Research on the Regulation and Management of the Optimal Dimensional Collective Housing Scale for Living in Sustainable Cities

Jyh-Harng Shyng(✉)

Landscape Architecture, School of Life Sciences, Zhaoqing University, Zhaoqing, Guangdong, China

hidosing@outlook.com

Abstract. Living space is an extended value of land resources, a finite environmental resource, and important governance for the government departments to conduct urban and rural planning and public management. Within such an era suffering from the resource crisis, how to manage urban living space resources with equity and efficiency will be a significantly important issue for the sustainability of the human living environment in the smart era. This research, adopting the theory of "Pareto Optimality" in environmental economics, verifies to which extent does the ideal dimensional scale to approach the "Pareto Optimality", thus achieving the sustainable goal of "effective utilization" and "resource sharing" of dimensional environmental resources. The results can effectively provide developers, users, and managers with a macroscopic reference for "dimensional scale" in the implementation of sustainable living environment and residential improvement, based on which the results of dimensional scale can be estimated to verify the optimality of equity and efficiency.

Keywords: Sustainable Development · Collective Housing · Dimensional Scale · Pareto Optimality · Living Space Standard

1 Introduction

"Living" belongs to one of the basic human rights. Moreover, living space is an extended value of land resources and a finite environmental resource. Against the current environmental resource crisis, equity and efficiency in the use of resources are important issues for the sustainability of the human living environment. This research investigates whether the dimensional scale and the use of the dimensional scale of different household sizes in the real environment are consistent with the "optimality" of Pareto Optimality. By using the characteristic of equal marginal utility in Pareto Optimality in economics, the equity and efficiency of environmental resources in living space explored under the concept of sustainable development in further. Besides, this research, by means of quantitative estimation, targets at comparing the sustainable dimensional scale, including:

(1) The analysis of the "Pareto Optimality" in economics to explore the characteristics of equity and efficiency in the concept of sustainable development. (2) The

© The Author(s) 2023
A. Luqman et al. (Eds.): PMIS 2022, AHCS 6, pp. 541–553, 2023.
https://doi.org/10.2991/978-94-6463-016-9_56

theoretical definition of the "Marginal Rate of Substitution" and "Scale Adjustment Rate" to illustrate the dimensional scale per person for different household sizes in the current situation and the characteristics of equity and efficiency of sustainable development based on the changes of MRS and SAR. (3) The comparison of various dimensional scale models to discuss the standard for dimensional scale per person, to reach the state that "Pareto Optimality" fits the concept of sustainability.

2 Literature Review

2.1 International Standards for Dimensional Scale

With regard to the enactment of international standards for living space, development varies in different countries. It is obvious, after comparing the standards of various countries (as shown in Table 1), that a great disparity exists in the average residential area per person, which is due to the different physical conditions and the use of space in each country, thus affecting the establishment of standards. For now, a method of estimating housing standards recognized worldwide has not been establish.

International countries, differing in terms of climate, customs, health and sanitation, density, cost, and construction policies, should not follow the model standard developed in highly-developed countries for planning but should set feasible standards in accordance with the national resources, existing housing conditions as well as the equity and efficiency of the use of existing spatial and environmental resources.

Throughout the research on Taiwan collective housing, because of the inadequate focus living space standards, or the more emphasis on the field of ergonomics, or the limitation of date and research scope. Taiwan seems to rely too much on the foreign standard, "Proposed Taiwan Standards for Minimum Living Space" and refer to "Japan Standards for Minimum Living Space (1981) " to enact its own standards. As a result, the living space standards that are in line with the overall environment, except for the more recent study of the "Standards for Minimum Space" formulated by the [11], lack scientifically validated standard theories and actual surveys. As the "Space Standards" formulated by the Institute fails to take the ideal factors that households expect in the future into account, the standards do not completely conform to the dimensional scale required by households.

2.2 Exploration of the Theory of Sustainable Dimensional Scale

It is known from the literature related to sustainable development that "sustainable development" is a development opportunity that meets the needs of the present without compromising those of future generations; it is a standard that not only advocates consumption within ecological possibilities but also promotes reasonable consumption for all [6].

[1] argued that the purpose of supporting sustainable economic development is to ensure that future generations have access to the resources and environment of today without destroying the original resources and environment; the prerequisite for sustainable development is efficient resource management.

Table 1. List of International Standards for the Dimensional Scale for each Household in different Countries Unit (m^2)

Nationality	Number of Households and Properties	1	2	3	4	5	6	7
UK Parker Morris	Apartment	30	44.5	57	72	82	92.5	—
	Duplex Apartment	—	—	—	72	82	92.5	—
USA American Public Health Association (APHA)	Apartment-style Flat Housing	37.2	69.7	92.9	106.8	130.1	144	—
Japan Standards for Minimum Living Space	Public Housing	21	36	47	59	65	76	87
Russia	Public Housing	17	29.65	40.8	49.35	55.5	65.6	70.65
Netherlands	Public Housing	—	26.5–32	34–36	39–40.5	46	49	—
Italy	Public Housing	30	50–64	70–80	90–96	90–96	110–112	110–112
South America	Public Housing	—	33.9–39.6	41.8–47.5	48.8–54.5	55.8–61.5	61.6–70.9	—
International Federation for Housing and Planning (I.F.H.P.)	Public Housing	—	51.5–56.3	60.5–76.2	80.2–93.7	97.7	—	—

Data source: Partial references are compile by this research from Narufumi Suzuki, 1970, *Collective Housing Households(Permission obtained)*

Tisdel (1991) regarded the maintenance of the economic welfare for all generations as one of the basic concepts of sustainable development; [9] discussed the concept of sustainable development in terms of needs and constraints. The satisfaction of human needs and desires is the main goal of development. And sustainable development is one in which, as far as their lives allow, all people can achieve the minimum standard of living needs but embrace the opportunity to pursue a better life. In order to equip human beings with the ability of sustainable development, the abilities of future generations to meet their needs should never jeopardized when striving for current satisfaction.

The characteristics of sustainable development require that all needs in the development process taken into account at the same time. From the perspective of living space

as an environmental resource, the specific theories and research literature on sustainable development differ from one professional field to another in terms of perceptions and needs. Based on the discussion of sustainable development and related research before. They can observed that "sustainable development" seems widely and unobjectionably used since 1980, and sustainability is increasingly use as a means of discussing the global environment. As a result, the term appears to overly and widely used in a vague way, and no single definition can cover all the characteristics of sustainable development. Hussen, A. M. (2000).

To explore the dimensional scale in terms of sustainable development, it is necessary clearly define the sustainability of the living environment. The main summary is as follows: Sustainable development encompasses two main concepts, namely need and constraints. The satisfaction of human needs and desires is the main goal of development, and residential development is relate to the three directions of sustainable development (social, economic, and environmental), including three sustainable development goals: equity issues, environmental crises, and household consumption habits, which related to dimensional scale directly.

This research is based on the issues related to residential environment and sustainable development and the opinions related to sustainable residential development by Bhatti, M. & Dixon, A. (2003), which includes three perspectives, namely "overall social welfare", "environmental-ecological and economic development", and "sustainable technology" [5].

This research, under this framework, also refers to the relevant literature [10, 8, 7]. In particular, "sustainable technologies" must be measurable and calculable [2]. The issue of environmental sustainability is fundamentally a finite one, and finite issues cover fairness, equity, and distribution of resources; the issue of sustainability must addressed at the level of "preferences" and "technologies" rather than the level of optimal prices, and the efficiency of the corresponding "optimality". Then it can called true environmental sustainability [5].

To concrete implement the equity and efficiency within the concept of sustainable development in residential development, the significance of sustainable development of the discussed issues can be define. (1) To cultivate a long-term perspective in time that is in line with the concept of sustainable inter-temporal effective use. (2) To take into account the fairness of generations and to achieve the sustainable spirit of equal rights in the use of space. (3) To target environmental conservation as the goal of sustainable development, and to enhance the "efficiency in the use of environmental resources". Therefore, starting from the living needs of household users, the effective use of environmental resources in living spaces will be promoted and at the same time, and the fair use of rights will be emphasized to achieve the goal of "sustainable development of environmental resources" with balanced use of urban living spaces.

3 The Analysis Methods and Definition of Pareto Optimality Concerning Dimensional Scale

The "Pareto Optimality" in economics adopted to implement the characteristics of equity and efficiency in the concept of sustainable development. The characteristics of equity

and efficiency featured by "Pareto Optimality" further illustrate the "equitable trade-off" and "efficiency of use" on the dimensional scale. Then, the meaning of the Pareto Optimality graph and inference results explained. After calculating "Marginal Rate of Substitution" and "Scale Adjustment Rate" based on the theory, the calculation results of the relevant characteristics display the difference between the "dimensional scale level" and "Pareto Optimality". The optimality of the "ideal dimensional scale" as defined by this research verified to demonstrate whether it conforms to the characteristics of equity and efficiency of sustainable development. The main analysis items are as follows:

(1) It explains the significance of the "Pareto Optimality" theory in terms of equity and efficiency and the calculation and significance of the "Marginal Rate of Substitution" and "Scale Adjustment Rate".
(2) With the "ideal dimensional scale", a long-term consideration taken into the concept of sustainable development, to estimate the characteristics of the "realistic dimensional scale" for each household. The equity of trade-offs in the concept of "Pareto Optimality" is analyzed to propose the MRS of the dimensional scale for different household sizes.
(3) To analyze the efficiency of use of dimensional scale in the concept of "Pareto Optimality" and calculate the SAR based on the characteristics of the "realistic dimensional scale" of each household, suggestions and improvement proposed in terms of the "direction of adjustment" and "degree of adjustment.

3.1 Pareto Optimality in the Analysis of Equity and Efficiency and the Significance of Indicators

[4] mentioned that the general "Pareto Optimality" used as a criterion of social welfare, whose main purpose is not to emphasize that if the utilization state of a certain resource meets general social moral standards but to examine. The utilization state of a certain resource can be change so that social welfare promoted with the most efficient use of the limited resources.

As this paper treats the "dimensional scale" as a limited resource, one of the non-renewable environmental resources, the "Pareto Optimality" theory is adopted to, in light of the spirit of enhancing the efficiency of resource utilization in the concept of sustainable development, explore the significance of dimensional scale optimality from the viewpoint of economics. That is, based on the "Pareto Optimality" theory, the closer it approaches the "Pareto Optimality" in terms of "equitable trade-offs" and "efficiency of use" of dimensional scale. The more it will help to achieve the goal of equity and efficiency in sustainable development, as shown in Fig. 1.

The sustainable scale of living space: (I-H) is the "Platonic optimum interval"; (J) is the Platonic optimum point, which is the "optimum scale of living space per person" for the household. The zone favorable to future development is above the (0-J) line, and the zone detrimental to future development is below the (0-J) line. The intervals divided into "weak sustainability" and "strong sustainability" according to the degree of closeness to the optimum.

This research, adhering to "equal marginal utilization" of "Pareto Optimality" theory, makes it possible to use the degree of two indicators, namely MRS and SAR, to verify the

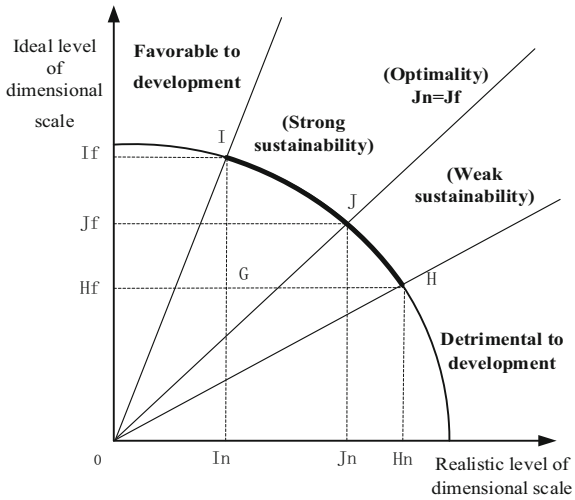

Fig. 1. "Pareto Optimality" Diagram of the Dimensional Scale per Person

characteristics that contribute to the degree of sustainability. The main concepts applied are as follows:

1. If the MRS is greater than 1, it is the "weak sustainable interval" (J-H), which represents the improvement measures for the dimensional scale to reduce the current "dimensional scale per person". While the MRS is less than 1, it is the "strong sustainable interval" (J-I), which represents the improvement measures for the dimensional scale to increase the current "dimensional scale per person".
2. According to the characteristic of "equal marginal utilization" of "Pareto Optimality" theory, when the MRS of the "dimensional scale per person" and the ideal "dimensional scale per person" equal 1, the "Pareto Optimality" will be reached.

3.2 "Marginal Rate of Substitution" (MRS) for Equitable Trade-Offs in Dimensional Scale

Based on the estimation model, the dimensional scale per person under the long-term consideration defined as the "ideal dimensional scale" per person. The dimensional scale per person the current survey as the "realistic dimensional scale" per person. It defined as the housing welfare indicator to explore the "Pareto Optimality" theory.

In light of the difference in the use of residential environmental resources between the ideal and the current situation as discussed in the economics of sustainable development, the MRS, as shown in Eq. (1) can reach the substitutability of the "ideal dimensional scale" for the existing dimensional scale.

$$\text{MRS} = \frac{\Delta Y}{\Delta X} = \frac{Jf}{Jn} \tag{1}$$

ΔY Stands the amount of change in the "ideal dimensional scale" per person; ΔX Stands change in the "realistic dimensional scale" per person; Jf Stands the "ideal level

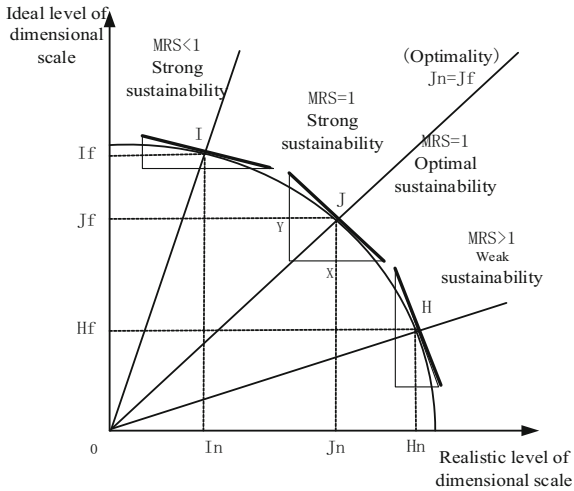

Fig. 2. MRS Diagram of Pareto Optimality Analysis of Dimensional Scale

of dimensional scale" per person; *Jn* Stands the "realistic level of dimensional scale" per person.

The MRS in this research represents the ratio of "ideal dimensional scale" per person to "realistic dimensional scale" per person, which is shown in Fig. 2 as the slope ratio of the line of changes. The meanings of MRS between the "ideal level of dimensional scale" and the "realistic level of dimensional scale" of the sample studied in this research can be concluded that MRS = 1 refers to "optimal sustainability" (optimal for development), MRS > 1 "less than ideal" (detrimental to development) while MRS < 1 "too ideal" (favorable to development).

3.3 "Scale Adjustment Rate" (SAR) for the Utilization Efficiency of Dimensional Scale

IT found from the sustainable dimensional scale discussed before in this research that the uneconomic situation occurs in the efficiency of use for the realistic dimensional scale. Neither "overmuch" nor "inadequacy" has reached the "Pareto Optimality" for the use of dimensional scale by households. Therefore, the SAR defined as the adjustment rate of the "realistic dimensional scale per person", that is, the adjusted dimensional scale divided by the "realistic dimensional scale" per person reaches the direction of adjustment strategy and the degree of adjustment in Fig. 3, as shown in Eq. (2):

$$\mathrm{SAR} = \frac{\Delta Y}{Gn} = \frac{Gn - Gf}{Gn} \times 100\% \tag{2}$$

ΔY Represents the adjustment for "ideal dimensional scale" per person and "realistic dimensional scale" per person; *Gn* Represents the "realistic dimensional scale" per person at point G; *Gf* represents the "ideal dimensional scale" per person at point G.

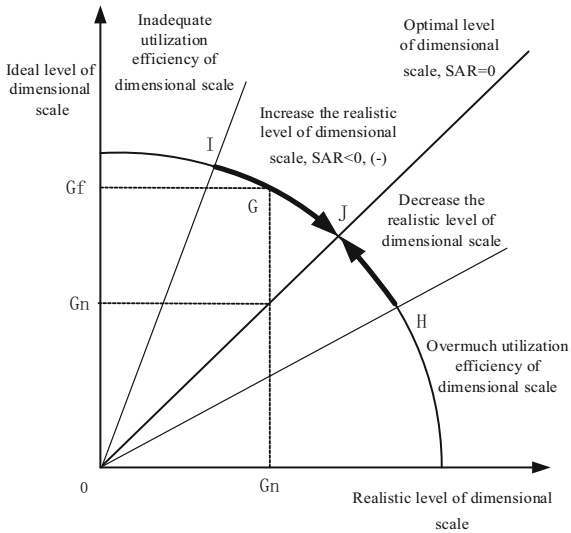

Fig. 3. SAR Diagram of Pareto Optimality Analysis of Dimensional Scale

(1) Meaning Represented by the Calculated Results

SAR $>$ 0 means that the dimensional scale per person needs to be "reduced" to reach the optimal level of dimensional scale for the household. SAR $<$ 0 means that the dimensional scale per person needs to be "increased" to reach the optimal level of dimensional scale for the household. SAR $=$ 0 means that the current level of dimensional scale per person has already reached the optimal level of dimensional scale for the household.

The "positive" and "negative" values stand for the direction of the adjustment strategy, serving as the basis for "decreasing" or "increasing" the level of dimensional scale; the resulting value |MRS| indicates the percentage of the degree of adjustment.

(2) Graphic Meaning Represented by the Calculated Results

4 The Analysis of Pareto Optimality of the Ideal Dimensional Scale

The meaning of the "equal marginal utility" featured by the "Pareto Optimality" in this research is that when the MRS equals 1 and SAR equals 0 between the realistic and the ideal dimensional scale per person, the "Pareto Optimality" is reached. In addition, the closer it is, the more it contributes to a sustainable concept of equity and efficiency.

However, in the reality, there are often discrepancies between the "ideal dimensional scale per person" and "realistic dimensional scale per person", making the accurate estimation imperative to achieve the "Pareto Optimality". Therefore, in this research, the MRS and SAR are calculated based on the "realistic dimensional scale per person"

Table 2. The Ideal Dimensional Scale per Person for Different Household Sizes Unit (m^2)

Number of Households	1	2	3	4	5	6
"Estimated Ideal Dimensional Scale" (Ideal Dimensional Scale)	42.6	35.8	31.5	28.2	24.3	21.5
"Surveyed Realistic dimensional Scale" (Realistic dimensional Scale)	73.0	49.1	34.4	29.4	25.6	23.9
"Minimum Dimensional Scale for National Housing" (Minimum Dimensional Scale)	29.7	24.2	21.0	18.1	17.2	15.3

and "ideal dimensional scale per person" to understand the differences between the "ideal dimensional scale per person" and the "realistic dimensional scale per person" in different household sizes.

In order to verify the optimality analysis of "dimensional scale under long-term consideration", the "Pareto Optimality" in economics adopted to measure the equity and utilization efficiency of dimensional scale, thus confirming whether the estimated "ideal dimensional scale" under long-term consideration is closer to the "Pareto Optimality".

According to (1) "Estimated Ideal Dimensional Scale" (Ideal Dimensional Scale) [14], (2) "Current Surveyed Dimensional Scale" (Realistic Dimensional Scale) (Taiwan Population and Housing Statistics, 2016). (3) "Minimum Dimensional Scale for National Housing" of Standards for National Housing Space (minimum dimensional scale) (He Youfeng and Wang Xiaolin, 1993), the data of the ideal dimensional scale per person for these three household sizes is shown as Table 2.

It is suggested in (1) that under the concept of sustainable development, the focus of architectural planning is no longer limited to the planning and completion of the building itself but extends to the proposals that contribute to environmental conservation. Combining "spatial planning" with "the concept of environmental sustainability", this research takes the apartment-style collective housing as an example and uses inferential statistics to reach the appropriate dimensional scale for Taiwan and establish a spatial plan that is consistent with sustainable development under the principle of satisfying occupant behavior and spatial comfort. The "prepared dimensional scale" and "chosen dimensional function" have always played an important role in spatial planning. Under the premise of a livable environment, the previous minimum scale under research will transferred to a sustainable scale setting, which will further control the floor area of the building and reduce the waste of external resources.

The research attempts to propose the factors that influence residential spatial planning, especially the factors related to sustainable development. With the understanding of the significance of factors affecting the residential unit area, a regression model established to quantitative analyze the dimensional scale. The current survey data compared with the research results to illustrate the impact of sustainability considerations on residential spatial planning.

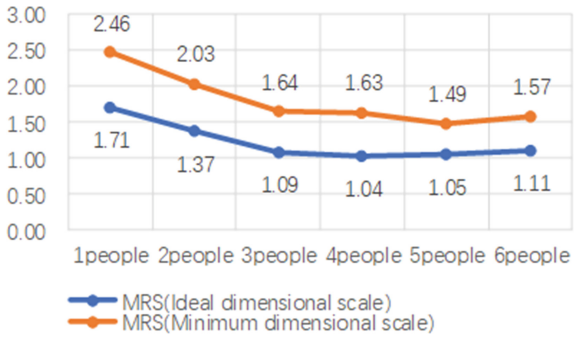

Fig. 4. MSR between the Ideal and Minimum Dimensional Scale per Person

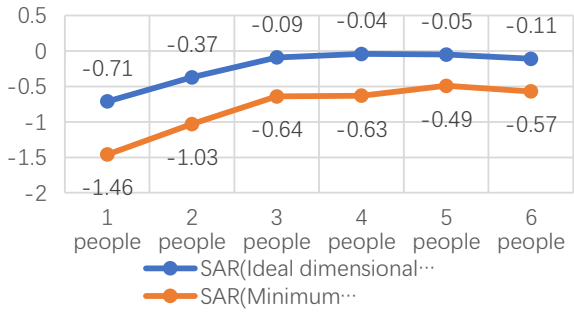

Fig. 5. SAR between the Ideal and Minimum Dimensional Scale per Person

4.1 The "Marginal Rate of Substitution" and the "Size Adjustment Rate" of the Ideal Dimensional Scale Per Person

Based on the different data compared in [9, 14], the MRS and SAR are calculated.

(1) The "ideal dimensional scale" estimated in this research approaches the "Pareto Optimality" the most when the number of households is 4. In addition, when MRS is 1.04, it means that the household size of 4 people is the closest to the "Pareto Optimality" as shown in Fig. 4.
(2) It can observed from Fig. 5 that the dimensional scale adjusted given the number of households. The dimensional scale should be reduced: 51.99 m^2 for a household size of one person; 18.23 m^2 for a household size of two people; 3.22 m^2 for a household size of three people; 1.21 m^2 for a household size of four people; 1.35 m^2 for a household size of five people; 2.62 m^2 for a household size of six people; and 13.10 m^2 for average household size. Overall, the "realistic dimensional scale" all surpasses the "ideal dimensional level" under risk of overuse.

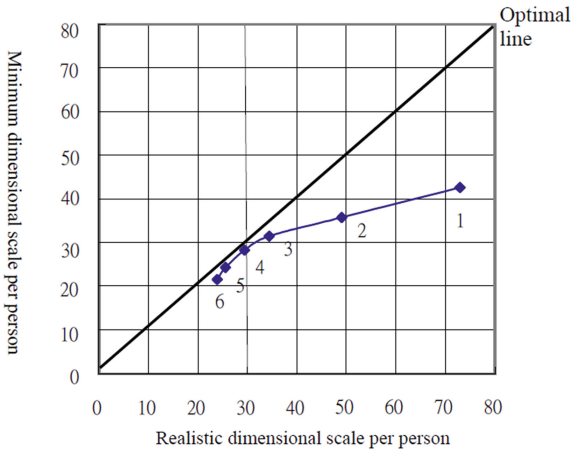

Fig. 6. Optimal Analysis of "Ideal Dimensional Scale per Person" for Different Household Sizes

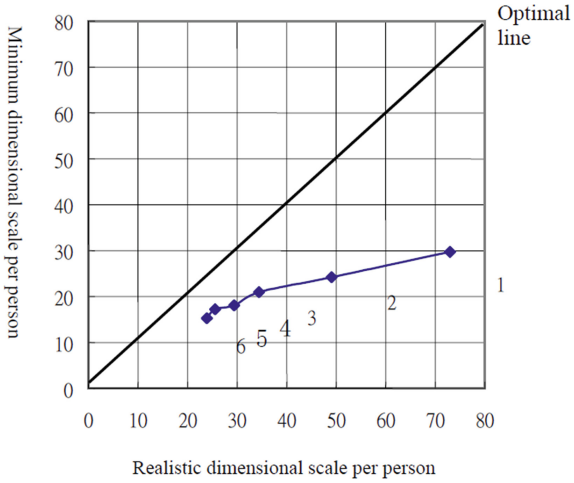

Fig. 7. Optimal Analysis of "Minimum Dimensional Scale per Person" for Different Household Sizes

4.2 Optimal Analysis of "Ideal Dimensional Scale Per Person" for Different Sizes of Households

(1) The "ideal dimensional scale" estimated in this research as shown in Fig. 4 approaches the "Pareto Optimality" the most and enjoys better optimal, When the MRS reaches 1.04 for the household size of four people.

(2) As can be seen from Figs. 6 and 7 that the "ideal dimensional scale" estimated in this research has an average MRS of 1.23 for each household size, which is closer to the "Pareto Optimality". In addition, the result of the "ideal dimensional scale" estimated in this research proves to be the optimal for the household size of 3 to 6 people.

Table 3. Comparison of the Difference between the Suggested Living Area and that in the Current Situation

Number of Residents Category	1	2	3	4	5	6
The Gap between the Ideal Dimensional Scale Estimated by this Research and that of the Current Situation (m^2)	30.36	26.58	8.83	4.64	6.42	14.15

5 Analysis on Verification Results

Adopting the "Pareto Optimality" in economics to implement the characteristics of equity and efficiency in the concept of sustainable development, its characteristics of equity and efficiency can be used to discuss sustainable development, illustrating the "equitable trade-off" and "utilization efficiency " of dimensional scale. The meaning presented and explained through the graph of Pareto Optimality and inference results, which is completely different from the standards for the dimensional scale set following Japan or the United States or those set from the ergonomic perspective (as shown in Table 3).

6 Conclusion and Suggestion

The ideal dimensional scale, as defined in this research, proves to be close to the "Pareto Optimality", boasting the characteristics of equity and efficiency for sustainable development. The reasons attributed to aspects:

(1) This research takes the households' needs for dimensional scale as the basic concept for survey and estimation. Starting from the estimated living unit space scale of each living space, the combined space unit scale is then estimated under the concept that "household dimensional scale is a combination of different living unit space scales", pressing it closer to the real needs of households.
(2) The structure of the influencing factors selected for this research takes the multiple aspects of the real dimensional scale used into consideration. In this way, not only the influence of physical space is included, but also the concept closer to the real dimensional scale used by households formed with the addition of households' living characteristics, usage behavior, and perception of the definition of sustainability. Therefore, the results presented in the estimation model of this research validated to be more in line with the Pareto Optimality, more representing the meaning of equity and efficiency in the concept of sustainable development.

From the results, the "Scale Adjustment Rate" (SAR) of the ideal and realistic dimensional scales of the collective housing in the case area are both negative, indicating that the "realistic dimensional scale per person" necessitates a reduction for households with 1 to 6 people and the realistic dimensional scale in the area represents a "weakly sustainable" level. It is also proposed that the "Marginal Rate of Substitution" (MRS = 1.23)

for the average household size of four people should be adjusted to approach the Pareto Optimality (MRS = 1) to achieve a suitable dimensional scale that fits the sustainability.

References

1. Alberta ECO (1991). The environmental effects of forestry operations in alberta. Report and recommendations. Environment Council of Alberta, Edmonton
2. Balkema AJ, Preisig HA, Otterpohl R, Lambert FJD (2002) Indicators for the sustainability assessment of wastewater treatment systems. Urban Water 4(2):153–161
3. Bhatti M, Dixon A (2003) Special focus: housing, environment, and sustainability. Hous Stud 18:501–504. https://doi.org/10.1080/02673030304246
4. Callan SJ, Thomas JM (1996) Environmental economics and management: theory, policy, and applications. IRWIN, Chicago
5. Costanza R, Perrings C, Cleveland CJ (1997) The development of ecological economics. Edward Elgar, London
6. Development WCOEA (1987) A global agenda
7. William ML, Oluf L (1999) Towards sustainable development: on the goals of development —and the conditions of sustainability, pp1–13, 21–29. Macmillan Press Ltd., New York. ISBN 0-312-21669-6
8. Hong Y (1999) Research on the Sustainability Structure of Urban Development. (M.S.), National Cheng Kung University
9. Li Y, Zhang N (1994) Exploring urban development from the perspective of environmental behaviour. Regional Science Institute
10. Lu Z, Huang Q (1995) The Origin and Development of Global Sustainable Development: Institute of Energy and Resources of Industrial Technology Research Center
11. Architectural Research Institute, Ministry of the Interior (1993) Standards for Minimum Space
12. Executive Branch, CEPD, Department of Housing and Urban Development (1984) Research on the Standardization of National Housing Space, Executive Branch, CEPD
13. Executive Branch, CEPD, Department of Housing and Urban Development (1985) Proposed Standards for Minimum Living Space in Taiwan, Executive Branch, CEPD
14. Zhang H, Shyng JH (2004) A study on the establishment of an estimate model for sustainable residential size-collective housing for example. Arch J (45), 99–120. https://doi.org/10.6377/ja.200402.0099
15. Written by Narufumi Suzuki, Compiled by Yoshitake Yasumizu (1970) Collective Housing Households. Arch Plan 6:260–269

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (http://creativecommons.org/licenses/by-nc/4.0/), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.