Residential Building Projects: Building Cost Indicators and Drivers

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Abstract: Time and costs are considered to be substantial success factors of building construction projects. In Germany, early cost estimates are provided by multiplying the cost indicator with the gross floor area. When preparing these estimates, the question arises as to which specific cost indicator has to be selected? The relevant cost drivers provide guidance for this selection. Drivers show which parameters are the determinants for the selection of the project-specific cost indicators. However, currently these drivers are not known for building construction projects in the German-speaking region. The relevant cost drivers for residential properties in Germany are identified by using regression analysis. These drivers are the median floor height, the share of the ancillary area for services, the construction duration, and the compactness of the building. Of the four cost drivers, the median floor height proved to have the greatest explanatory significance. The method proves to be suitable for answering the research question. However, some theoretically relevant drivers were not available for the properties being examined. Therefore, these drivers have to be followed up and examined during future studies. Detailed information should be included especially about materials, the planning and construction process, and specific data about various dimensions of the building.

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Introduction

Time and cost are considered to be substantial success factors of building construction projects. Against the background of this statement important roles are played by time and cost planning for each building construction project. Thus, cost planning must be understood as a process that generally starts with the definition of the budget, which is based on the requirements of the owner and its financial possibilities. Therefore, a cost estimate based on these requirements is needed in an early phase of the project. In Germany, the inaccuracy of these cost estimates is around 30% and they are based on the following equation (Ruf 2003): area (m^2 gross external floor area) $\times$ indicator (€/m^2 gross external floor area) = cost (€). The high inaccuracy of these cost estimates is particularly due to the selection of the indicators (Ruf 2003), which are made extensively available, for example, by Baukosteninformationszentrum Deutscher Architektenkammern (BKI). The question that has to be answered with respect to this selection and that is at the heart of this study is the following: What are the relevant drivers that influence the building construction cost indicator? This question is so important because the project-specific indicator can only be selected if the relevant drivers are known for the specific project.

Data for residential building construction projects are available for the analysis of cost drivers. This involves data for uniformly documented new construction projects collected by BKI. On the basis of these data from Germany, building construction cost indicators are determined in a first step, and regression analysis is used in a second step to identify their significant drivers. In particular, this is based on the study by Emsley et al. (2002), which though not focused on residential building projects in Germany, identifies relevant cost drivers for new construction projects.

The structure of this paper is guided by the sequence of this study and starts with the description of the theoretically relevant causal relationships between building construction costs and the corresponding cost drivers. This is followed by an initial presentation of the survey sample, as well as the building construction cost indicators derived from the sample. In addition, a discussion of the regression model and its independent variables (drivers) is offered.

Theoretically Relevant Causal Relationships

Definition of Building Construction Costs

Before the survey of the properties can commence, both the potential cost drivers and also the concept of "building construction costs" must be defined. For this purpose, the definition of the cost concept is based on the German "DIN 276" (DIN 1993) standard for cost estimation and includes the cost elements shown in Fig. 1. Not included, among other items, are the cost of land, financing costs during the construction period, and the cost of government as well as professional fees.

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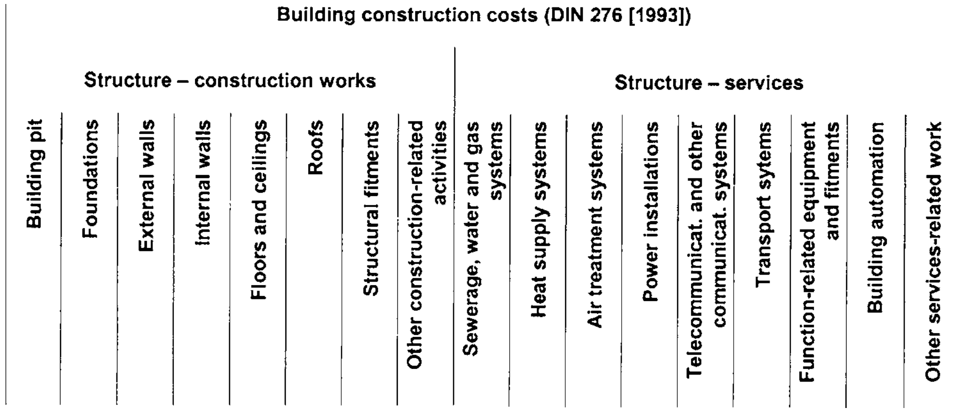

Fig. 1. Definition of cost types in accordance with DIN 276 (DIN 1993)

It is further necessary to specify the functional unit for costs, which in accordance with the German DIN 277 (DIN 2005) standard, is the gross external floor area. "The gross external floor area is the sum of all floor areas of all ground projection plans of a building. This does not include the surface areas of unusable roof space and crawl spaces that are necessitated by the design. The gross external floor area is made up of the area of internal divisions and external constructions and the gross internal floor area" (DIN 2005).

Since the properties in the survey sample, and thus also the associated cost data, are based on different dates, the costs have been normalized as at a uniform base date (2004), using the building price index of the German Federal Statistical Office (Statistisches Bundesamt Deutschland 2005). In addition, it should be noted that all of the following presentations and analyses of cost data are inclusive of 16% value-added tax.

State of Research

The studies identified in Table 1 can be used in order to define the theoretically relevant causal relationships. In Germany there are currently no such studies available to support early cost estimates. The study by Emsley et al. (2002) must be emphasized among the listed studies (data pool of 288 properties). They worked with regression analyses as well as with neural networks to compare both statistical methods. Up to 41 independent variables (drivers) were included in the models they developed. The practical application of these models was made more difficult by the fact that the necessary information (41 independent variables) was too extensive. However, the work of Emsley et al. (2002) offered an extensive list of potential cost drivers for the present study.

Hedonic cost models for residential and office properties were developed by Wheaton und Simonton (2005). Their study used data from 62,000 properties (including 42,000 residential properties) and was concerned primarily with a view of six American construction markets. The focus of their work was the question of determining a "true" cost trend over a period of 35 years. The availability of cost indicators and their drivers was not at the center of their study. However, the present study is able to work with the proposed models and their drivers and ask if these drivers are also relevant in the German construction market.

The result of the literature review summarized above is a list of relevant cost drivers (see Table 1). The list is further refined in expert interviews: 16 real estate owners, architects, cost planners, and cost estimators for construction firms were given the assignment of adding to the prepared list or of crossing off drivers from the list that were irrelevant from their perspective. The result of this preparatory work was a list of 72 drivers.

Empirical Study

Thirty-seven cost drivers (see the Annex section) out of these 72 drivers are available and are included in the empirical analyses of theoretically relevant causal relationships. Detailed information about materials (e.g., materials used in foundations, external walls, internal walls, floors, ceilings, roofs), the planning and construction process (e.g., planning duration, planning organization, characteristics of the construction company), and specific data about various dimensions of the building (e.g., window and door area in external walls or roofs, prefabricated facade area), in particular, are not available.

Data Pool

After the preproject work has been completed, it becomes possible to survey 290 properties in the BKI construction database. These involve exclusively residential building projects, for which not all potential drivers can be captured on the basis of the data provided. The survey depth varies between properties. The size of the survey sample for an individual driver is shown in the Annex section.

In comparison, for instance, to the study by Emsley et al. (2002), the quality of the data provided can be ranked as exceedingly good. On the one hand, all data are drawn from a single source (BKI construction cost database) and not from different survey samples based on different survey methods. On the other hand, the data are based on the accounting records of the construction projects in question, which are directly analyzed and tested for plausibility by BKI. Thus, they involve completed buildings and the associated actual payment streams generated during construction (from the perspective or the purchaser or real estate investor).

The geographic distribution of the survey sample is shown in Fig. 2. It becomes apparent that the two large Bundesländer (German Federal states), Baden-Württemberg and North-Rhine Westphalia, are prominently represented. The absolute size of the

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Table 1. Studies to Determine the Relevant Cost Drivers

Study	Data pool	Method	Cost drivers (extract)
Thalmann (1998)	15 properties (residential)	Regression	• Usable floor area • Proportion of external wall areas underground • Proportion of openings in external wall areas • Year of construction
Elhag and Boussabaine (1998)	30 properties (schools)	Neural networks	• Type of building (primary, secondary school) • Gross floor area • No. of stories •Project duration
Emsley et al. 2002	288 properties	Neural networks and regression	• Project strategic drivers (e.g., type of contract) • Site related drivers (e.g., topography) • Design related drivers (e.g., gross internal floor area)
Picken and Ilozor 2003	36 properties (residential)	Regression	• Building height (>100 m)
Attalla and Hegazy (2003)	50 properties (reconstruction projects)	Neural networks and regression	• Scope definition and planning • Tendering stage • Schedule • Cost • Quality • Communication • Safety • Project completion
Skitmore and Ng 2003	93 properties	Regression	• Client sector • Contractor selection method • Contractual arrangement • Project type • Contract period • Contract sum
Love 2002; Love et al. 2005	161 properties	Regression	• Duration (time–cost relationship) • Gross floor area
Elhag et al. 2005	Literature and interviews		• Client characteristics • Consultant and design parameters • Contractor attributes • Project characteristics • Contract procedures and procurement methods • External factors and market conditions
Wheaton and Simonton 2005	42,340 properties (residential) 18,469 properties (office)	Regression	• Number of stories • Absolute size • Number of units • Frame type • Year of construction

properties can be specified in m^2 of gross external floor area, with the sample showing a median value of 1,142 m^2 (lower and upper quartiles, respectively, of 499 and 2,487 m^2).

Building Construction Costs

On the basis of the sample survey, the indicators for building construction costs can be illustrated. In this context, the median is shown to be 806 €/m^2 gross external floor area, together with the lower and upper quartiles of, respectively, 629 and 1,013 €/m^2 gross external floor area ($R=290$). In addition to producing this figure for total building construction costs/gross external floor area, the survey sample also permits a closer look at cost subgroups (see Fig. 1). It emerges from this analysis, that the cost relevance of the cost of the external walls and technical services is very high (see Fig. 3).

Proposed Regression Model

Regression analysis is used for the empirical examination of the theoretically relevant cost drivers (see Skitmore 1990; Boussabaine 2001). The regression model is developed using the software SPSS 13 for Windows. This applies the iterative method of analysis (significance level 5%), which is based on a foundation of theoretically causal relationships (see Section "State of Research").

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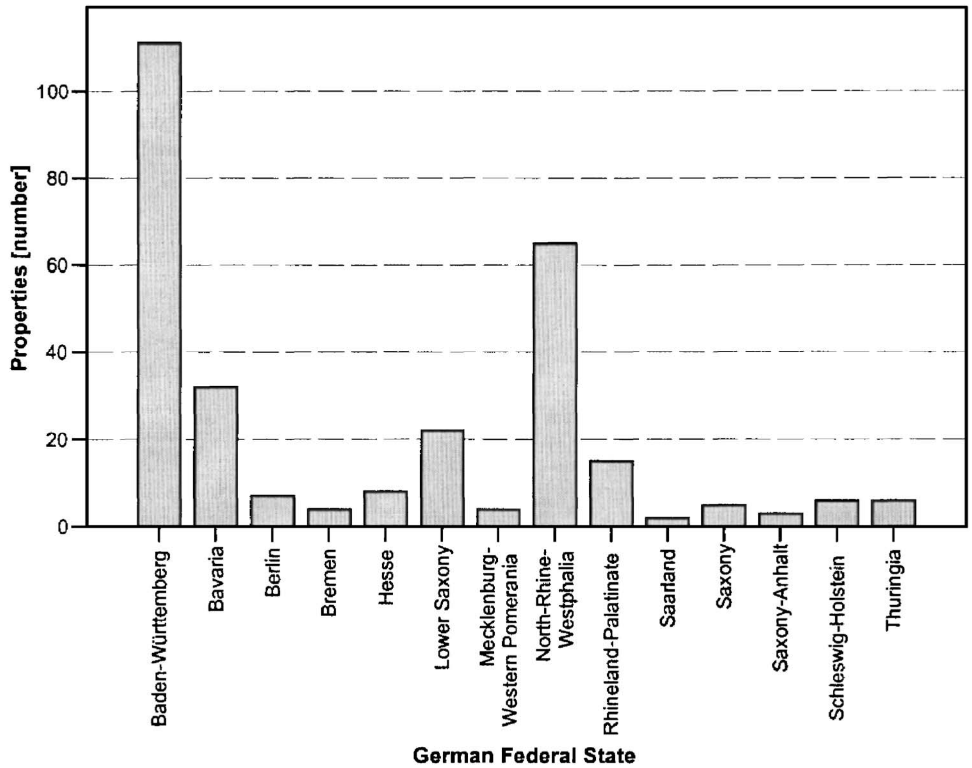

Fig. 2. Geographic distribution of properties

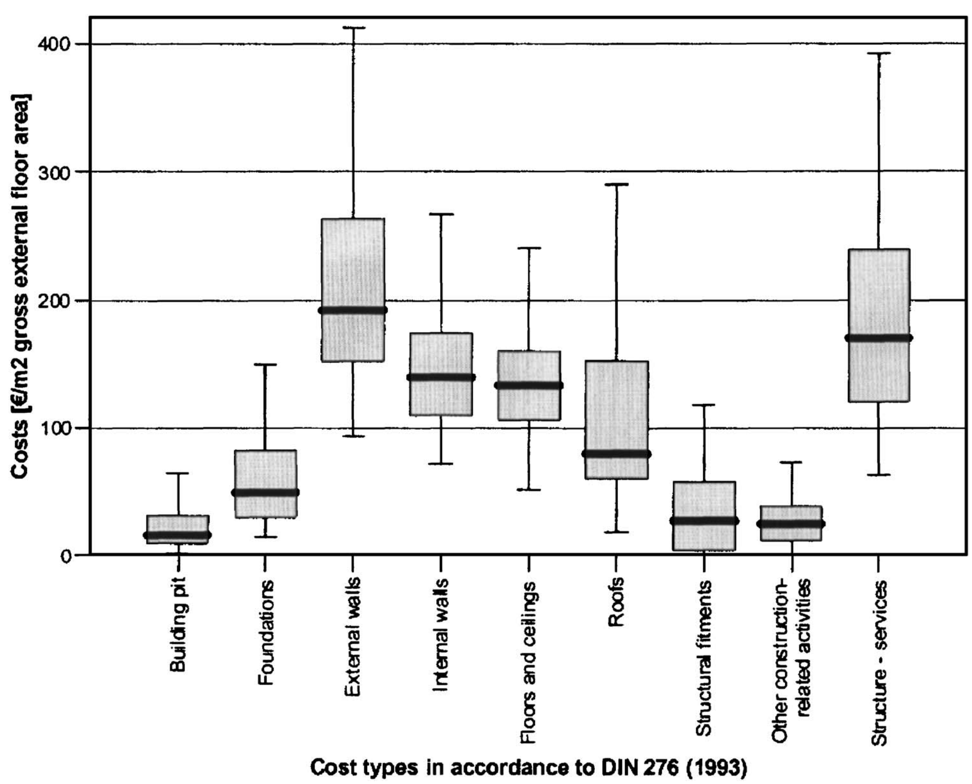

Fig. 3. Building construction cost indicators on the basis of cost types according to DIN 276 (DIN 1993) [€/m^2 gross external floor area (R=149, including VAT, costs as in 2004)]

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Table 2. Model Summaries (Dependent Variable: Transformed Building Construction Costs per m^2 Gross External Floor Area, $R=149$)

Model	Transformation	R^2	R^2 adjusted	F value	Significance
1	None (linear)	0.633	0.621	55.963	0.000
2	Logarithmic	0.589	0.577	46.610	0.000
3	Inverse	0.508	0.493	33.537	0.000
4	Quadratic	0.621	0.610	53.346	0.000
5	Cubic	0.564	0.550	41.970	0.000

Untransformed building construction costs per m^2 of gross external floor area are found to be the suitable dependent variable in the proposed model. In addition, however, the transformed forms of the building construction costs per m^2 of gross external floor area (logarithmic, inverse, quadratic, and cubic) are also tested. However, as in the study by Emsley et al. (2002), they do not produce improved models compared to the untransformed form (see Table 2).

The regression model as developed (Model 1 from Table 2) can ultimately incorporate four independent variables (see Table 3), which are the relevant identified cost drivers used in this analysis:

- Median floor height [gross volume/gross external floor area (m)];
- Ratio of ancillary area for services (ancillary area for services/gross external floor area);
- Construction duration [end of construction–start of construction (months)]; and
- Compactness of the building (external wall area/gross external floor area).

Discussion of Results

Median Floor Height

Within the model, by far the most significant, explanatory content was demonstrated for the cost driver "median floor height" ($\beta=0.607$). With this finding, the present study confirms the opinion of the interviewed experts who also described the importance of the median floor height. According to the experts, the reason for the high explanatory content of this driver is as follows: a high median floor height is, among other things, an indicator of high air treatment installation rates in buildings. This is so because air treatment installations require additional room, which generally requires high ceiling superstructures (for instance, for suspended ceilings), thus resulting in a comparably high median floor height. This relationship is also indicated for the residential building projects in this survey sample. In projects with air treatment systems (mechanical ventilation and/or air conditioning systems), the floor height is, on average, 0.11 m higher than in projects without air treatment systems. It is apparent that mechanically vented and ventilated, as well as air conditioned, buildings are associated with higher median floor heights resulting from these systems on the one hand, and with comparatively higher building construction costs on the other hand.

Against this background, the writers are of the opinion that the interpretation of the regression model requires particular caution. The above cost driver "median floor height," for example, is also an indicator for other drivers not included in the model. The standard of building air treatment systems has already been discussed in greater detail. Beyond that, there are other conceivable relationships that must be taken into account in the interpretation of this model and in further studies. Thus, a greater median floor height is also associated with, for example, a proportionately greater surface of internal walls, stairwell and staircase areas, as well as more complex cabling and wiring for technical services.

Table 3. Coefficient Table for Model 1 (Dependent Variable: Building Construction Costs per m^2 Gross External Floor Area, $R=149$)

Independent variables	B	beta	T value	Significance
Median floor height	355.358	0.607	10.956	0.000
Ratio of ancillary area for services	4,685.534	0.252	4.634	0.000
Construction duration	7.169	0.206	3.806	0.000
Compactness of the building	236.052	0.164	3.055	0.003
Constant	−574.474	—	−5.365	0.000

Ratio of Ancillary Area for Services

Beside the median floor height, the ratio of ancillary area for services also emerges as a relevant cost driver. The reason for its relevance is found in the high cost of the technical services (see Fig. 3). As the standard of such technical services rises, so do building construction costs. In addition, a higher installation standard of such technical services generally results in a higher ratio of ancillary areas for services. This is so because, for example, cost intensive properties with ventilation and air conditioning systems need more ancillary areas for services than properties without such systems.

Table 4. Building Construction Costs [€/m^2 Gross External Floor Area (Including VAT Costs as of: 2004)]

Cost	Lower quartile	Median	Upper quartile	R
Building construction costs	629.34	806.44	1,013.20	290
Structure (construction works)	524.07	655.36	830.57	290
Building pit	7.15	14.87	28.32	149
Foundations	27.32	43.05	72.65	149
External walls	151.69	188.33	246.64	149
Internal walls	105.07	126.51	164.04	149
Floors and ceilings	107.67	128.92	154.75	149
Roofs	61.09	78.83	128.05	149
Structural fitments	4.98	29.40	58.23	149
Other construction-related activities	9.06	21.03	36.14	149
Structure (services)	94.14	128.62	184.55	290
Sewerage, water and gas systems	39.35	48.57	65.17	149
Heat supply systems	38.32	48.61	66.02	149
Air treatment systems	2.85	5.78	17.26	149
Power installations	16.88	26.33	37.46	149
Telecommunications and other communications systems	2.15	3.86	7.03	149
Transport systems	16.71	20.97	28.36	149
Function-related equipment and fitments	2.39	9.71	56.39	149
Building automation	2.05	5.39	8.72	149
Other services-related work	1.85	3.13	6.03	149

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Table 5. Cost Drivers (Metrically Scaled)

Cost drivers	Lower quartile	Median	Upper quartile	R
Gross external floor area (m^2)	498.50	1,142.50	2,486.55	290
Gross internal floor area/gross external floor area	0.81	0.84	0.87	244
Area of internal divisions and internal construction/gross external floor area	0.13	0.15	0.18	244
Floor space/gross external floor area	0.65	0.69	0.74	240
Circulation area/gross external floor area	0.09	0.12	0.17	236
Ancillary area for services/gross external floor area	0.01	0.02	0.03	217
Usable floor area/gross external floor area	0.46	0.53	0.62	229
Area ancillary to main function/gross external floor area	0.09	0.15	0.22	222
Median floor height	2.71	2.89	3.21	290
Levels below ground (number)	1.00	1.00	1.00	290
Levels above ground (number)	2.00	3.00	4.00	290
Levels (number)	3.00	4.00	5.00	290
Gross external floor area/levels (m^2)	160.05	308.18	617.44	290
Excavation volume/gross external floor area	0.59	0.88	1.24	149
Building base surface/gross external floor area	0.23	0.30	0.40	149
External wall surface/gross external floor area	0.57	0.68	0.82	149
Internal wall surface/gross external floor area	0.70	0.84	1.01	149
Ceiling area/gross external floor area	0.59	0.69	0.77	149
Roof space/gross external floor area	0.28	0.38	0.55	149
Facade glass/gross external floor area	0.10	0.13	0.18	149
(Building base surfaces+external wall surfaces+roof space)/gross external floor area	1.12	1.38	1.79	149
(External wall surfaces+roof space)/gross external floor area	0.91	1.08	1.37	149
Ventilated gross external floor area/gross external floor area	0.00	0.00	0.00	290
Vented and ventilated gross external floor area/gross external floor area	0.00	0.00	0.00	290
Partly air conditioned gross external floor area/gross external floor area	0.00	0.00	0.00	290
Gross external floor area subject to air treatment systems/gross external floor area	0.00	0.00	0.00	290
Construction duration (months)	9.00	12.00	17.00	290
Site area/gross external floor area	0.74	1.13	1.97	290
Site area covered by buildings/gross external floor area	0.24	0.33	0.45	290

Construction Duration

The construction duration is defined as the duration from when work begins at the construction site until the work comes to an end. The regression model presented in this study shows a positive relationship between duration and costs. This means that building construction costs rise with increasing construction duration and/or decrease with a drop in construction duration.

In addition, it is well known in practice that this relationship can quickly be pushed to its limit. The assumption is that there is an optimal construction duration for each project. If this duration is reduced beyond its optimal length, building construction costs will generally rise. In this connection, a construction duration that is too long, as well as one that is too short, can negatively influence building construction costs and the project's success.

Compactness of the Building

In this study, the compactness of the building (measured in m^2 external wall area/m^2 gross external floor area) shows a positive cost impact. The reason for this impact is particularly found in the high costs of external walls (see Fig. 3). With lower compactness of the building the cost of external walls per m^2 gross external floor area rises, largely because more m^2 external wall area must be provided. In consequence, building construction costs also rise, which explains the positive cost impact of the compactness of the building.

Limitations

Thirty-five drivers that were originally identified in addition to the 37 analyzed cost drivers were not available. Especially detailed information about materials, the planning and construction process, and specific data about various dimensions of the building were not analyzed. For this reason the existing database has to be developed through further studies and all missing potential cost drivers have to be examined.

On the basis of the literature review and the expert interviews, it is to be expected that a detailed investigation of the planning and construction process, above all, will lead to significant improvements of the model. However, the writers do not believe that exclusive concentration on this group of drivers, alone, is promising success. The proposed model has already delivered significant results without these drivers, which will also need to be considered during further studies.

Conclusion

The main objective of this study is to identify the relevant drivers of building construction costs to support early cost estimates. The examination of these drivers could be based on 37 available relevant drivers, which were derived from a literature review and expert interviews. Four of these drivers are included in the proposed regression model (R^2=0.633):

Table 6. Cost Drivers (Not Metrically Scaled)

Cost driver	Spread	R
Low energy standard	2% Low-energy standard 98% Not low-energy standard	290
German Federal State	38% Baden-Württemberg 11% Bavaria 2% Berlin 1% Bremen 3% Hesse 1% Mecklenburg-Western Pomerania 8% Lower Saxony 22% North-Rhine Westphalia 5% Rhineland-Palatinate 1% Saarland 2% Saxony 1% Saxony-Anhalt 2% Schleswig-Holstein 2% Thuringia	290
Soil class	0% Topsoil 4% Watery soil types 11% Easily soluble soil types 82% Moderately soluble soil types 1% Hardly soluble soil types 1% Easily soluble rock and similar soil types 0% Hardly soluble rock	290
Site gradient	64% Level site 24% Sloping site 12% Hillside	290
Construction space	70% Open construction space 17% Restricted construction space 13% Gap between buildings	290
Type of call for tenders	2% Single tender action 38% Limited tender 60% Open tender	176
Assessment of economic activity at the time that the main contract is awarded	23% Poor 58% Moderate 19% Increasing	290

- Median floor height;
- Ratio of ancillary area for services;
- Construction duration; and
- Compactness of the building.

The proposed method proves to be suitable to answer such questions and to support cost estimates during early project phases. In contrast to the study by Emsley et al. (2002), it has further been possible to identify a practicable number of four relevant cost drivers. By this process, it is shown for residential properties in Germany, which drivers determine building construction costs and must, therefore, be considered in the selection of construction cost indicators.

Further studies can be developed on the basis of these results. However, in the writers' opinion it is above all, necessary to extent the database qualitatively. This means that in addition to the analyzed 37 potential cost drivers further drivers have to be examined, which could not be considered so far. Detailed information about materials, the planning and construction process, and specific data about various dimensions of the building, in particular, has to be included in further studies to improve the present results (see also, Tables 4–6).

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