Research Article

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Bill of quantities and quantity survey of construction works of renovated buildings - case study

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Abstract: The article presents detailed analysis of the case of the renovation of one of historic tenement houses in Warsaw. Other, similar cases analyzed in less detail- were called verification cases. The aim of the article was, first of all, to present the scale of discrepancies between planned and performed amount of works and possibly precise indication of the reasons for these underestimations. The scope of the research included the inventory of the technical condition of selected building elements, the execution of bill of quantities, quantity survey and cost estimates of selected works. The conducted research shows that quantity survey of works subjected to analysis such as: repair of walls, chimneys and brick walls reached the value at least twice as large. The planned cost of works calculated on the basis of the event was exceeded approximately twice. This was mainly due to the fact that the impact of repair works on deterioration of the technical condition of existing building elements was not foreseen. The poor technical condition of elements that were covered was not foreseen either. On the basis of the case studied, universal observations about renovated facilities can be provided. First of all, it should be stated that a person who makes bill of quantities on such facilities should have executive experience on similar projects. Thus, a good practice would be a cooperation with a person experienced in the implementation of similar investments.

Keywords: bill of quantities, quantity survey, renovation, historical facilities, renovated buildings

1 Introduction

After the industrial revolution, the role of precise calculation of the number of works for the purpose of calculating the costs of construction or modernization of construction works began to be appreciated. In 1859, the formation of Bill of Quantities or BQ appeared for the first time in the world [1]. bill of quantities and quantity survey are documents that accompany most construction projects and concern the determination of the number of works. Bill of quantities is usually a part of a tender documentation, while quantity survey is, in a simplified form, its quantitative verification at the construction site. However, according to the Polish regulations, quantity survey is defined as a document containing a list of basic works performed, prepared after completing works, on the basis of quantity survey book [2]. The amount of works specified in quantity survey, consistent with the actual scope of their execution, regardless of whether it is greater than the one specified in the offer, should be the basis for settlement of remuneration for construction works. The conditions are as follows: the parties set quantity survey of work rule for the conversion of remuneration, the fitting of quantity survey of works in the accepted dimensional tolerance and compliance with the project documentation. The number of works must be approved by the ordering party [2, 3]. Bill of quantities is a study containing a list of basic works planned for execution in the technological order of their execution together with their detailed description or indication of appropriate technical specifications for the execution and acceptance of construction works, with the calculation and specification of the quantities of primary works [4] (ordinance of 2 September 2004 on the detailed scope and form of project documentation (*Journal of Laws of 2013, No. 0, item 1129*)). bill of quantities was also defined

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in “Polish Standards for Costing of Construction Work [5] and in PN_ISO 67047-2 from 2000 [6]. These definitions are identical to the definition of bill of quantities provided above. A different definition of bill of quantities was introduced in §1 section 2 point 6 of the Regulation of the Minister of Infrastructure of 18 May 2004, regarding methods and basis for preparing the investor’s cost estimate, calculations of planned costs of project works and planned costs of construction works defined in the functional and utility program [7]. According to this provision, bill of quantities is a study containing a list of works expected to be done in the technological order of their execution together with their detailed description, place of execution in a technological order or indication of the basis determining a detailed description, calculation and list of units of basic works measurements and indication of the basics to establish unit prices of material inputs [8].

The problem of disproportion between bill of quantities and quantity survey is undoubtedly a very common phenomenon. The dynamic of construction processes makes it hard to predict all factors affecting the scope and size of works. While maintaining the appropriate scrupulousness, it is possible to limit the size of the erroneous calculation of quantities, however, as the level of complexity of the construction project increases, the probability of underestimation (more seldom overestimation) of the value of bill of quantities and, consequently, cost estimates, grows as well.

The main problem of the discussed issue is relatively common among cost estimators, the practice of using the investor’s share as a basis for the offers prepared. This is usually the result of time constraints that do not allow for a thorough analysis of projects and specifications. Precise familiarization with the whole provided documentation, would, to a large extent, allow to identify possible gaps in the pre-dimension and, as a result, to calculate an offer closer to the actual costs of the investment [9].

The degree of verifying the deficiencies or quantities specified on the bill is largely dependent on the nature of investment [10]. In case of renovated facilities, especially those made using traditional methods, both the person preparing the receipt and the cost estimator should have at their disposal an inventory and a detailed technical expertise of the building. It should be borne in mind here that the offerer is in principle an entity involved on behalf of an investor. Due to this fact, his pre-calculations made on the basis of the submitted documentation will not go beyond those from the study. In case of such specific facilities like the renovated buildings, a cost estimator verifying these quantities, the aim of which is to make the most accurate valuation, should expand the scope of materials on which

he bases his cost estimate. A good supplement would be site inspection by the cost estimator accompanied by an expert who would help in the verification of documentation and studies on the construction site.

In a situation where the contractor could not afford such a precise preparation of the offer, the provisions of construction works contract will be key in the entire course of the investment. Bearing in mind the discussed problem of disproportion between bill of quantities and quantity survey, as a result of which one of the parties (usually the contractor) may incur a loss, the issue of contractual provisions seems to be significant. Adjusting the form of settlements to the degree of project predictability may have a significant impact on the profitability of works performed from the perspective of the contractor. Currently, as a result of the resolution of the Composition of the Seven Judges of the Supreme Court of 29 September 2009, (docket number: III CZP 41/2009) [11], it was clearly explained that the provisions of the XV Civil Code [12], regulating the contract for work, provisions regarding a flat pay remuneration and cost estimate can be applied by analogy to a construction contract. The conditions set out therein can therefore be the basis for changing the amount of remuneration agreed in the contract for construction works [11]. However, it should be taken into consideration that in accordance with the principle of freedom of contract set out in art. 3531 of the Civil Code [12], contracting parties can establish a legal relationship at their own discretion. Therefore, considering the possibility of a change in the remuneration of the contractor due for the works performed, the provisions of merging parties should first be followed. If there are no contractual arrangements in this area, provisions of art. 629 and the next Civil Code should be applied [12, 13].

The information of practitioners shows that there are serious disproportions between bill of quantities and quantity survey during the renovation of historic buildings. Despite the universality of this phenomenon in construction, it is difficult to reach materials that provide unambiguous values of underestimates and their cause. It seems right to try to identify the causes of overruns, which will minimize the consequences of these differences in subsequent similar projects.

2 The impact of the form of settlement of works on renovated buildings on investment profitability

In Poland, there are two basic forms of settlement of remuneration for construction works: a lump sum settlement and a cost estimate settlement. In the form of a lump sum settlement, the value of the order is assumed in advance, which will constitute remuneration, usually with the provision that the entity carrying out a construction project will not be able to apply for additional remuneration exceeding a fixed sum. Lump sum settlement has become a commonly used practice, especially noticeable in the field of public procurement. Contractors, however, in many cases are forced to take this risk to meet realities that prevail in the industry.

The basis for the cost estimate settlement is a list of planned works and their costs in the form of a cost estimate calculation. For each cost estimate, unit prices are given. In this settlement variant, the cost estimate is used as a summary of the work to be done, but it is not final. The settlement takes place on the basis of a cost estimate drawn up after the implementation of the project, supplemented with additional work. These works are also subject to remuneration. This is called as-built project costs.

It is worth noting that not every enclosure of a cost estimate to the offer means that the settlement will be a cost estimate. The nature of the settlement must be clearly stated in the terms of the contract.

If the construction project is carried out under public procurement, then it is not possible to make significant changes that affect the content of the contract. It results from art. 144 para. 1 on public procurement law [14] and relates in particular to the content that influenced the selection of the offer as the most advantageous. A deviation from this is possible if the ordering party included such an option in the tender documents, *i.e.* in the contract notice or specification of essential terms of the contract [14]. In connection with the above, changes to the subject of the contract are also excluded. In this situation, it is necessary to award an additional or supplementary contract in a single-source mode. In some cases, it is required to provide a separate order for additional works outside the scope of the contract. In the case when the contract on awarding a public contract contains a provision on cost estimate settlement, only the amount of work carried out as part of the contract is subject to change, but no additional work may be introduced that was not previously consid-

ered. The notion of quantity survey is decisive here, which includes only works included in the documentation made available to the contractor at the moment of awarding the public contract [15]. quantity survey of works will be the basis for settlement in this case.

The situation is different in the case of a lump sum settlement, which, according to the assumption, is immutable. The basis for receiving remuneration is the performance of works in accordance with a detailed description of the subject of the contract. Therefore, neither additional costs resulting from errors in the calculation, nor those which were not foreseeable at the time of concluding the contract constitute additional settlement. According to the case-law, no additional works are also subject to settlement, when bill of quantities provided to the contractor by the ordering party did not include all the works. The basis for preparing the offer is namely the subject of the contract described in the construction and execution design, therefore it is assumed that the price offered for the work resulted from this documentation, so it also includes works that were not listed in bill of quantities.

The most common form of settlement of works performed on renewable facilities is, unfortunately, a lump sum settlement, which carries a high risk in Polish realities [13].

3 Case study

As a part of this work, the issue of cost and settlement assessment was analyzed through the prism of a tenement house located in Warsaw and built in 1913-1914 in the late Art Nouveau style (Figure 1). The selected facility is a five-storey building with a single-unit, closed system. The ground floor of the main building and parts of the outbuildings were used for commercial and service purposes, and

Figure 1: View of the facade of the tenement house and the courtyard elevations [16]

Table 1: List of bill of quantities and quantity survey of selected renovation works

No.	Description of works	Amount of bill of quantities	Amount of quantity survey	Amount of additional works	The excess over bill of quantities [%]	Method of quantity survey
1	Stitching the scratched fragments of walls	986 [running meters] (164 pcs.)	2039 [running meters] (176 pcs.)	1053 [running meters]	106.80	The quantity survey of works is the sum of the product of the length of a single stitching and the number of these stitchings in relation to a specific, selected scratch.
2	Concreting of flues	112.39 [m ³] (804 pcs.)	323.59 [m ³] (804 pcs.)	211.2 [m ³]	187.92	The volume is the product of the number of channels in one cluster, the cross-sectional area of a single channel and its length on each storey
3	Reconstruction with solid bricks	95.37 [m ³] (358 pcs.)	289.66 [m ³] (358 pcs.)	194.29 [m ³]	203.72	The volume is the sum of the product of reconstructed area and its thickness

the rest of the building served as a residential area. Currently, the facility is unused. The development consists of:

- front building with a length of 24.4 m and width of 14.2 m,
- two single-storey side annexes with a length of 19.5 m and 21.4 m and a width of 6.9 m,
- rear transverse outbuilding with a length of 21.1 m and width 6.4 m.

Characteristic data of the building: gross covered area - 807 m², cubature - 19 997 m³, number of floors: underground: 1 above-ground: 5 + attic (usable in the main building). The building was equipped with electrical and plumbing installations. Currently, these installations are dismantled. The building is located in the area entered in the register of monuments.

In the work, selected structural elements of the building were analyzed, such as stitching the walls (Figure 2), concreting of flues and reconstruction with solid bricks, which are the most important from the point of view of the number of works needed for their replacement or renovation. On the basis of the available documentation [17], bill of quantities compiled on the basis of catalogues of material inputs was compared to the contract between the investor and the contractor with quantity survey prepared after the renovation (Table 1). It is worth noting that the sur-

Figure 2: Examples of wall scratches (own study)

veyed project was settled in a lump sum. Due to the technical condition of the facility, not all elements could be reliably measured. On the basis of bill of quantities and quantity survey, cost estimates of selected works were made. The results of calculations are presented in Table 2. A comparison of definitive cost and as-built cost estimate are presented in Figure 3. A similar analysis was also carried out for reference facility No. 1; a historic building located in the Old Town in Warsaw. The results of the analysis are presented in Tables 3 and 4. Contrary to the case previously

Table 2: Cost list of selected renovation works from a bill of quantities and a quantity survey

No.	Description of works	The work cost in accordance with the bill of quantity [PLN]	The cost of additional works [PLN]	The total cost of the performed works [PLN]	Cost-overruns [%]
1	Stitching the scratched fragments of walls	32 687.47	34 908.71	67 596.18	206.79
2	Concreting of flues	227 157.37	426 867.97	654 025.34	287.91
3	Reconstruction with solid bricks	212 943.29	428 928.32	641 871.61	301.43
TOTAL:		472 788.13	890 705.00	1 363 493.13	288.39

Table 3: List of bill of quantities and quantity survey of selected renovation works for comparison facility No. 1 - renovation of external communication routes of the historic building

No.	Description of works	Amount of bill of quantities	Amount of quantity survey	Amount of additional works	The excess over bill of quantities [%]	Method of quantity survey
1	Mechanical execution of the trough on the width of the roadways and car parks	232.00 [m ²]	1495.69 [m ²]	1263.69 [m ²]	544.69	Quantity survey of works is the product of the sum of the length of the segment along the road axis and the width along a straight line perpendicular to the road axis
2	Foundation from cement stabilized soil	109.00 [m ²]	124.42 [m ²]	15.42 [m ²]	14.15	Quantity survey is the product of the width of the foundation defined by the outer edges of the foundation and the length of the road section along the axis.
3	Earthworks with disposal	146.17 [m ³]	518.42 [m ³]	372.25 [m ³]	254.67 [m ³]	Quantity survey is the product of length and measured cross-section
4	Surface paving of garden paths	803.00 [m ²]	980.88 [m ²]	177.88 [m ²]	22.15 [m ²]	Quantity survey is the product of is the product of the length and width of the surface

analyzed, the parties agreed on a settlement based on the actual number of works carried out. It is worth noting that the cases described above are not isolated. Presented below in Table 5 is a comparison of selected values of bill of quantities and quantity survey for the renovation of a tenement house (Warsaw Śródmieście) – facility No. 2, and

earthworks for the construction of an office building – facility No. 3.

Table 4: Cost list of selected renovation works from a bill of quantities and a quantity survey for comparison facility No. 1 - renovation of external communication routes of the historic building

No.	Description of works	Work cost in accordance with bill of quantity[PLN]	The cost of additional works [PLN]	Total cost of performed works [PLN]	Cost-overruns [%]
1	Mechanical execution of the trough on the width of the roadway	7426.32	40251.10	47677.42	642.01
2	Foundation from cement stabilized soil	3037.83	429.75	3467.58	114.15
3	Earthworks with disposal	22594.96	57542.40	80137.36	354.67
4	Surface paving of garden paths	44831.49	9931.04	54762.53	122.15
TOTAL:		77 890.60	108154.29	186044.89	238.85

Table 5: Comparison of values of bill of quantities and quantity survey of selected works in facilities 2 and 3

No.	Description	Bill of quantities value	Quantity survey value	Additional value	Exceeding of the BQ value [%]
Facility No. 2- Renovation of a tenement house (Warsaw Śródmieście)					
1.	Implementation of new lintels	72 pcs.	186 pcs.	114 pcs.	158.3
2.	Repair of cracked brick-built walls	230 m ²	420 m ²	190 m ²	82.8
3.	Brick-built walls – filling with solid brick. filling the holes	156 m ³	224 m ³	68 m ³	43.6
4.	Filling chimneys in walls with concrete. removing the soot	20 m ³	115 m ³	95 m ³	475.0
5.	Demolitions related to making grooves for steel beams and ring beams	103 m ³	150 m ³	47 m ³	45.6
6.	Breaking holes in walls and ceilings with rubble disposal	80 m ³	177 m ³	97 m ³	121.2
Facility No. 3- Earthworks in the construction of an office building					
1	Excavation	1654 m ³	2102 m ³	448 m ³	27.1
2	Embankment	1229 m ³	2377 m ³	1148 m ³	93.4

4 Analysis of the results

The comparison in Table 1 shows that the value of works in structural renovation was vastly exceeded, even by three-fold, in relation to the value of bill of quantities.

In case of stitching of scratched fragments of walls the value originally assumed was exceeded by 106.8%. For this item, the value adopted in bill of quantities was probably close to the real one due to the ease of inventory of Fig-

ure 2. which is visible on the plaster and does not require outcrops. The error resulted from adopting an inappropriate factor, which disregarded the work of structure. A significant part of scratches requiring stitching was created during the implementation of a new reinforced concrete structure of the building including ceilings, staircases or lift shafts. The emergency condition of wooden ceilings and stairs prevented a thorough inspection of the upper storeys.

Figure 3: Comparison of definitive cost and as-built cost estimated of selected renovation works with the division into labor, materials and equipment

The quantity survey of works in the field of chimney concreting was almost three times higher than bill of quantities. First, as in the case of stitching the walls an accurate inventory prevented the emergency condition of the building. Locating and determining the number of plumbs was possible only after plastering. In the place of running chimney stacks on walls there was a distinctive arrangement of bricks, enabling them to be traced. Another factor, significantly affecting the amount of work performed in the area of chimney concreting, was the lack of taking into account the dimensions of the chimney vertical section. The section area was increasing with its the length from approx. 400 cm² in the basement to approx. 1400 cm² in the attic. Determination of the section was possible only after chiselling the wall just before concreting.

The biggest error in terms of bill of quantities was met in the case of solid brick reconstruction. In this position the amount of quantity survey was more than three times higher than the maximum. The overriding reason for this discrepancy is to be found in the state of existing walls, which was possible to determine only after plastering. It turned out that many elements, such as window sills or foundation walls required reconstruction. Another reason was inventory errors. It turned out several times that load-bearing walls, whose thickness was incorrectly inventoried, require full-length reconstruction in order to obtain the parameters assumed in the assumptions at the design stage. In addition, the idealizations and simplifications adopted for the needs of drawings meant that many elements, such as some window and door openings, need to be reconstructed to obtain the designed dimensions.

In addition, the occurrence of errors was influenced by purely technological issues that were noticed directly during the performance of works. Both, bill of quantities

and the project, assume the execution of precise chasing for a new reinforced concrete structure, but they do not take into account that it is impossible to make such carvings in an old, sometimes rotten wall of solid brick. During chasing, even small vibrations cause that adjacent elements detach. As a consequence, after making the ceiling with the designed thickness, between the surface and the wall in which it is embedded, a gap is created which requires walling. A similar situation occurs with seemingly small reconstructions. When doing them, it is important to tie the old element with the new one. During such works the wall often needed to be reconstructed on a larger fragment because of its poor technical condition.

The consequence of such large differences between bill of quantities and quantity survey is a significant increase in costs. Table 2 presents costs of performing works on the basis of bill of quantities and additional costs based on excessive values of bill of quantities, and the total cost of works. From the above list it is clear that the planned cost was exceeded almost three times. When analyzing Figure 3, it can be seen that the largest impact on exceeding the pre-cost estimate had material costs and the smallest – the cost of equipment work. The problem of exceeding the pre-cost value relates to many investments.

In the first compared historic building with parameters similar to the case analyzed above (reconstruction of external communication routes), excess quantities were also exceeded. Despite the fact that the investment was cleared with credits the prevention of disputable situations was not possible. In this case, the following exceedances of exemplary works were noted (Table 3): for works related to the execution of the foundation by about 14%, and for the execution of a mechanical roadway and a car park at the facility by approximately 550%. In item 1 in Table 3, according to the contractor, works were carried out on the area of 1495.69 m², and according to the ordering party on the surface of 232 m². When analyzing other cost estimate items, an as-built estimate can be stated that the mechanical execution of the channel did not take place on the surface of 1495.69 m², since it is the total area of parking spaces and the communication route from the geodetic survey carried out on request of the contractor. In position No. 2 (execution of ballast and substructure under granite paving at the entrance gate and on the band), the geodetic survey indicated the area of 124.42 m² of works which should be accepted for settlements. In the case of item 3 - removal of excess land (material from demolition) with export, it was not possible to unequivocally verify the difference in the number of works given by the contractor and the ordering party. The size indicated by the contractor is not credible due to the fact, that rubble that was allegedly

taken away was found in the foundation layer in inspection pits made on the area of running roads. In the case of item No. 4 - the surface of the road and the square as the right amount of work carried out, the value of 980.86 m² should be taken in the geodetic survey that is, proposed in the cost estimate by the contractor.

Summing up, it can be stated that exceedances of the excess values on the facility No. 1 were caused primarily by evident executive errors and incorrect work of investor's supervision, who should efficiently react to exceedances that are noticeable during the execution of works. On the basis of the analyzed project documentation for the reference facility No. 1, it was noticed that in the estimate and as-built cost estimate there were no differences in the types of works. In view of the above, it should be noted that no additional work occurred during the implementation of the contract in question. Therefore, there should also be no differences in the final quantities of works and their costs. The exceedances in the number of works in the comparative facility No. 1 resulted in significant cost overruns (Table 4). In this case, the costs were exceeded more than twice in relation to the cost of the offer cost estimate.

Thus, when comparing the values of exceedances of selected works of other construction projects in Table 5, such as the renovation of a tenement house (a case very similar to the one discussed in the article) and selected earthworks on the site in Warsaw it can be stated that both the first and the second exceeded the value of bill of quantities. During the renovation of the building (facility No. 2) depending on the type of works the exceedances were from 0.5 to 5 times higher than the original values and in the case of earthworks (facility No. 3) from 0.3 to 1.

Analyzing the data presented in the study on facilities with similar functionality *i.e.* tenement houses in Warsaw, a similar relationship in relation to the occurrence of high values of bill of quantities renovation works is visible. This does not mean that the occurrence of exceedances in case of earthworks did not affect the increase of investment costs. In the budget of each investment the occurrence of even small oversupply, including the results of the conducted detailed analysis may have a considerable impact on the success of the entire project and its financing. In connection with the above, in the case of budget analyzes, it is worth to pay special attention to the need of research and monitoring differences in excess, especially on historic buildings.

5 Conclusions

The analyzed cases show that the quantities of works given in bill of quantities and quantity survey were different. Depending on the specificity of the facilities, the reasons for exceedances / differences were various. It must be said, that the correct estimation of the amount of works on modernized facilities (requiring measurements to create an offer cost estimate) is mainly influenced by errors in bill of quantities. Underestimates usually arise from difficulties in the measurement of covered works. Another reason for these differences is the integrity of the contractor, who does not always show the actual amount of works for settlements. Therefore, correct and reliable control over the site by the inspector of investor supervision is so important at every stage of the construction process, which should eliminate the differences in bill of quantities and quantity survey values resulting from the dishonesty of the contractors. Both quantity survey and a lump sum form of settlements between the investor and the contractor do not guarantee the completion of the construction process without any disputes.

On the basis of the cases analyzed in the article, the following conclusions can be formulated - depending on the type of works, the highest bill of quantities exceedances were: for modernized facilities approx. 550% and for earthworks approx. 94%,

- for the facility being analyzed in detail, the largest quantitative excesses concerned reconstruction with solid bricks amounting to 203.72%, which resulted from the difficulty of estimating the number of works before commencement of modernization works;
- for the reference facility No. 1, the largest overruns of 544.69% concerned the construction of a mechanical carriageway and car parks; they were the result of an exaggerated value by the contractor (*i.e.* the road surface along with the car park),
- for the reference facility No. 2, the highest value of exceedances - 475.00% (Filling chimneys in walls with concrete, removing the soot), which also resulted from the difficulty in estimating the number of works before starting modernization works,
- in the case of earthworks and facility No. 3, the largest value of exceedances was 93.40% for embankment, which was caused by errors in the project documentation,
- for the studied facility (case study), the largest differences in the costs appearing in the offer and as-

built cost estimate relate to materials; the difference is PLN 237409.7,

- excess intake overruns noted had an impact on the increase in costs in the case of case studies, they increased by 288.39% and for facility No. 1 by 238.85%.

Analyzing all the aforementioned cases, we conclude that there is no general dependence on what works change their value to the greatest extent in the offer and as-built cost estimates. However, in order to minimize the differences between the amount of the works in bill of quantities and quantity survey, the Authors propose to take the following recommendations before performing work on a given facility into account. A person with executive experience in similar facilities should be involved in the execution of bill of quantities and cost estimate on the renewed facility as well as on any other facility. In addition, such person should take an active part in the process of carrying out the inventory. The cost estimator should not be limited to KNR (National Contractors Estimator) only, because the specificity of work on historic buildings as well as other facilities, such a facility sometimes requires its own analyzes. A cooperation with a person experienced in similar projects would be very helpful in this situation. The database, a list of problematic works with renovated facilities which the person performing bill of quantities would be able to use and especially pay attention to, would also be helpful. Increasing expenditures on inventory would allow the use of technologies enabling the inventory of places that would not allow direct inspection.

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