Influence of sustainable construction aspects and quality of public space on the price of houses in the Czech Republic

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Abstract. The construction industry produces 25 to 30% of greenhouse gases and consumes 40% of globally required energy. The construction industry and buildings contribute significantly to the climate change. Also the buildings are the cornerstone to the public space and affect its quality. One of the approaches to reduce greenhouse gas production (especially carbon dioxide) is the construction and operation of buildings according to the principles of sustainability. Houses are mostly not certified (environmental certification programs as LEED or BREEAM) because it is uneconomical to certify. However, the houses can fulfill sustainable construction aspects like using natural or recycled materials, design of energy efficient buildings, using alternative energy sources, connection to public transport, etc. The influence of using basic sustainable principles and quality of public space as an important part of sustainability to a price was tested through a database. The database consists of 98 samples of houses sold over the year 2017 in Brno - venkov district. Significant price settings factors were identified. Due to the number of variables, testing by multivariate regression analysis was performed on submodels, individual variables could be correctly identified. Tested database confirmed basic price setting factors for houses, such as the technical condition of the house, distance from the city of Brno, as well as the useable area of the house and the factor of liquidity. The influence of sustainable principles like using renewable energy, low energy demand, solar panels for hot water or photovoltaic panels was rejected. Some kind of sustainable principle was detected at 10% of samples. Material base, especially using natural materials like timber, was not found as a price setting factor. One of the submodels was focused on the social part of the sustainability given to the location and public space. The possibility of using public transportation or car park close to the house was not confirmed as price setting factors affecting the price. Also the danger of flooding, index of criminality and noise level were considered and were rejected as price affecting. This paper presents results aimed at exploring the importance of the basic aspects of sustainable construction and quality of public space on the price of houses in the database of 98 houses in Brno - venkov district, Czech Republic.

1. Introduction
Sustainable development consists of three pillars: economic, environmental, and social, which need to be balanced. As a part of sustainable development, there is sustainable construction which significantly contributes to climate change. The construction industry is not only about the process of constructing buildings or infrastructure but also about building's lifecycle and building's operation. According to the principles of sustainability, it is necessary to reduce the production of greenhouse...
gases through construction and building operations. The paper focuses on typical price setting factors that include sustainable constructions and technologies used at selling houses.

2. Literature review

There are many price setting factors which affect the price of real properties including houses. These factors are possible to divide into several groups, such as locality, public space and amenities, type, condition and equipment of the buildings. The following paragraphs are focused on price setting factors which are placed into the groups.

2.1 Locality

According to many articles, the locality is the most significant price setting factor. It usually includes good availability of amenities, such as school facilities, stores as well as working options and social life opportunities. It's confirmed by many studies. [1], [2]

2.2 Building

Many articles indicate technical conditions as a significant price setting factor. [3], [4] It goes hand in hand with the age of the building. Energy performance (class of energy labels) is derived from the age of the building and it affects operation cost as well. [5] Since climate change is a very discussed topic, there are researches focused on energy label and its effect on the price of buildings. [6], [7]

2.3 Sustainable features

One of the basic sustainable principles is using natural and renewable materials. Construction of timber based houses fulfills the idea of sustainability. Material base (like timber, concrete, bricks) of houses can affect the price as well as the construction cost. There are studies focused on the influence of material base on the construction cost [8], [9]. Only a few studies have considered the influence of material base on selling prices. [10] It shows that there is an influence of house material base on the selling price. It depends on the local house market and the popularity of each material base.

An inherent part of sustainability is also the use of renewable energy as well as reduced energy demand generally. According to the research from Japan [11], new green buildings (including green technologies as well) have a negative price difference. On the other hand, the price of the houses tends to increase after two years. Also, renewable energy such as photovoltaic and wind power generators is associated with greater costs of maintenance and replacement.

2.4 Transport, noise and criminality

For environmental protection, it is important to prioritize the use of public transport at the expense of private cars. Collins & Chambers inform in their articles that using private vehicles at the expense of public transport leads to climate deterioration. [12] Collins and Chambers note that “personal car use contributes to the environmental pollution, decreased air quality, greenhouse gas emissions, and fossil fuel consumption” [12]. Gerald T. Gardner & Paul C. Stern, “argues that domestic motor vehicle use, along with home space heating are the most important targets for emissions reduction.” [13] Hunecke et al.note that the transportation sector accounts for around 10 % of greenhouse gasses globally. [14]

Noise in public space has a negative environmental effect according to Nijland et al. say that “today’s urbanization will lead to noise being a bigger problem in the future unless efforts are made to mitigate the problem.” [15] Day et al. points to road traffic noise which affects the price more than railway noise. [16] Same idea was also confirmed by Miedema and Oudshoorn. [17] Nellthorp et al.
draw attention to the fact that “the effect of traffic noise is often assumed to be negligible below an assumed baseline threshold at around 55 LAeq (measured outdoors).” [18]

Lorenc et al. informs that the urban environment may affect the health of inhabitants, especially the psyche caused by fear of crime. [19] This field is an important part of the social pillar of sustainability as well as the field of culture landmark and public space generally.

3. Methodology and data
The primary database of house selling prices in a selected locality was compiled. House market was monitored in a relatively compact area in the district of Brno – venkov in 2017. The district of Brno - venkov is an urban area (approximately 222 300 inhabitants) connected to Brno city (approximately 380 000 inhabitants). The district is bordered by a protected landscape area in the north and by an area of vineyards in the south. There is a great deal of agriculture and industry possibilities.

Real estate advertising was the cornerstone data source of the market. Individual offers from real estate advertisements have been continuously tracked and searching for the core information from the Land Register. For each house, there is an asking price and selling price available, as well as the time on the market. Selling prices have been requested from the Land Register.

Following characteristics have been registered for the houses (items of the database): the cadastral territory, address, asking price, selling price, time on the market, the year of selling, energy label, usable area of the house, size of the building plot and other information which was included in the real estate advertising. More information, which was needed to choose an individual variable, was traced in public resources.

Individual variables were chosen and divided into several groups as it is also mentioned in the literature review of this article, such as locality, public space and amenities or the type, condition and equipment of the buildings.

In the condition and equipment of the building group, the technical condition of the house, age, material base, the usable area of the house, size of the building plot, other appurtenances (for example shed, wine cellar, pergola et cetera), fireplace, above standard, shape of the roof and number of floors were included.

Variables connected to locality: public space and amenities or type: distance from the city of Brno, index of criminality and noise level, train to Brno, an important monument in the village, direct bus to Brno, parking, distance from Brno, population, criminality, catchment area.

For better recognition of price setting factors, indicators of the market efficiency were considered. The first one is the monitoring of asking price development until realizing a market transaction (ΔP). The second one is the time on the market for an individual offer.

The factor related to sustainable principles was considered. This factor included technologies, for example the use of renewable energy, solar panels for hot water or photovoltaic panels. All of them were tested as one variable called alternative technologies. Sustainable construction principles like material base or shape of the building were included as well.

The database consists of 98 items of houses sold over in the year 2017 in Brno - venkov district.

4. Results and discussion
Based on the multivariate regression analysis and the determined significance level of 0.05, the influence of the price setting factors was determined. Testing was performed on submodels that
individual variables could be correctly identified. Submodels and variables were divided into groups of the same structure as the literature review. The most affecting price setting factors are tested through all models to keep the high informative ability of models.

The first submodel (Table 1, 2) focused on basic price setting factors showed expected results that the most influential factors are the age and the condition of houses, distance from Brno (as a center of this region), size of the house and size of the building plot. Also, other appurtenances and a fireplace were found to be important price setting factors.

Table 1. First submodel: Statistical summary with the dependent variable (selling prices)

| Statistics          | Value          |
|---------------------|----------------|
| R                   | 0.894497058    |
| R2                  | 0.800124986    |
| Adjusted R2         | 0.771907337    |
| F (12.85)           | 28.3554802     |
| p                   | 1.04814795E-24 |
| Std. error of estimate | 952283.66    |

Table 2. First submodel: Regression result with dependent variable (selling prices)

| N=98                | b*             | Std. error b* | b             | Std. error b | t (85) | p-value    |
|---------------------|----------------|---------------|---------------|--------------|--------|------------|
| Abs. mem.           | -784529        | 873707.5      | -0.89793      | 0.371759     |
| usable area of the house | 0.193253     | 0.055958      | 4534          | 1313.0       | 3.45354| 0.000865   |
| size of the building plot | 0.139306     | 0.054614      | 392           | 153.5        | 2.55074| 0.012541   |
| distance from the city | -0.302086    | 0.054840      | -70557        | 12808.8      | -5.50850| 0.00000    |
| population          | 0.098566       | 0.056626      | 94            | 53.9         | 1.74066| 0.085362   |
| ΔP                  | 0.124198       | 0.053749      | 1994107       | 862993.7     | 2.31069| 0.023272   |
| time on the market  | 0.037336       | 0.051499      | 1265          | 1744.5       | 0.72499| 0.470452   |
| age and the tech. condition | 0.456876      | 0.062295      | 1091638       | 148845.5     | 7.33403| 0.000000   |
| train to Brno       | 0.002065       | 0.059022      | 9667          | 276264.9     | 0.03499| 0.972168   |
| other appurtenances  | 0.192271       | 0.052975      | 768611        | 211768.8     | 3.62948| 0.000484   |
| fireplace           | 0.206188       | 0.062914      | 965112        | 294483.8     | 3.27730| 0.001519   |
| above standard      | 0.050290       | 0.063181      | 294112        | 369501.1     | 0.79597| 0.428266   |
| alternative         | -0.000916      | 0.052635      | -6006         | 344940.8     | -0.01741| 0.986149   |

Another submodel (Table 3, 4) focused on sustainable features. All tested factors were rejected. There is no influence of tested price setting factors like the material base of houses (especially if wood was used), a number of floors and a roof shape as factors primarily influencing heat loss and energy demand. Also, the ability of sustainable principles like the use of renewable energy, low energy demand, solar panels for hot water or photovoltaic panels were not found to be price setting factors.
Any alternative technology was detected at 10 % of the items of the database. The market of houses fulfilling sustainable principles is not yet developed in the Czech Republic.

Table 3. Second submodel: Statistical summary with the dependent variable (selling prices)

| Statistics          | Value          |
|---------------------|----------------|
| R                   | 0.874435251    |
| R²                  | 0.764637008    |
| Adjusted R²         | 0.737583791    |
| F (10.87)           | 28.26418       |
| p                   | 3.06783778E-23 |
| Std. error of estimate | 1021423.87    |

Table 4. Second submodel: Regression result with dependent variable (selling prices)

| N=98                | b*       | Std. error b* | b       | Std. error b | t (85) | p-value |
|---------------------|----------|---------------|---------|--------------|--------|---------|
| Abs. mem.           | 644092   | 595371.7      | 1.08183 | 0.282317     |
| usable area of the house | 0.177793 | 0.062360       | 4172   | 1463.2       | 2.85106 | 0.005441 |
| distance from the city | -0.326857 | 0.055600      | -76343 | 12986.4      | -5.87868 | 0.000000 |
| size of the building plot | 0.134431 | 0.060906      | 378    | 171.2        | 2.20719 | 0.029933 |
| age and the tech. condition | 0.512452 | 0.066137     | 122430 | 158024.4      | 7.74836 | 0.000000 |
| other appurtenances | 0.184447 | 0.055977      | 737335 | 223772.1      | 3.29503 | 0.001425 |
| above standard      | 0.134474 | 0.064167      | 786444 | 375264.2      | 2.09571 | 0.039014 |
| alternative         | -0.018068 | 0.056610   | -118407 | 370990.2      | -0.31916 | 0.750367 |
| material base       | 0.070121 | 0.057891      | 171569 | 141664.8      | 1.21126 | 0.229076 |
| shape of the roof   | -0.071376 | 0.058266     | -590596 | 482117.0      | -1.22501 | 0.223879 |
| number of floors    | 0.113929 | 0.066344      | 458157 | 266797.7      | 1.71725 | 0.089492 |

Finally, the last model (Table 5, 6) focused on the field of public space and the option of transportation. All tested factors like criminality, bus and train connection to Brno, as an important catchment city and noise level, were shown to not affect the price of the houses at the database of 98 houses in Brno - venkov district. Only the options of a park close to the house or the use of their own garage were closely rejected at the significance level of 0.05.
Table 5. Third submodel: Statistical summary with the dependent variable (selling prices)

| Statistics          | Value        |
|---------------------|--------------|
| R                   | 0.858906388 |
| R²                  | 0.737720184 |
| Adjusted R²         | 0.700692445 |
| F (10.87)           | 19.9234468  |
| p                   | 7.32391724E-20 |
| Std. error of estimate | 1090861.25 |

Table 6. Third submodel: Regression result with dependent variable (selling prices)

| N=98                | b*            | Std. error b* | b          | Std. error b | t (85) | p-value |
|---------------------|---------------|---------------|------------|--------------|--------|---------|
| Abs. mem.           | 451929        | 498617.2      | 0.90637    | 0.367305     |
| usable area of the house | 0.254909 | 0.064163      | 5981       | 1505.5       | 3.97283 | 0.000148 |
| distance from the city | -0.275612 | 0.084902      | -64374     | 19830.4      | -3.24622 | 0.001674 |
| size of the building plot | 0.173018 | 0.063438      | 486        | 178.4        | 2.72734 | 0.007755 |
| population          | 0.117448      | 0.079313      | 112        | 75.4         | 1.48081 | 0.142353 |
| age and the tech. condition | 0.537102 | 0.059980      | 1283328    | 143314.4     | 8.95463 | 0.000000 |
| monument in the village | 0.038974 | 0.073469      | 177359     | 334333.8     | 0.53048 | 0.597160 |
| catchment area      | -0.064575     | 0.085413      | -67541     | 89334.7      | -0.75604 | 0.451716 |
| criminality         | 0.059381      | 0.064816      | 165659     | 180821.8     | 0.91615 | 0.362182 |
| direct bus to Brno  | 0.090316      | 0.065814      | 360207     | 262486.1     | 1.37229 | 0.173584 |
| noise               | 0.006872      | 0.058747      | 37862      | 323677.9     | 0.11697 | 0.907158 |
| train to Brno       | -0.029446     | 0.066671      | -137830    | 312067.8     | -0.44167 | 0.659852 |
| parking             | 0.123017      | 0.065704      | 269050     | 143702.2     | 1.87227 | 0.064607 |

5. Conclusions
The construction industry and operation of buildings represent a large potential to reduce greenhouse gas production via buildings meeting sustainable principles. The research explores how the sustainability features affect the price and identifies the price setting factors of houses in Brno-venkov district of the Czech Republic. Pricing factors were tested on a database containing 98 items of houses.

According to multivariate regression analysis, the basic price setting factors were tested in three groups. The most significant factors were the age, condition of houses and distance from Brno. The size of the house and the building plot were shown as very important factors at the database of 98 houses in Brno-venkov district.

As stated by one of the submodels focused on sustainable features, there is no influence on the use of alternative technology such as heat pump, solar panels for hot water or photovoltaic panels on the price. The influence of the material base of houses and the building shape was not confirmed.
as well. The market of houses fulfilling sustainable principles is not developed yet in the Czech Republic. Only 10% of the houses in the database have been detected to use alternative technology and less than 5% of items were built as timber houses.

Another tested submodel showed that all tested factors focused on the field of the social part of sustainability were not significant at the tested database. These were intangible pricing factors with regard to socio-economic factors and location factors, including crime as a sign of the public space, traffic noise, noise in the public space, transport in relation to the environment and the location of a significant monument in the immediate vicinity.

The next step of the research supported by a larger database should comprise statistical modeling divided into technical price setting factors as a material base or technical condition of houses etc. and social price setting factors as a neighborhood attributes or public space etc.

The research could be also generally useful as input values to the sales comparison approach in microeconomic contexts in Brno-venkov district of the Czech Republic.

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References
[1] J. Frew, and B. Wilson, Estimating the Connection between Location and Property Value. Journal of Real estate practice and education, 5, pp. 1, 17–25, 2002.
[2] M. Haider, and E.J. Miller, Effects of Transportation Infrastructure and Location on Residential Real Estate Values: Application of Spatial Autoregressive Techniques. Transportation Research Record: Journal of the Transportation Research Board, 1722, 1–8, 2000. https://doi.org/10.3141/1722-01.
[3] L. Williams, Jr. Ventolo, and M.R.J.D. Williams, Fundamental of real estate Appraisal, 9th Ed. Chicago: Real Estate Education Company, 2005.
[4] M. Buriskiene, V. Rudzkiene, and J. Venckauskaite, Models of factors influencing the real estate price. Environmental Engineering, The 8th International Conference, 873–878, 2011.
[5] I. Psunder, and N. Ferlan, Subjektivno dojemanje vplivnih faktorjev pri ocenjevanju vrednosti nepremičninških pravic. [Subjective perception of influential factors in evaluation of real estate rights values] In A. Kozar & A.Belsak. (ed.). Book of abstracts from 20th annual congress Dealing in real estate: state, citizens, properties, (pp. 246251), Ljubljana: real estate institute, 2009.
[6] M. Hyland, C.L. Roman, and L. Seán, The Value Of Domestic Building Energy Efficiency - Evidence From Ireland. Energy Economics 40: 943-952, 2013. doi:https://doi.org/10.1016/j.eneco.2013.07.020.
[7] D. Brounen, and K. Nils, On The Economics Of Energy Labels In The Housing Market. Journal Of Environmental Economics And Management 62 (2): 166-179, 2011. doi:https://doi.org/10.1016/j.jeem.2010.11.006.
[8] D. Walberg, Solid and timber construction in residential buildings / Massiv- und Holzbau bei Wohngebäuden. Mauerwerk. John Wiley, 16-31, 2016. DOI: 10.1002/dama.201600685, ISSN 1432-3427.
[9] R. Stasiak-Betlejewska and M. Potkány, Construction Costs Analysis and its Importance to the Economy. Procedia Economics and Finance. DOI: https://doi.org/10.1016/S2212-5671(15)01589-1. ISSN 2212-5671, 2015.
[10] N. Ferlan, M. Bastic and I. Psunder, Influential Factors on the Market Value of Residential Properties. Engineering Economics, 28(2). http://doi.org/10.5755/j01.ee.28.2.13777, 2017.
[11] J. Yoshida, and S. Ayako, The Effects of Multiple Green Factors on Condominium Prices. The Journal of Real Estate Finance and Economics. 2014/04/01, 50, 2014. DOI: 10.1007/s11146-014-9462-3.

[12] C.M. Collins, and S.M. Chambers, Psychological and Situational Influences on Commuter-Transport-Mode Choice. Environment and Behavior, 37(5), 640–661, 2005. https://doi.org/10.1177/0013916504265440.

[13] T.G. Gerald, and C.S. Paul, The Short List: The Most Effective Actions U.S. Households Can Take to Curb Climate Change, Environment: Science and Policy for Sustainable Development, 50:5, 12-25, DOI: 10.3200/ENVT.50.5.12-25, 2008.

[14] M. Hunecke, S. Haustein, S. Böhler, and S. Grischkat, Attitude-Based Target Groups to Reduce the Ecological Impact of Daily Mobility Behavior. Environment and Behavior, 42(1), 3–43, 2010. https://doi.org/10.1177/0013916508319587.

[15] H. Nijland, E. Kempen, G.P. Wee, and J. Jabben, Costs and benefits of noise abatement measures. Transport Policy. 10. 131-140. 10.1016/S0967-070X(02)00064-1, 2003.

[16] B. Day, I. Bateman, and I. Lake, Beyond Implicit Prices: Recovering Theoretically Consistent and Transferable Values for Noise Avoidance from a Hedonic Property Price Model. Environmental & Resource Economics. 37. 211-232, 2007. 10.1007/s10640-007-9121-8.

[17] H.M. Miedema, and C.G. Oudshoorn, Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals. Environmental health perspectives, 109(4), 409–416, 2001. https://doi.org/10.1289/ehp.01109409.

[18] J. Nellthorp, A.L. Bristow, and P.J. Mackie, Developing Guidance on the Valuation of Transport-Related Noise for Inclusion in WebTAG, 2005.

[19] T. Lorenc, S. Clayton, D. Neary, M. Whitehead, M. Petticrew, H. Thomson, S. Cummins, A. Sowden, and A. Renton, Crime, Fear of Crime, Environment, and Mental Health and Wellbeing: Mapping Review of Theories and Causal Pathways. Health & place. 18. 757-65, 2012. 10.1016/j.healthplace.2012.04.001.