_and_using_them_to_improve_the_routing_analysis
- Sarmad, Z., Bazargan, A., & Hejazi, E. (2014). Research Method in Behavioral Sciences. Agah Publication, Tehran.
- Yeang, K. (1995). Designing with Nature: The Ecological Basis for Architectural Design. McGraw-Hill. New York.

HOW TO CITE THIS ARTICLE

Ziaee, A., Moztarzadeh, H., & Movahed, K. (2020). The Role of Parametric System in the Analysis of Sim Van Der Ryn's Ecological Architecture Principles in Iranian Plateau. *Armanshahr Architecture & Urban Development Journal*. 13(30), 149-163.

DOI: 10.22034/AAUD.2020.183579.1862
URL: http://www.armanshahrjournal.com/article_108586.html