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Anita Erbe

Cost Estimate Classification and Accuracy for Major Industrial Plant Projects (MIPP) versus Building Construction in Germany

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Address for correspondence:

Anita Erbe, M.Sc.
Technische Universität Bergakademie Freiberg
Fakultät für Wirtschaftswissenschaften
Professur für Allgemeine Betriebswirtschaftslehre,
speziell Baubetriebslehre
Lessingstr. 45, D-09596 Freiberg
Telefon: ++49 / 3731 / 39 4082
Fax: ++49 / 3731 / 39 4092
E-mail: ErbeA@mailserver.tu-freiberg.de

Internet: http://tu-freiberg.de/fakult6/baubetriebslehre

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Abstract

Ongoing pressure on prices for construction projects adds to the significance of cost estimation accuracy in building construction. Due to competition from Asian entrants, main contractors in the plant engineering industry are starting to face a similar situation.

In the present paper, the cost estimation standards for Major Industrial Plant Projects (MIPP) are analyzed and compared with the cost estimation standards for Building Construction (BC).

The research method uses a literature and standards review, comparing MIPP cost estimation guidelines by the Association for the Advancement of Cost Engineering (AACE) with a guideline known as the 'cone of cost' following the Official Scale of Fees for Services by Architects and Engineers (German: HOAI) for comparable phases of performance.

It is shown that MIPP industry cost estimation guidelines are much more tolerant in terms of accuracy than for Building Construction in Germany, especially in the early phases.

With the help of examples (Hot-Briquetted-Iron plant projects versus residential housing projects), a set of possible reasons is identified and categorized by (1) competition intensity incl. technology impact and frequency of project occurrence, (2) demands on cost estimation professionals, (3) materials and supplies used, (4) duration of project execution, (5) Certainty of projected Cash Flows.

Finally, the study marks starting points for further research: First, comparing MIPP cost estimation guidelines to non-German Building Construction standards, and second empirically validating and possibly extending the set of explanations.

JEL classification: F-21/ G-31; L-74; L-60; L-70; Y80

Keywords: major industrial plant projects, building construction, cost estimation

Zusammenfassung

„Kalkulationsklassifikation und -genauigkeit nach Leistungsphasen für Großanlagenbauprojekte im Vergleich zu Hochbauprojekten“

Durch den zunehmenden Kostendruck im Hochbau gewinnt die Kalkulationsgenauigkeit in der Planungsphase an Bedeutung. Auch heimische Großanlagenbauer stehen seit einigen Jahren aufgrund zunehmender Konkurrenz aus Asien unter erhöhtem Preisdruck. Das vorliegende Arbeitspapier untersucht die im internationalen Großanlagenbau verwendeten Richtlinien zur Klassifikation und Genauigkeit von Kalkulationen in bestimmten Leistungsphasen nach AACE und vergleicht diese mit den Vorgaben des ‚Kostentrichters' in Anlehnung an die HOAI für den Hochbau. Der Vergleich zeigt, dass für äquivalente Leistungsphasen die Großanlagenbau-Richtlinien zur Genauigkeit deutlich toleranter sind als die Vorgaben für den Hochbau, insbesondere für die Frühphasen der Planung. Anhand von Beispielen (Eisenerzheißbrikettieranlagen- versus Wohnbau-Projekte) werden mögliche Gründe hierfür aufgezeigt und kategorisiert: (1) Wettbewerbsintensität inklusive Technologiebezug und Projekthäufigkeit, (2) Anforderungen an die Kalkulatoren, (3) verwendete Baumaterialien, (4) Dauer der Projektausführung, (5) Sicherheit der prognostizierten Cashflows.

Schließlich weist die Studie auf Ausgangspunkte für die weitere Forschung hin: Ein Vergleich von Kalkulationsrichtlinien im Großanlagenbau mit Hochbau-Standards außerhalb Deutschlands sowie eine empirische Validierung und Erweiterung der Untersuchung der möglichen Gründe.

JEL Klassifikation: F21/ G31; L-74; L-60; L-70; Y80

Schlagworte: Großanlagenbau, Hochbau, Kalkulation

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1 Introduction

The present paper analyses cost estimation standards and accuracy for Major Industrial Plant Projects (MIPP) comparing it with the cost estimation standards for Building Construction (BC).

The study is motivated by two reasons. First, continuing pressure on prices for construction projects leads to an increasing importance of cost estimation accuracy in building construction. Main contractors in the plant engineering industry have recently found themselves in a similar situation, facing increasing competition from Chinese and South Korean entrants (c.f. Knauthe 2013: 9).

Second, cost deviations, and in particular cost overruns, happen for MIPP, i.e. process facilities, as well as in Building Construction (BC) projects. However, due to the inherent risks in the realization of process facilities, including completion and performance of process design risks, the probability for the occurrence of cost overruns of MIPP is considerably higher than for building construction (c.f. Rapp 2004: 52ff.)[1]. It is coherent to assume that these inherent risks and the comparably high probability of cost deviations for MIPP are reflected in the respective cost estimation standards, which are investigated as compared to BC standards.

2 Research Objective and Method

The objective of the study is to find out, on an indicative level, how tolerant MIPP cost estimation standards are versus BC standards. Therefore, the research method used includes a literature and standards review, comparing MIPP cost estimation guidelines

[1] In this respect, the author noted that opinions of MIPP vs BC industry experts vary as of which budget deviation a project might be considered a success or failure. Aiming to divide project failure from success in Major Industrial Plant construction, the 50% rule had been suggested (c.f. Erbe 2012: 4; AACE International 2005: 3, 7). The rule states that a MIPP may be considered a failure if, among other conditions, the project's budget is overrun by more than 50%. Some contractor's representatives, in particular from the BC sector, discussing the topic with the author on several occasions during 2012-13, were of the opinion that a MIPP is a failure already if the budget overrun amounted to considerably less than 50%. Others, particularly from the MIPP industry, felt the 50% rule could be an applicable rule-of-thumb for the success of a MIPP.

by the Association for the Advancement of Cost Engineering (AACE), headquartered in the United States, with a guideline from Germany known as the ‘Cone of Cost’ following the Official Scale of Fees for Services by Architects and Engineers (German: HOAI) for comparable phases of performance.

3 Conceptual Demarcation

3.1 Characterizing a Major Industrial Plant Project (MIPP)

A Major Industrial Plant Project (MIPP) is characterized by the following features (c.f. Erbe 2013: 3-6): It involves planning and realizing[2] (but not operating) an industrial process plant. It is a “Greenfield” investment requiring a Total Investment Cost (TIC) of a minimum of USD 100 million. TIC, for purposes of simplification, is understood to include the Engineering, Procurement and Construction (**EPC**) of a process plant. TIC comprises process engineering and equipment of over 50%, typically 65-75%, which, in simplified terms, represents the Engineering and Procurement (**EP**) part of the project. The remaining percentage of TIC is the Construction (**C**) part.[3] The purpose of the process plant to be planned and realized is to produce a tradable product by material conversion. Typically, a minimum of 100 suppliers are involved in a MIPP, and the phase of Project Execution lasts for at least 12 months (2-5 years on average). The duration of Project Development amounts to a minimum of 6 months (12-24 months on average). Examples of MIPP include the planning and realization of power plants (fossil/biomass fuelled), chemical as well as metallurgical plants.

3.2 Defining Building Construction (BC)

Building Construction (BC) is the part of civil engineering that deals with the design and construction of buildings that are mostly above the ground line, e.g. buildings such as

[2] In simplified terms, the realization of a MIPP is also known as Engineering, Procurement and Construction (EPC).
[3] Owner’s costs of any kind are disregarded for the purpose of this study.

houses or towers (Grütze 2007: 126). As such BC forms a part of a MIPP (i.e., the “C” part – as elaborated above).

3.3 Cost Estimation

Cost estimating is the predictive process used to quantify, cost, and price the resources required by the scope of an investment option, activity, or project. Budgeting is a sub-process within estimating used for allocating the estimated cost of resources into cost accounts (the budget) against which cost performance will be measured and assessed (Hollmann 2012: 48).

With the complexities involved, it is not surprising that many business practitioners consider pricing an art (c.f. Kerzner 2013: 677). Because of the considerable risks involved, this is particularly true for cost estimation for MIPP, which, apart from costing various engineering trades (process, mechanical, electrical engineering, etc.), also includes BC cost estimation.

4 Cost Estimate Classification and Accuracy for MIPP – EPC

The present chapter provides guidelines for applying the principles of estimate classification specifically to project estimates for engineering, procurement, and construction (EPC) work for the **process industries** as recommended by the AACE[4] in their Recommended Practice No. 18R-97 (2005).

According to AACE International, the term process industries is assumed to include firms involved with the manufacturing and production of chemicals, petrochemicals, and hydrocarbon processing. The common thread among these industries (for the purpose

[4] AACE stands for the Association for the Advancement of Cost Engineering, formerly known as the American Association of Cost Estimators. (c.f. Peurifoy and Oberlender, 2002: 5; AACE 2014: Article 1).

of estimate classification) is their **reliance on process flow diagrams (PFDs) and piping and instrument diagrams (P&IDs)** as primary scope defining documents. These documents are key deliverables in determining the level of project definition, and thus the extent and maturity of estimate input information (AACE 2005: 1).

The reliance on PFDs and P&IDs is applicable indeed to MIPP as characterized in Chapter 3.1, and in particular the feature “process plants producing a tradable good by material conversion”. Examples include not only chemical (including petrochemical and hydrocarbon processing) plants as specified by the AACE, but can be extended to fossil (or biomass equivalent) fuel-fired power plant projects, basic and advanced materials plant projects, metallurgical, pulp & paper, and certain building materials plants.

Estimates for **process facilities** center on mechanical and chemical process equipment, and they have significant amounts of piping, instrumentation, and process controls involved. The cost estimates covered by the AACE International Recommendation are for engineering, procurement, and construction (EPC) work. They do not cover estimates for the products manufactured by the process facilities, or for research and development work in support of the process industries. The guideline also does **not** cover the significant **building construction** that may be a part of process plants (ibid: 2).

The five AACE estimate classes are presented in the table below: The level of project definition determines the estimate class. The other four characteristics are secondary characteristics that are generally correlated with the level of project definition. The characteristics are typical for the process industries but may vary from application to application. This matrix and guideline provide an estimate classification system that is specific to the process industries.

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	**LEVEL OF PROJECT DEFINITION** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges [a]	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment, or Analogy	L: -20% to -50% H: +30% to +100%	1
Class 4	1% to 15%	Study or Feasibility	Equipment Factored or Parametric Models	L: -15% to -30% H: +20% to +50%	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	L: -10% to -20% H: +10% to +30%	3 to 10
Class 2	30% to 70%	Control or Bid/ Tender	Detailed Unit Cost with Forced Detailed Take-Off	L: -5% to -15% H: +5% to +20%	4 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Detailed Unit Cost with Detailed Take-Off	L: -3% to -10% H: +3% to +15%	5 to 100

Notes: [a] The state of process technology and availability of applicable reference cost data affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.
[b] If the range index value of “1” represents 0.005% of project costs, then an index value of 100 represents 0.5%. Estimate preparation effort is highly dependent upon the size of the project and the quality of estimating data and tools.

Source: AACE 2005: 2

1: AACE Cost Estimate Classification Matrix for Process Industries (MIPP)

5 Cost Estimate Classification and Accuracy for BC

While MIPP as process plant projects rely on PFDs and P&IDs as primary scope defining documents, civil engineering documents used by building cost estimators draw on design schemes and bills of quantities (c.f. Möller 1996: 119-20; HOAI 2013: 5, §2).

So, one of the key differences between MIPP and building construction is that rather than **process engineering**, which has also been referred to as “planning” in the MIPP/ process plant industry (c.f. Bernecker 2001: 4ff.), building construction uses civil and **architectural planning**. Unlike MIPPs, which typically represent multi-national endeavors, building construction can be considered a local business (c.f. Brockmann 2009: 173). In Germany, building construction planning is regulated by the "Official Scale of Fees for Services by Architects and Engineers", also known as HOAI[5] as well as the German Industry Norm DIN 276 (c.f. HOAI 2013: 5, §2 (10), (11); Werner 2013: 150; Kalusche and Dusatko 2009: 139; Lechner 2013: 2f., 9ff.; Siemon 2012: 3).

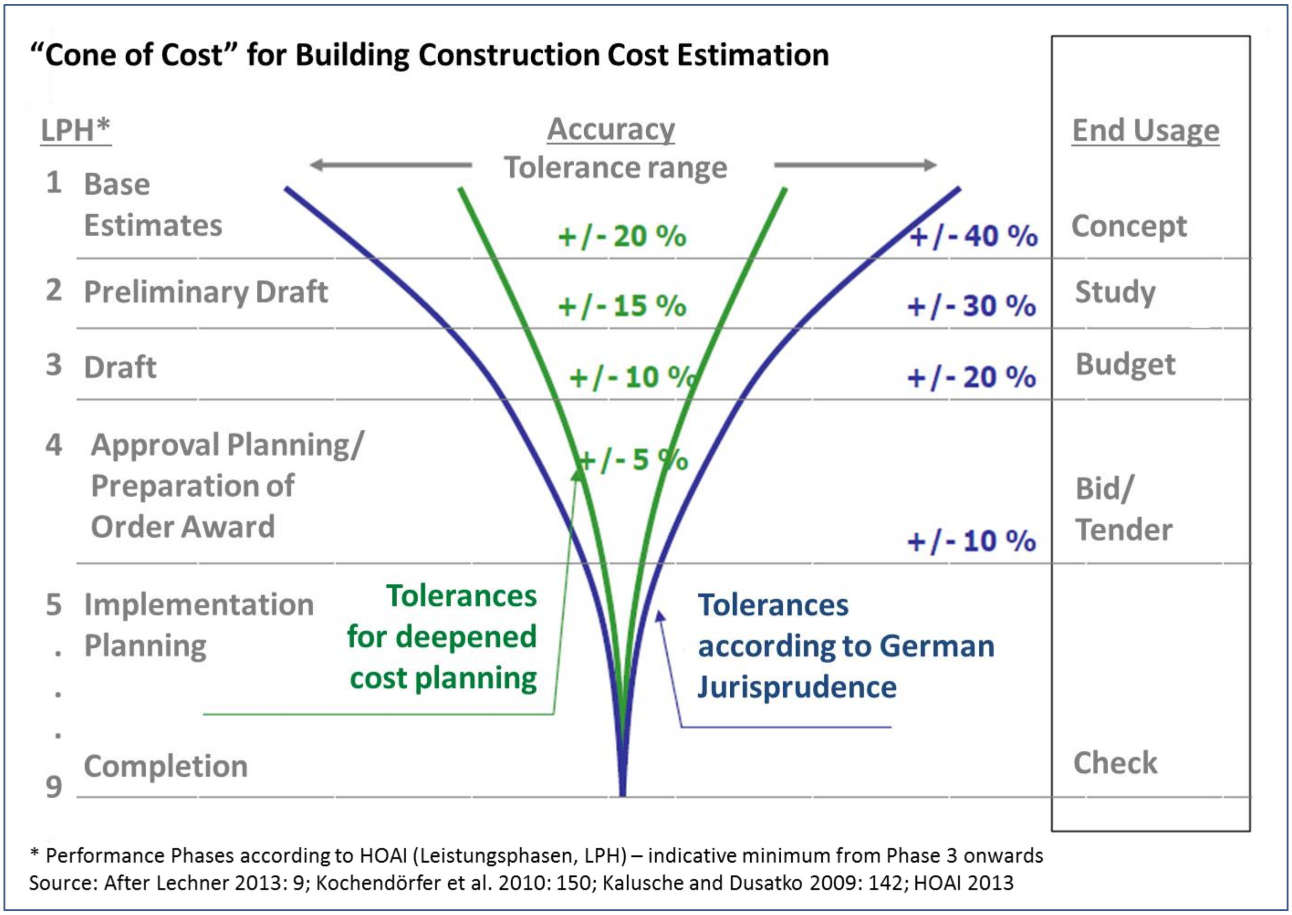
Competition in building construction is comparably intense[6] versus process plant EPC construction: While GCs for MIPP usually act in an oligopolistic market, GCs in building construction, at least for standard building projects, such as residential housing, may find themselves confronted with hundreds of competitors[7]. Actually, in 2010, the total number of building construction firms in Germany amounted to 73,290 with an average number of ten employees per firm (BWI-Bau et al. 2013: 66). The eminent "atomic market structure" (ibid: 119) is one of the reasons why building cost estimators are under **considerable cost and accuracy pressure** in their calculations even in the early phases of a project, the pre-calculations or concept phase (c.f. Jacob, Stuhr et al. 2011: 11, 31; BWI-Bau et al. 2013: 125ff.).

There are no clear legal or normative provisions for the required accuracy of a cost estimate according to DIN 276. From case law and literature, common practice values for permissible cost deviations can be derived (c.f. Kalusche and Dusatko 2009: 142; Kochendörfer et al. 2010: 150; Werner 2013: 256 ff.; BWI-Bau 2013: 75). These are presented by performance phase in the figure below, which is also known as the "**Cone of Cost**" (German: "Kostentrichter") of building construction cost estimate accuracy.

[5] HOAI stands for Honorarordnung für Architekten und Ingenieure (HOAI).

[6] Runeson (2000: 170) considers *perfect competition* to be the appropriate model for the most of the building construction sector.

[7] For example, in the building construction (Hochbau) sector, in Germany the on-line trade directory "Gewerbeverzeichnis Deutschland" alone shows over 550 results in searching for a GC specializing in building construction (GvD 2014). Meanwhile, companies specializing in HBI plant or other MIPP construction are hardly found in trade directories. Worldwide, only three companies world-wide specialize as a GC in HBI plant construction (Mattusch 2013).



2: "Cone of Cost" of Building Construction Cost Estimate Accuracy

6 Comparison and possible reasons for differences

6.1 Comparing cost estimate accuracy for MIPP vs BC

The results of the cost estimate accuracy comparison for MIPP versus BC are presented in Table 3 below. As noted by the ACCE (2005: 2), the level of project definition determines the estimate class. Levels of definition for Building Construction (BC) performance phases according to HOAI (German: Leistungsphasen, abbreviated LPH) are described, for instance, in Kochendörfer et al. (2010: 147ff.). As they vary from project to project, the BC LPH shown in Table 3 represent only rough indicative ranges of the MIPP estimate classes as provided by the AACE. The same is true for the End Usage: the purpose of the cost estimate depends on the individual endeavor. The table presents the maximum accuracy tolerance ranges for international MIPP versus BC in Germany by estimate class/ performance phase.

MIPP (AACE) Estimate Class	**BC Performance Phase (HOAI LPH) Equivalent***	**End Usage: Typical Purpose of Cost Estimate**	**MIPP (AACE) Accuracy Range max.**	**BC (Germany) Accuracy Range max.**
Class 5	1	Concept Screening	-50% to 100%	+/- 40%
Class 4	2	Study or Feasibility	-30% to +50%	+/- 30%
Class 3	3 … 4	Budget	-20% to +30%	+/- 20%
Class 2	5 … 7	Bid/ Tender	-15% to +20%	+/- 10%
Class 1	6 … 9	Check	-10% to +15%	+/- 5%

*indicative equivalent ranges depending on project, LPHs in Class 2 & 1 Equivalent may overlap

Source: AACE 2005: 2; Lechner 2013: 9; Kochendörfer et al. 2010: 150; Kalusche, Dusatko 2009: 142; HOAI 2013; Werner 2013: 256ff.; own analysis

3: Comparison of Cost Estimate Accuracy Ranges for MIPP vs BC (Germany)

The comparison shows that in the MIPP industry cost estimation is much more tolerant in terms of accuracy than for BC in Germany, especially in the early phases (Concept Screening and Feasibility Study). Due to the above mentioned limitations concerning the variance of LPHs from project to project, the present comparison may serve as an indication only. Nonetheless, it may help to understand the different reactions of MIPP vs BC industry experts as from where a project might be considered a success or failure (50% rule) noted in Chapter 1. If a MIPP is 50% over budget[8], this represents a back fall to a Class 4 Estimate ("Study or Feasibility" Level) which could be accepted as a threshold between success and failure by a MIPP professional. Meanwhile, a building construction (BC) project, in particular a standard building like a residential house, which is 50% over budget may understandably be considered a total disaster by a German BC professional, as this kind of inaccuracy in a cost estimate would not even be acceptable at the level of "Concept Screening".

[8] In fact, the fulfillment of the customer's specifications and the compliance with time schedules, in particular the accomplishment of Mechanical Completion on time, may be at least as important adherence to budget for the success of a MIPP.

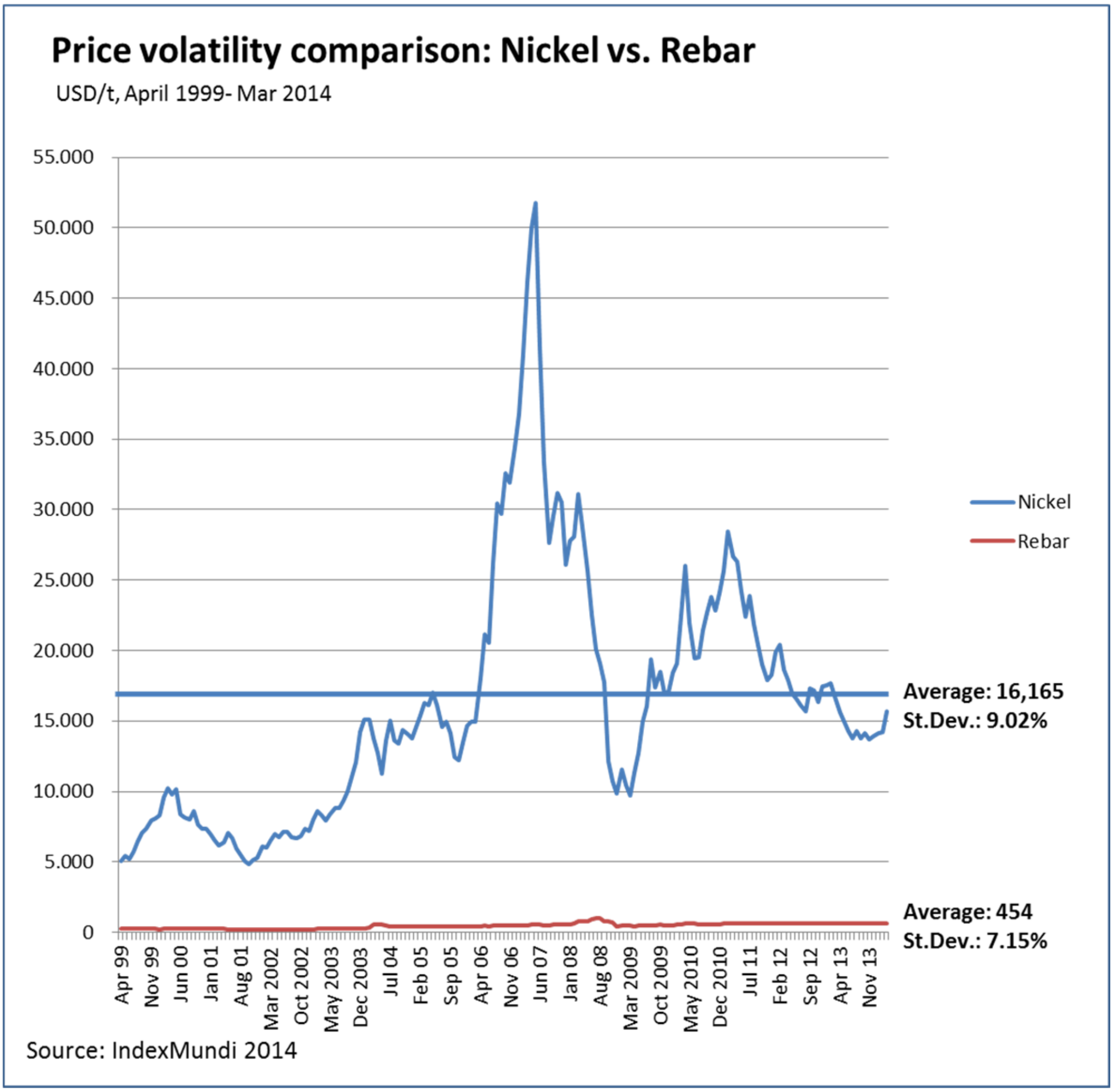
6.2 Possible reasons for accuracy differences

There are various reasons why (German) BC cost estimation, represented for this purpose by **residential housing** construction, tends to be more accurate than the one for MIPP, represented by Hot-Briquetted-Iron **(HBI) plants**. The author takes on, but does not empirically validate the following, mutually interdependent, possible reasons:

1. Cost and accuracy pressure due to **competition intensity** in BC (hundreds of competitors in housing construction in Germany alone) vs MIPP (General Contractor (GC) acts in an oligopolistic market structure; for HBI plants: three competitors globally) which in turn is due to
    a. **Technology licensing impact** (globally, two companies own the shaft furnace process technology for HBI plants, which is subject to licensing and constant research & innovation; in contrast, hundreds of companies are able to build a standard residential building/ house without a technology license),
    b. **(In)frequency of occurrence**: world-wide contracts to build residential houses are awarded frequently, assumedly several times each day, EPC contracts to build HBI plants less than once in two years,
    c. **Company size**: In Germany, the average number of employees in building construction (Bauhauptgewerbe) is ten (c.f. BWI-Bau 2013: 66). GCs for HBI plants, for instance Danieli, Siemens VAI or Kobe have ten thousands of employees.
    d. **Barriers of entry** are rather low in standard residential housing construction (c.f. BWI-Bau 2013: 137) while they are high in HBI plant construction (a know-how, technology driven business).
    e. **Standardized product.** A customary residential house (in its extreme form: prefabricated) is a standard product with an openly available competitive market price. Therefore, a BC contractor will have to use target costing to be able to compete in the market. An HBI plant project is a tailor-made endeavor, allowing the EPC contractor to use much higher mark-ups.
2. **Demands on the cost estimation professional**: building construction estimation can be relatively straightforwardly taken up by anyone with a commercial background and some IT skills by using standard calculation software (e.g. RIB iTWO Stuttgart/ Germany; RIB 2010). In contrast, cost estimators for chemical and other process

plants are rare experts, oftentimes using proprietary, self-developed spreadsheet and/ or database models. Officially marketed IT solutions (Cleopatra Enterprise Netherlands, Aspentech/ Icarus Cambridge/ Massachusetts; Aspentech 2000) became available in Europe only comparably recently. Becoming a MIPP cost estimation professional requires a process engineering degree plus long-term MIPP commercial experience, especially concerning contingency and risk planning, to be able to estimate the cost of a MIPP which includes various types of engineering (mechanical, electrical, process and others) plus Civil (building) construction (c.f. Chapters 3.1, 3.2).

3. In BC, **standard materials** and supplies (e.g. concrete reinforcing steel bar (**rebar**) are used. In contrast, piping and instruments, made of **specialty steels** and alloys like **nickel-based alloys** are a major part of MIPP (process plants). The prices for standard materials (e.g. rebar) fluctuate to a lesser extent than the prices for special materials (e.g. Nickel) as presented in Figure 4.
4. **Local vs. international supplies** (e.g., concrete for BC vs. stainless pipes for MIPP) result in lower vs. higher risk (for BC/ MIPP).
5. **Short vs. long term** of planning and realization: A standard residential building can be erected within a short term (some months); a MIPP is built in several years, typically two to five (c.f. Chapter 3.1).
6. **(Un)certainty of projected Cash Flows** (CF)**.** Income, i.e. rents for residential housing projects, in Germany is typically fixed in the private residential rental index (German: Mietspiegel) with often only minor deviations. Thus, the projected CFs from a BC residential housing project are relatively certain. In contrast, the CF from a MIPP depends on prices of inputs, which are globally traded commodities (for HBI plants: iron ore and natural gas) and prices for the end product (HBI), which are subject to considerable fluctuations on world markets. This is resulting in a comparably high uncertainty of projected CFs.



4: Price volatility comparison for Nickel vs Rebar

It should be re-emphasized that the above list of possible reasons for differences in cost estimation accuracy of building construction versus MIPP is not exhaustive and just partly validated in its intend to serve as a starting point for further research in the area. For example, rather than using the extreme examples of standard residential housing vs. HBI plants, more complex BC projects could be used for comparison with MIPP.

7 Excursus: Reliability of Cost Estimates in Industrial Feasibility Studies

The UNIDO Manual for the Preparation of Industrial Feasibility Studies (1995: 36-7), widely used in the MIPP practice, defines the following “ranges of reliability” for estimates of investment and production costs to be considered acceptable[9]:

Opportunity Study	+/- 30 per cent
Pre- feasibility Study	+/- 20 per cent
(Bankable) Feasibility Study	+/- 10 per cent

5: UNIDO Manual for Industrial Feasibility Studies: Ranges of Reliability

As can be seen from the table, an Opportunity Study would correspond to an AACE Class 4, a Pre-feasibility to a Class 3, and a Bankable Feasibility to a Class 2 estimate, conservatively referring to the accuracy ranges in Table 3 of Chapter 6.1.

8 Conclusions and Starting Points for Further Research

In the present paper, AACE cost estimation standards for Major Industrial Plant Projects (MIPP) have been compared with German cost estimation standards for Building Construction (BC) according to HOAI. It is shown that the AACE cost estimation guidelines for the MIPP industry are much more tolerant in terms of accuracy than for BC in Germany, in particular for the early phases of Concept Screening, Study/ Feasibility and Budget (Class 5 to Class 3 estimates).

[9] The authors of the UNIDO Manual note that the given ranges differ from project to project depending on the applied method of cost estimates, for example how components of foreign and local currency origin are accounted for (c.f. ibid: 37, 151).

Using examples for MIPP versus BC projects, Hot-Briquetted-Iron (HBI) plants versus residential housing, a set of possible explanations is identified and categorized by (1) **competition intensity** including technology impact and **frequency of project occurrence**, (2) demands on **cost estimation professionals**, (3) materials and **supplies** used (international versus local), (4) **duration** of project execution, (5) **certainty of projected Cash Flows**.

The results of the study, however, are to be seen as indicative and are intended to serve as a **starting point for further research**. Potential topics yet to be explored include but are not limited to:

First, comparing MIPP cost estimation guidelines to non-German Building Construction (BC) standards, such as for example BC standards or guidelines in the US or the UK.

Second, an empirical investigation using examples other than HBI plants and residential housing resulting in a possible extension, restriction, confinement of or deviance from the above-mentioned set of explanations for the higher accuracy tolerance of MIPP versus BC standards would be useful.

Third, it could be further investigated whether or not, facing the situation of increasing cost competition, cost estimation guidelines for the MIPP industry may become subject to adaptation in terms of accuracy.

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