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An assessment of sustainable housing affordability using a multiple criteria decision making method

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ABSTRACT

Housing affordability is a complex issue that must not only be assessed in terms economic viability. In order to increase quality of life and community sustainability the environmental and social sustainability of housing must also be taken into consideration.

The paper considers the application of a methodology that can be applied to assess the affordability of different housing locations in a sustainable manner, taking into account a range of economic, environmental and social criteria. The COPRAS method of multi-criteria decision making (MCDM) is selected and applied to three residential areas as an example of how sustainable housing affordability can be assessed using a MCDM method. The outcome of the study reveals that considering a range of social and environmental criteria can greatly affect the calculation of an areas affordability, in comparison to focusing solely on financial attributes. COPRAS was found to be an effective method for the assessment and could be applied in other regions or internationally.

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1. Introduction

Currently affordable housing and sustainable development are major challenges facing the UK and many other countries across the globe. Sustainability and affordability concerns are now often discussed mutually and are recognised as being important to one another [1–6]; namely, affordable housing ought to be located within sustainable mixed communities and sustainable communities must provide affordable housing products. Accordingly, it is essential that affordability and sustainability issues are tackled simultaneously. However, housing affordability is frequently defined and assessed only in terms of economic viability. Other important issues, such as sustainability, housing location and quality are sometimes overlooked.

Comparing the relationship between housing expenditure and household income is the most common way to define and measure housing affordability internationally [7–9]. Such an assessment relies on a ‘rule of thumb’ which suggests that any household spending more than a certain proportion of its income on housing costs lives in unaffordable housing. This approach stems from initial studies on housing affordability, which date back to 19th century studies of the household budget, which commonly equated “one week’s pay for one month’s rent” [7, p. 471]. Housing cost to income ratios are

extensively applied to measure affordability in the UK and other European countries, the U.S., Canada, Australia, New Zealand and China [10–14]. The ratio approach appears to be ubiquitously and often indisputably adopted in international housing policies, within developed countries, to measure housing affordability. This is not surprising since it has the advantage of being easy to compute as it only relies on a few variables which are usually easily accessible. However, the housing expenditure to income ratio has been subject to criticism by several authors [7,13,14,15]. This is primarily due to its arbitrary and normative nature [7,13,14,16] and inability to account for issues such as housing quality [15].

In contrast to the conventional way of conceiving and measuring affordability, Stone [13,14] recognises that housing affordability is not separable from housing standards. Accordingly Stone [13] introduced the ‘shelter poverty’ measure which attempts to assess affordability by taking into account the adequacy of household income to cover both housing costs and other necessary non-housing costs, thus seeking to maintain an adequate standard of living. This measure therefore focuses on the residual income remaining after housing costs have been met. However, the residual approach shares some of the shortcomings of the ratio measure, such as the inability to control for housing or location quality. Bogdon and Can [15] criticised the pre existing affordability literature for focusing on house prices rather than the condition, location and neighbourhood characteristics of the housing. However, even today day the majority of tools used to assess affordability have little or no regard for housing quality,

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location and neighbourhood characteristics, i.e. what households get in return for what they spend on housing.

2. Research problem

The ODPM [5] admit that, previously, in a rush to build more homes to meet demand the government too often did not build communities. Jobs, shops and services, transport and green spaces are also important factors for creating thriving communities [5]. It is not enough to simply provide more homes, there must also be a strong focus on creating sustainable communities [3]. Sustainable communities are defined as “Places where people want to live and work, now and in the future” [4, p. 56]. They should be active, inclusive and safe, well run, environmentally sensitive, well designed and built, well connected, thriving, well served and fair for everyone [4].

Building housing that is not well connected to jobs, high quality services and infrastructure can and has contributed to areas experiencing low demand and abandonment. The Housing Market Renewal Initiative was prompted by the government to tackle problems of low demand and the emergence of housing abandonment in several parts of the North and the Midlands in England. In such neighbourhoods, high levels of low demand properties, population loss and high vacancy rates created decline and deprivation [17]. These areas suffer from a lack of jobs, poor public services, crime and anti-social behaviour, with streets and parks in disrepair [5]. The traditional way of conceiving and measuring affordability (the ratio of housing costs to income) may indicate that such areas are affordable, simply because they are low-cost. However, this fails to indicate anything about the quality of the housing or the environment in which the housing is situated. Accordingly, this may be a rather simplistic and unsustainable way to view affordability.

Research undertaken by the Australian Housing and Urban Research Institute (AHURI) stresses that OECD countries are increasingly recognising the need for a broad and more encompassing understanding of housing affordability, such measures would replace simple ratio measures based on housing costs and income which cannot deal with issues such as housing adequacy, location quality and access to services [18]. Nevertheless, research by the AHURI continues to focus on housing costs and incomes [19]. This research advocates the continued use of the expenditure to income ratio due to its long tradition; ease of use and to provide continuity [18]. In contrast, other research conducted in Australia advocates that housing affordability must account for ancillary costs that households may face, e.g. accessing key services, facilities and employment, and the cost of electricity, gas and water [20]. It seems that a number of authors are seeking to challenge the conventional ratio standards which are frequently used to define and assess housing affordability.

It has been suggested that the traditional way of defining and measuring housing affordability (the ability of household income to cover housing costs) may be too limited; the interaction between housing and location is thought to provide a more meaningful measure of housing affordability [21]. Furthermore, Fisher et al. [22] suggest that an important aspect of housing affordability depends on the amenities based on the particular housing location, which affects the welfare of households. Their study looks at affordability in terms of a bundle of attributes an area possesses, such as school quality, job accessibility and safety. The authors assess whether accounting for the implicit prices of such attributes influences an areas affordability measure. The authors conclude that focusing on price alone may lead to inaccurate conclusions about the affordability of an area [22].

But how is the concept of affordability perceived by low and moderate income families themselves? Seelig and Phibbs [16]

conducted qualitative analysis of housing affordability to understand how low-income renters understand residential affordability. They found that low-income families often did not choose areas that had poor amenity and location measures. Thus, while cost was an essential consideration, addressing needs or preferences for dwelling features, location or proximity to services and facilities was a priority for many low income renters, even though such choices resulted in tighter household budgets and paying more for housing [16]. The research demonstrates that an array of attributes, in addition to purely economic factors, can influence a household's perception of affordability. Specifically, quality, location and access to services and facilities appear to be important considerations directly related to a household's perception of affordability.

Clearly, improving housing affordability is not the only means by which housing can become economically viable. As well as housing costs, the aforementioned literature advocates that a wider range of criteria must be taken into consideration in order to determine true housing affordability and quality of life. Such findings have motivated the authors to conduct this particular research and develop a methodology that can be used to assess the affordability of different housing locations in a sustainable manner, taking into account a range of economic, environmental and social criteria that influence both the affordability and sustainability of housing. Given the complexity of the issue under consideration, multiple criteria decision making (MCDM) appeared to be appropriate as the basis of an assessment tool for sustainable housing affordability.

Multiple criteria decision making (MCDM), often called multi criteria decision aid (MCDA) and multi criteria analysis (MCA), is a set of methods which allow the aggregation and consideration of numerous (often conflicting) criteria in order to choose, rank, sort or describe a set of alternatives to aid a decision process [23]. MCDM is suitable for the said topic as it is able to address the numerous quantitative and qualitative criteria that affect both housing affordability and sustainability, all of which can be incorporated into one evaluation process.

There are three steps that all MCDM techniques follow [24, p. 5–6]:

1. Determine relevant criteria and alternatives;
2. Attach numerical measures to the relative importance of the criteria and to the impacts of the alternative on these criteria;
3. Process the numerical values to determine a ranking of each alternative.

Step 1 can be aided by methods which assist in structuring decision making problems. For example, Kenney's value focused thinking [25] which uses hierarchical structures to build criteria, leading from primary goals to fundamental objectives, which are further broken down to specific criteria or Strategic Options Development and Analysis (SODA) which utilises cognitive mapping [26].

In order to process the numerical values (step 3) there are various different MCDM methods available, each with their own varying characteristics. Some of the most commonly used methods include the AHP [27], TOPSIS [28], PROMETHEE [29], ELECTRE [30] and COPRAS [31]. For a survey and comparison of different MCDM methods see [32], [33] and [34], although the COPRAS method is not discussed.

Several MCDM methods have been applied in property, planning and built environment related research. For example, Ball and Srinivasan [35] proposed the AHP method to aid house selection for buyers. Bender et al. [36] used the AHP to analyse the environmental preferences of homeowners in three Swiss cities, though the ELECTRE method was mentioned as a possible alternative for environmental quality problems. Johnson [37]

utilised the PROMETHEE method to enable clients under the Housing Choice Voucher Programme (USA) to make better decisions about neighbourhoods in which to search for housing. Natividade-Jesus et al. [38] proposed a decision support system, including the use of SAW (Simple Additive Weighting), TOPSIS and ELECTRE, in order to assist several stakeholders in making better decisions on housing evaluation; the research concluded that ELECTRE was the preferred method. Lotfi and Solaimani [39] made an assessment of urban quality of life in Iran using the AHP.

The COPRAS method in particular has been used for a variety of decision making problems found within the built environment. For example, Zavadskas et al. [40] utilised the method to assess building life cycles in order to select an optimal alternative. Zavadskas et al. [41] presented a model of housing credit access for a Lithuanian case study, which sought to determine the most rational housing investment instruments and lenders, using the COPRAS method. Kaklauskas et al. [42] applied the technique in order to design and realise efficient building refurbishment options. COPRAS has also been used in order to define the utility and market value of real estate [43]. Viteikiene and Zavadskas [44] valued the sustainability of residential areas in Vilnius City using COPRAS. Additionally, a model for measuring sustainable city compactness has been developed based on the COPRAS method [45]. Banaitiene et al. [46] adopted COPRAS to support decision-making on a building's life cycle selection by designing alternatives of the building life cycle and evaluating their qualitative and quantitative aspects. Furthermore, SAW (simple additive weighting) and TOPSIS methods were used in order to compare and examine the effectiveness of COPRAS; the final rankings produced by the three methods were the same [46]. COPRAS, along with SAW and TOPSIS, were also used in the evaluation of social and economic development of Lithuanian regions [47]. Ulaityte and Martinaitis [48] sought to identify a building's optimal renovation solution, from a number of possible alternatives, using COPRAS. Furthermore, COPRAS, SAW and MEW (multiplicative exponential weighting) were applied for the purpose of selecting an appropriate one flat dwelling house, taking into account the environmental impact of its construction, financial and qualitative criteria; all three MCDM methods produced the same final ranking of alternatives [49].

The paper presents a tool that can be used to assess sustainable housing affordability, which is based on a criteria system developed by the authors and validated by professionals. A method of MCDM is utilised to carry out an initial assessment of sustainable housing affordability. The application of the MCDM method will ultimately establish the priority order (ranking) of given alternative residential areas in respect of their sustainable housing affordability. This approach will provide a full criteria analysis of the various factors that influence sustainable housing affordability.

An example of how the tool can be applied is provided in this paper using three residential areas (housing wards) in Liverpool, England as a case study (see Fig. 1). Liverpool in particular was selected as a case study location because the city has a diverse and polarised housing market, with some areas experiencing low demand and housing market failure, whilst others areas have rapidly rising house prices. Such a diversity in the city's housing markets will assist in demonstrating how a full criteria analysis can better determine true housing affordability, reflecting the quality and sustainability of a housing location, rather than relying on price alone as the principal determinant of affordability.

3. Materials and methods

3.1. Data collection

The data collection process included the following stages: determining sustainable housing affordability criteria, determining

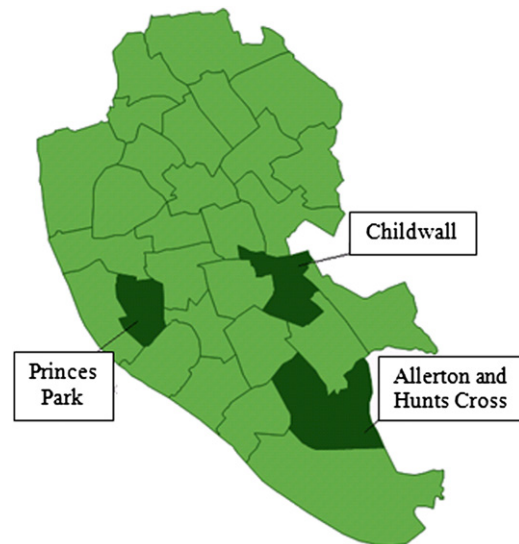


Fig. 1. Map of Liverpool housing wards with case study areas highlighted.

criteria weights, selecting decision alternatives for comparison, calculating criteria values for each alternative, and finally, forming a decision-making matrix with the aforementioned data.

A two stage approach was adopted to develop the criteria system and to validate and subsequently weight such criteria. Initially, a system of criteria defining sustainable housing affordability was identified via an extensive literature review and semi-structured interviews with local authorities in Merseyside and Cheshire, England. The semi-structured interviews probed professionals on their opinion on the factors that are important to housing affordability. Furthermore, relevant literature on the subjects of housing affordability and sustainable communities was reviewed to determine attributes that influence sustainable housing affordability. A total of 20 criteria were identified. Table 1 displays the full criteria system and indicates the derivation of each criterion (i.e. literature source and/or interview process).

Subsequently, the criteria system was validated and weighted via questionnaire surveys. The 20 criteria differ according to their relative importance to sustainable housing affordability. Therefore, weighting was introduced in order to reflect the significance of the criteria. A questionnaire survey was distributed to experts in order to elicit data on the importance of the sustainable housing affordability criteria. The survey was conducted with 65 housing and planning experts in North West England. These experts, basing their answers on their knowledge, experience and perception, ranked the sustainable housing affordability criteria on a scale of importance ranging from 1 to 10, where a ranking of 1 meant "not important at all" and a ranking of 10 meant "most important". This allowed criteria to be validated, or even excluded, from the proposed sustainable housing affordability criteria system. The mean ranking of importance obtained for each criterion was converted into a weight by dividing by the sum of mean scores and multiplying by 100. As such, we ensure the total of all weights is 100%. The mean scores of importance obtained via the questionnaire process and the subsequent weights for the criteria are displayed in Table 1.

Three alternative residential areas (housing wards) in Liverpool, England were selected for comparison purposes. As the presented methodology is a pilot exercise only a small data set was used at this stage. The three alternative case study areas were randomly selected from the 30 housing wards located within Liverpool. The first alternative is Princes Park (A_1), the second alternative is Childwall (A_2) and the final alternative is Allerton and Hunts Cross (A_3) (shown in Fig. 1).

Criteria values were determined using secondary sources, such as local authority and government publications. GIS (geographic information systems) mapping, provided by the local authority (Liverpool City Council), was also used in order to assist in determining ease of access to amenities and facilities for each case study area (e.g. for criterion 7 through to criterion 14). Some examples of how criteria values were calculated are as follows:

Criterion 1 (house prices in relation to income) was assessed by equating average house price to income ratios. A ratio is calculated by dividing house price by household income. The average income for North West England (£33,263 for 2010) was used to compute the ratios. The ratio was calculated for four tenures (detached/semi-detached/terraced/flat) and then an average house price to income ratio was obtained for each alternative area. For this case study the values were calculated as follows:

Tenure	Princes Park		Childwall		Allerton and Hunts Cross	
	Average price	Ratio	Average price	Ratio	Average price	Ratio
Detached	£263,333	7.9	£269,321	8.1	£397,450	11.9
Semi	£124,278	3.7	£183,985	5.5	£186,563	5.6
Terraced	£70,817	2.1	£134,433	4	£117,368	3.5
Flat	£78,843	2.4	£137,967	4.1	£117,150	3.5
	Average=4		Average=5.4		Average=6.1	

(House prices sourced from: www.rightmove.co.uk).

Criterion 2 (rental costs in relation to income) was assessed by calculating the average percentage (%) of income spent on rent. This was equated for 1, 2, 3 and 4 bedroom properties and an average value was then concluded. To compute this data, the average annual income figure for North West England (£33,262 for 2010) was used to determine a monthly household income figure (£2,560). Using this average monthly household income figure the average percentage of income spent on rental costs was calculated as follows:

Beds	Princes Park		Childwall		Allerton and Hunts Cross	
	Average rent	% income spent	Average rent	% income spent	Average rent	% income spent
1	£454	17.7	£486	19	£514	20.1
2	£565	22.1	£594	23.2	£673	26.3
3	£757	29.6	£698	27.3	£714	27.9
4	£814	31.8	£955	37.3	£1,093	42.7
	Average=25.3		Average=26.7		Average=29.3	

(Rental costs sourced from: www.nestoria.co.uk).

Criterion 6 (safety/crime) was assessed using crime statistics from Liverpool City Council's (LCC) ward profiles, which provide economic and social data concerning all of Liverpool's housing wards. The crime rate (all crime per 1000 persons) for each neighbourhood area was compared against the City average and a corresponding score was established (see below).

Valuation of criterion 6—safety (crime):

Crime rate	Associated score
Well above city average	5
Above city average	4
Average	3
Below city average	2
Well below city average	1

Thus, for this case study the values for criterion 6 were calculated as follows (data on Liverpool is provided as an average benchmark):

Alternative	Crime rate	Associated score
Liverpool (average benchmark)	48.8	N/A
Princes Park	61.7	4
Childwall	21.3	1
Allerton and Hunts Cross	26.2	1

Criterion 7 (access to employment) was assessed in two parts: part A—distance to employment opportunities and part B—employment deprivation. Distance to employment opportunities

was calculated for each neighbourhood using maps provided by LCC which show key employment sites and access boundaries (i.e. access within 15 min, access within 30 min). Employment deprivation was calculated using Job Seekers Allowance (JSA) data which shows the percentage claimants within a neighbourhood area. JSA is a benefit paid to people who are unemployed, but who are available for, and actively seeking work. The national average JSA claim rate was used as a benchmark and then data

for each neighbourhood area was assessed against it and given an associated score (see below). The scores for part A and part B were then combined in order to obtain a final value for criterion 7.

Valuation of criterion 7 part A—distance to employment opportunities:

Distance	Associated score
High—key employment site within 15 min by public transport	3
Moderate—key employment site within 30 min by public transport	2
Low—key employment site over 30 min away by public transport	1

Valuation of criterion 7 part B—employment deprivation:

Employment deprivation	Associated score
Well below average JSA claims	5
Below average JSA claims	4
Average JSA claims	3
Above average JSA claims	2
Well above average JSA claims	1

JSA (Job Seekers Allowance).

Accordingly, for this case study the values for criterion 7 part A and part B were calculated as follows (data on the national average JSA claim rate is provided as a benchmark for part A):

Alternative	Criterion 7 part A		Criterion 7 part B		Final value
	JSA claims (%)	Associated score	Access to employment	Associated score	
National average	3.5	N/A	N/A	N/A	N/A
Princes Park	12.7	1	High	3	4
Childwall	3.1	4	High	3	7
Allerton and Hunts Cross	3.8	2	High	3	5

Criterion 19 (% of area in most deprived 10% nationally) was assessed using the Index of Multiple Deprivation (IMD). The indices of deprivation identify the most disadvantaged areas in England. Deprivation is assessed by examining factors such as income deprivation, health deprivation and disability and barriers to housing and services. To calculate criteria values, Liverpool's average rate of deprivation (%) was used as a benchmark and each neighbourhood area was compared against it to establish an associated score (see below).

Valuation of criterion 19—% of area in most deprived 10% nationally by IMD (Index of Multiple Deprivation):

Deprivation	Associated score
Well below average IMD	1
Below average IMD	2
Average IMD	3
Above average IMD	4
Well above average IMD	5

Accordingly, for this case study the values for criterion 16 were calculated as follows (data on Liverpool is provided as an average benchmark):

Alternative	Deprivation rate (IMD %)	Associated score
Liverpool (average benchmark)	57.9	N/A
Princes Park	96.4	5
Childwall	5	1
Allerton and Hunts Cross	39.3	2

Following the data collection process a decision-making matrix must be prepared in order to carry out a MCDM assessment.

A matrix format easily expresses the MCDM problem [24]. The initial matrix, shown in Table 2, displays the criteria that define sustainable housing affordability, the criteria weights, a set of decision alternatives (residential areas) and criteria values for each alternative. Once the matrix has been created, the values can be processed using a suitable decision making method.

3.2. Evaluation of sustainable housing affordability using COPRAS

Despite the large quantity of MCDM methods available, no single method is considered the most suitable for all types of decision-making situation [32]. Therefore, Guitouni and Martel [32] proposed a conceptual framework for articulating tentative guidelines to choose an appropriate MCDA method. However, it has also been acknowledged that several methods can be potentially valid for a particular decision making situation; there is not always an

overwhelming reason to adopt one technique over another [33]. It seems that one of the most important criteria in selecting a MCDM method is its compatibility with the problem's objective [30]. The problem proposed in this study is the assessment of sustainable housing affordability of a number of alternative areas. To determine this, a ranking of alternatives needs to be identified. Therefore, the objective of this problem is to rank alternatives. Consequently, a MCDM method that has the ability to provide a complete ranking of alternatives (indicating the position of each alternative) is required. Additionally, the method must have the ability to handle criteria of both positive and negative influence and those of a quantitative and qualitative nature. Furthermore, ease of use and understanding of the MCDM technique is important so that any interested parties can easily adopt the proposed method.

It was established that COPRAS would be a suitable methodology to adopt for the initial pilot assessment of sustainable housing affordability owing to a number of factors:

- The method is transparent, simple to use and has a low calculation time in comparison with other MCDM methods, such as AHP and TOPSIS [50]. Therefore, this method could easily be adopted by any interested parties.
- COPRAS can provide a complete ranking of alternatives.
- The method can deal with both quantitative and qualitative criteria within one assessment.
- COPRAS has the ability to account for both positive (maximising) and negative (minimising) evaluation criteria, which can be assessed separately within the evaluation process. Some basic MCDM methods which could have been applied for this pilot assessment, such as SAW, would require transformation of negative criteria into positive ones, making the procedure more complicated and time consuming for potential users.
- An important feature that makes the COPRAS method superior to other available MCDM methods is that it may be used to estimate the utility degree of alternatives, showing, as a percentage, the extent to which one alternative is better or worse than other alternatives taken for comparison.

Table 1
Criteria system for sustainable housing affordability and criteria weights.

Sustainable housing affordability criteria		Criteria derivation: literature reference/interview	Mean score	Weight, <i>q</i>
1	House prices in relation to incomes	Local authority interview, [51], [52].	8.66	6.35
2	Rental costs in relation to incomes	Local authority interview, [51], [52].	8.69	6.37
3	Interest rates and mortgage availability	Local authority interview, [53], [54].	7.18	5.27
4	Availability of social and private rented accommodation	[5], [6], [55].	7.71	5.65
5	Availability of affordable home ownership products	[5], [6], [55].	7.09	5.20
6	Safety (Crime level)	[4], [5], [6], [22].	6.62	4.85
7	Access to employment opportunities	[4], [5], [6], [22].	7.49	5.49
8	Access to public transport services	[4], [5], [6], [20], [51]	6.80	4.99
9	Access to good quality schools	[4], [5], [22], [51], [56].	6.75	4.95
10	Access to shops	[4], [5].	6.70	4.91
11	Access to health services	[4], [5].	6.78	4.97
12	Access to child care	[4], [5].	5.42	3.97
13	Access to leisure facilities	[4], [5].	4.94	3.62
14	Access to open green public space	[4], [5], [6], [51], [55], [57].	5.66	4.15
15	Quality of housing	Local authority interview, [1], [6], [55].	8.36	6.13
16	Energy efficiency of housing	Local authority interview, [6], [9], [55].	7.42	5.44
17	Availability of waste management facilities	[5], [6], [55].	4.52	3.31
18	Desirability of neighbourhood area	[58], [59].	5.98	4.39
19	Deprivation in area	[2], [4].	6.89	5.05
20	Presence of environmental problems (e.g. litter, traffic)	[4], [6], [55], [58].	6.71	4.92

Table 2
Initial matrix for MCDM.

Criteria, <i>i</i>	<i>z</i>	Measurement unit	Weight, <i>q</i>	Alternatives, <i>j</i>			
				<i>A</i> ₁ , Princes Park	<i>A</i> ₂ , Childwall	<i>A</i> ₃ , Allerton and Hunts Cross	
1	House prices in relation to incomes	–	Ratio	6.35	4	5.4	6.1
2	Rental costs in relation to incomes	–	%	6.37	25.3	26.7	29.3
3	Interest rates and mortgage availability	+	Points	5.27	1	1	1
4	Availability of private and social rented accommodation	+	Quantity	5.65	79	13	19
5	Availability of affordable homeownership products	+	Points	5.20	1	1	1
6	Safety (Crime)	–	Points	4.85	4	1	1
7	Access to employment	+	Points	5.49	4	7	5
8	Access to public transport services	+	Points	4.99	4	5	5
9	Access to good quality schools	+	Points	4.95	11	21	18
10	Access to shops	+	Points	4.91	3	2	4
11	Access to health services	+	Points	4.97	12	12	12
12	Access to child care	+	Points	3.97	4	6	6
13	Access to leisure	+	Points	3.62	6	3	4
14	Access to open green public space	+	Points	4.15	4	2	4
15	Quality of housing in area	+	Points	6.13	5	9	9
16	Energy efficiency of housing in area	+	Points	5.44	1	1	1
17	Waste management in area	–	Points	3.31	1	1	1
18	Desirability of neighbourhood	+	Points	4.39	1	3	3
19	Deprivation in area (Index of multiple Deprivation)	–	Points	5.05	5	1	2
20	Presence of environmental problems	–	Points	4.92	2	1	2

The sign (+/–) indicates that a greater/lesser criterion value satisfies sustainable housing affordability.

- Furthermore, the COPRAS method has been frequently and successfully applied to a range of property, planning and sustainability related problems (highlighted in Section 2).

The COPRAS (COmplex PROportional ASsessment) method assumes direct and proportional dependence of significance and priority of investigated alternatives on a system of attributes [41]. The significance of the comparative alternatives is determined on the basis of describing positive and negative characteristics of the alternatives. The method estimates the priority order and utility degree of the alternatives.

The COPRAS method is a five-stage procedure [41,43]:

Stage 1: The first step is in any multi-criteria analysis is normalisation of the decision-making matrix *D* (Table 3). Normalisation translates data measured with different units – such as points, ratio and percentage – into weighted dimension-

less variables, allowing their direct comparison. The following formula is used:

$$d_{ij} = \frac{q_i}{\sum_{j=1}^n x_{ij}} x_{ij} \tag{1}$$

where *x_{ij}* is the value of the *i*-th criterion of the *j*-th alternative, and *q_i* is the weight of the *i*-th criterion. For example, taking the data presented in Table 2 the calculation would be as follows:

$$d_{21} = \frac{q_2}{x_{21} + x_{22} + x_{23}} x_{21} = \frac{6.37}{25.3 + 26.7 + 29.3} 25.3 = 2.0$$

with this transformation, the sum of the dimensionless weighted values *d_{ij}* of each criterion *x_i* always equals the weight *q_i* of this criterion:

$$q_i = \sum_{j=1}^n d_{ij} \tag{2}$$

Table 3
Normalised decision matrix *D*.

Criteria, <i>i</i>	<i>z</i>	Alternatives, <i>j</i>			
		<i>A</i> ₁	<i>A</i> ₂	<i>A</i> ₃	
1	House prices in relation to incomes	–	1.6	2.2	2.5
2	Rental costs in relation to incomes	–	2.0	2.1	2.3
3	Interest rates and mortgage availability	+	1.8	1.8	1.8
4	Availability of private and social rented accommodation	+	4.0	0.7	1.0
5	Availability of affordable homeownership products	+	1.7	1.7	1.7
6	Safety (Crime)	–	3.2	0.8	0.8
7	Access to employment	+	1.4	2.4	1.7
8	Access to public transport services	+	1.4	1.8	1.8
9	Access to good quality schools	+	1.1	2.1	1.8
10	Access to shops	+	1.6	1.1	2.2
11	Access to health services	+	1.7	1.7	1.7
12	Access to child care	+	1.0	1.5	1.5
13	Access to leisure	+	1.7	0.8	1.1
14	Access to open green public space	+	1.7	0.8	1.7
15	Quality of housing in area	+	1.3	2.4	2.4
16	Energy efficiency of housing in area	+	1.8	1.8	1.8
17	Waste management in area	–	1.1	1.1	1.1
18	Desirability of neighbourhood area	+	0.6	1.9	1.9
19	Deprivation in area	–	3.2	0.6	1.3
20	Presence of environmental problems	–	2.0	1.0	2.0

The sign (+/–) indicates that a greater/lesser criterion value satisfies sustainable housing affordability.

For example, looking at the normalised values in Table 3:

$$q_1 = d_{11} + d_{12} + d_{13} = 1.6 + 2.2 + 2.5 \approx 6.37$$

Stage 2: The sums of weighted normalised criteria describing the *j*-th alternative are calculated. The alternatives are described by positive (maximising) criteria S_{+j} and negative (minimising) criteria S_{-j} . The higher the positive (maximising) values are, such as ‘quality of housing in area’, the better satisfied is sustainable housing affordability. The lower the negative (minimising) values are, such as ‘deprivation in area’, the better satisfied is sustainable housing affordability. Sums are calculated according to the formulae:

$$S_j^+ = \sum_{z_i=+} d_{ij}$$

$$S_j^- = \sum_{z_i=-} d_{ij} \tag{3}$$

For example

$$S_3^- = d_{1,3} + d_{2,3} + d_{6,3} + d_{17,3} + d_{19,3} + d_{20,3} = 2.5 + 2.3 + 0.8 + 1.1 + 1.3 + 2.0 = 10.0$$

Stage 3: The significance (priority) of the comparative alternatives is determined on the basis of describing positive (+) and negative (–) qualities that characterise the alternative residential areas. The relative significance Q_j of each alternative A_j is determined according to:

$$Q_j = S_j^+ + \frac{S_{\min}^- \sum_{j=1}^n S_j^-}{S_j^- \sum_{j=1}^n \frac{1}{S_j^-}} = S_j^+ + \frac{\sum_{j=1}^n S_j^-}{S_j^- \sum_{j=1}^n \frac{1}{S_j^-}} \tag{4}$$

where S_{\min}^- – the minimum value of S_j^- – cancels. The first term of Q_j increases for higher positive criteria S_j^+ , whilst the second term of Q_j increases with lower negative criteria S_j^- . Thus a higher value of Q_j corresponds to more sustainable housing affordability. For example, taking the data considered in Table 3 the significance Q_2 of A_2 would be calculated as follows:

$$Q_2 = S_2^+ + \frac{S_1^- + S_2^- + S_3^-}{S_2^- \left(\frac{1}{S_1^-} + \frac{1}{S_2^-} + \frac{1}{S_3^-} \right)} = 22.5 + \frac{13.1 + 7.8 + 10.0}{7.8 \left(\frac{1}{13.1} + \frac{1}{7.8} + \frac{1}{10.0} \right)} = 35.5$$

Table 4
Results of COPRAS assessment.

Criteria, <i>i</i>	Alternatives, <i>j</i>		
	<i>A</i> ₁	<i>A</i> ₂	<i>A</i> ₃
S_j^+	22.8	22.5	24.1
S_j^-	13.1	7.8	10.0
Q_j	30.5	35.5	34.2
Priority	3	1	2
N_j (%)	86	100	96

Alternative formulations of Q_j are possible. For example, a simple subtraction of the negative criteria leads to the MCDM procedure known as the weighted sum model (WSM):

$$\bar{Q}_j = S_j^+ - S_j^- \tag{5}$$

Stage 4: The prioritisation Q_j of the alternative residential areas under consideration is determined in this stage. The greater the value Q_j , the higher the priority (significance) of the alternative. In this case, the significance Q_{\max} of the optimal alternative will always be the highest. From the results displayed in Table 4, we see that the highest Q_j value is given by alternative 2, followed by alternative 3 and alternative 1.

Stage 5: The final stage is the determination of the alternative that best satisfies sustainable housing affordability. With the increase/decrease of the priority of the analysed alternative, its degree of utility also increases/decreases. The degree of project utility is determined by comparing each analysed alternative with the most efficient one. The residential area that best satisfies the sustainable housing affordability criteria is expressed by the highest degree of utility N_j equalling 100%. All utility values related to the considered alternatives will range from 0%–100%, between the worst and best alternative out of those under consideration. The degree of utility N_j of the alternative A_j is determined according to the following formula:

$$N_j = \frac{Q_j}{Q_{\max}} 100\% \tag{6}$$

Table 5
Beneficiaries of research.

Beneficiaries	Benefits of assessment method to stakeholders
Local Authorities, Housing Associations and Government (local, regional or international) Developers and Investors in affordable housing	<ul style="list-style-type: none"> • Comprehensive assessment of sustainable housing affordability. • Assist in making better decisions on house purchase. • Provide and monitor affordable housing development. • Promote and maintain high quality of life for sustainable communities. • Aid in identifying areas which would be suitable for development of affordable housing and areas which may not be suitable. • Assist in identifying areas which may require alternative forms of investment to enhance affordability and create sustainable communities. • Use to compare and rank the affordability of different housing locations.
Housing Consumers and Wider Society	<ul style="list-style-type: none"> • Comprehensive assessment of sustainable housing affordability. • Assist in making better decisions on house purchase. • Aid in choosing a housing location appropriate to consumers' needs and preferences for criteria. • Assist in creating affordable, sustainable and high quality communities for society to reside in.

where Q_j and Q_{max} are significances of the alternatives calculated at stage 4. For example, taking the data considered in Table 3 the degree of utility N_1 of A_1 is calculated as follows:

$$N_1 = \frac{Q_1}{Q_{max}} 100\% = \frac{30.5}{35.5} 100\% = 86\%$$

The concluding results of stage 2 through to stage 5 of the COPRAS assessment are displayed in Table 4.

4. Results and discussion

Using the MCDM method COPRAS, an initial assessment of sustainable housing affordability was conducted. The analysis compared three alternative residential areas in Liverpool, based on 20 weighted decision criteria. Previously there was no criteria system established for assessing sustainable housing affordability. A ranking of the priorities of the residential areas was compiled (Table 5): priority 1= A_2 (Childwall), priority 2= A_3 (Allerton and Hunts Cross), priority 3= A_1 (Princes Park). Therefore, the residential area that best satisfies sustainable housing affordability is A_2 (Childwall). Of the three areas considered A_2 (Childwall) did not have the lowest house prices, however after considering all 20 weighted decision criteria it was calculated as the optimal alternative. A_1 (Princes Park) was determined as the worst performing area. Conversely, if affordability had been assessed exclusively on the basis of housing costs in relation to income then A_1 would have been prioritised as the most 'affordable' alternative. The results therefore demonstrate how considering additional criteria that better reflect housing quality, location and community sustainability – as opposed to focusing exclusively on housing costs and incomes – can provide a more comprehensive and sustainable analysis of affordability.

An assessment of three housing wards (alternative areas) in Liverpool was made as an example of the MCDM approach; however, the methodology could be applied to all housing wards across the City to assess sustainable housing affordability. The method may also be utilised in other regions. The proposed assessment method would be beneficial for a number of interested parties, such as local authorities, developers and consumers (see Table 5). It would provide local authorities, developers, investors and housing consumers with the information needed to make comprehensive and sustainable decisions about the affordability of housing. The tool could be utilised by local authorities as a potential planning indicator for shaping local housing markets. Developers, local authorities and investors could use the tool to select sites for affordable housing development between competing locations. It would assist in identifying

areas that are suitable for affordable housing development, along with areas which may require alternative forms of investment to enhance affordability and create attractive and sustainable communities for wider society to reside in. Thus, it could provide and monitor affordable housing development, at the same time promoting sustainable communities and high quality of life. For example, the results concluded that A_1 (Princes Park) was the worst performing alternative. However, housing costs in this area were lower than the other two areas considered. Accordingly A_1 (Princes Park) would benefit from improvements to the quality of the location, e.g. reducing crime and deprivation and increasing job opportunities. This area may not be particularly suitable for the development of affordable housing until the quality and sustainability of the community is increased. In comparison A_2 (Childwall) was calculated to be the optimal alternative. This area would be the most suitable for the development of affordable housing out of the three alternative areas considered as the quality of the location, its access to amenities and facilities, is already high. Identifying appropriate areas for affordable housing development would assist in ensuring high quality of life for sustainable communities. Furthermore, the tool could support housing consumers in making decisions on house purchase, identifying housing locations appropriate to consumers' needs and preferences for criteria.

5. Limitations

During the study some limitations were encountered. Specifically, the measurement and estimation of criteria values was not possible for the individual residential areas (housing wards) in some instances as sufficient and accessible data was not available. For example, for the valuation of criterion 16 (energy efficiency of housing) 'average SAP ratings' were not available at individual housing ward level, data was only accessible for Liverpool City as a whole. Thus, although the criterion was included into the MCDM calculations it actually had no affect on the final ranking of alternatives as each alternative area had to be given the same value. The same situation occurred with the valuation of criterion 17 (waste management). This was to be measured by the 'percentage of household waste sent for recycling, composting or reuse', but once more data was not available at individual housing ward level, rather it was only obtainable for Liverpool City as a whole. The authors suggest that additional data is needed so that such criteria can be more accurately measured at housing ward level and not only for the local authority as a whole. This will allow clearer distinctions to be made between areas regarding their sustainable housing affordability.

6. Conclusions

Housing affordability and sustainability are important topics for research which require close cooperation. Assessments of housing affordability must take a broader and more sustainable view of the wide ranging criteria that affect households, including economic, environmental and social aspects. Accordingly this paper has presented a methodology that can be utilised to assess sustainable housing affordability, which is capable of taking into consideration numerous decision criteria. A weighted criteria system – representing sustainable housing affordability – was the basis of the assessment method, which was developed by the authors following a recognition that such a criteria system did not previously exist. The MCDM method COPRAS was used for the evaluation and allowed alternative areas to be prioritised in respect of their sustainable housing affordability, based on 20 decision criteria. The paper presented the results of an assessment of three residential areas (housing wards) in Liverpool as an example of the approach. Although applied to Liverpool as a case study, the methodology is generalizable and could be applied to other regions. The case study data (criteria values) can be changed and computed for other areas.

The MCDM assessment method can assist stakeholders in making more accurate and comprehensive decisions concerning affordability, reflecting the quality and sustainability of a housing location, rather than focusing exclusively on housing costs and incomes. The presented methodology could be adopted by a number of interested parties, including local authorities, governments, developers and investors. The tool could be used on a local, national or international scale. The weighting (importance) of the criteria can be adapted given the requirements of the concerned party and depending on the local situation. Furthermore, the number of alternatives (residential areas) for consideration may be small or large depending on the decision maker's requirements. Furthermore, the presented methodology could be applied to individual housing units, rather than to housing wards (neighbourhood areas). This would allow the affordability of different housing units to be compared and ranked and could assist consumers in making decisions on house purchase.

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