A Quality Model for Residential Houses Construction Processes

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Key words: quality, quality model, construction process, residential houses

SUMMARY

The EU-project „Development of a Real Time Quality Support System for the Houses Construction Industry“ (QuCon) has been started in 2009. Within this project the Institute for Applications of Geodesy to Engineering“ (IAGB) is cooperating with the Frederick Institute of Technology (Nicosia, Cyprus), the TU Delft (Netherlands) and further partners. The real time system should enable SMEs of different countries to document their processes in a simple and fast manner. Recent project states and achieved quality targets should be visualizable. Therefore selected SMEs of Cyprus, the Netherlands and Germany are integrated into the project to express their needs, demands and requirements and to bring in their practical experience.
The focus of IAGB within this project is defined by the establishment of a consistent quality model for the building of residential houses. It will be distinguished between quality of products and processes. The quality of the construction process can be described by characteristics like time adherence, cost adherence and resource adherence. Besides the quality of the product, the residential house or a part of its realization are described by the characteristics correctness, completeness, availability and accuracy. The concrete parameters as well as the required numerical values of these parameters can be derived from standards, guidelines, general recognized codes of practice as well as from laws and contracts. The integration of these parameters into a consistent quality model will be described. This paper will not be restricted to surveying tasks, but related to the complete construction process.

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1. INTRODUCTION

Business competition is increasing in the construction sector. Although labour and material costs are increasing, quality should remain on a high level or even be improved without spending any additional money. Regarding residential houses construction small and medium enterprises (SME) are the most active players. SMEs have essential problems to build up a time-consuming and expensive quality management system that is needed to survive the competition.

Up to now no consistent quality model for construction processes exists. The main reasons are the different point of views on quality issues of the parties or crafts respectively, involved in the construction process. Another reason is the unique character of each building. This character is reduced to a certain extent with regard to residential houses construction processes. Here, many of the processes as well as sub-processes and activities are repeated in a similar way for different projects. Construction processes are describable and to a certain amount standardizable.

This was the reason to originate the EU-project „Development of a Real Time Quality Support System for the Houses Construction Industry“ (QuCon). Within this project the Institute for Applications of Geodesy to Engineering“ (IAGB) is developing together with further partners a real time system that should enable SMEs of different countries to document their processes in a simple and fast manner. Recent project states and achieved quality targets should be visualizable. The participating SMEs from Cyprus, the Netherlands and Germany are to express their needs, demands and requirements and to bring in their practice experience.

2. PROJECT QUCON

2.1 Project Objectives

The project QuCon „Development of a Real Time Quality Support System for the Houses Construction Industry“ is granted within the EU CORNET Programm. CORNET is a network for information exchange. It was founded to create opportunities to set up transnational collective research and to promote close cooperation between the responsible national/regional ministries and agencies across Europe, especially for small and medium sized enterprises (SMEs).

The main goal of QuCon is to develop a cost-effective innovative real-time quality assurance tool suitable for the houses construction industry (QuCon, 2010). The main objectives with the project are:

- Investigating and analyzing the building process from project initiation to commissioning,
- Developing a quality model and quality parameters as well as assurance indices,
- Optimising the indices with respect to time and money,
- Developing a prototype software appropriate for SMEs.
-

Besides two secondary targets exists:

- Studies and analyzes the current quality assurance practices realized by different SMEs in different countries,
- Development of guidelines for performance improvement and quality parameter optimization.

The developed quality assurance software should be low-cost and be able to point out the stages in house construction where a check of the work already done is necessary to avoid waste by premature proceeding with the next step.

2.2 Project Structure

The project partners come from Central Europe (Netherlands, Germany) and Southern Europe (Cyprus).

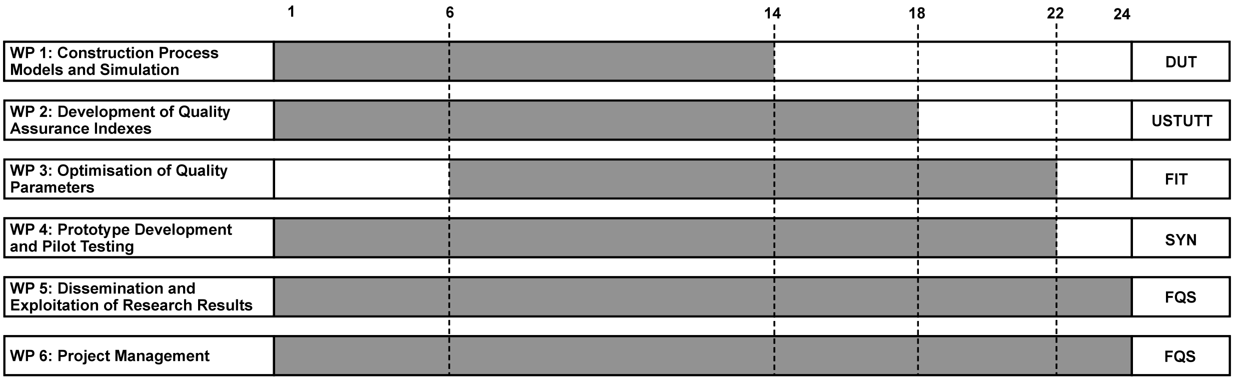

Fig. 1: Work packages for 'QuCon'

The project management is mainly effected by „Federation for Quality Research and Science“ (FQS, Germany), the partner associations of the other parter countries Cyprus and Netherlands are „Cyprus Association for Quality“ and „Bouwend Nederland“. Beside the ”project management” (WP 6) and the ”dissemination and exploitation of research results” (WP 5) there are four work packages: WP 1: construction process models and simulation, WP 2: development of quality assurance indeces, WP 3: optimization of quality parameters, WP 4: prototype development and pilot testing. As shown in Figure 1, the „Institute for Applications of Geodesy to Engineering, University of Stuttgart“ (USTUTT, Germany) is cooperating with the other research partners: the „Frederick Institute of Technology“ (FIT, Cyprus) and the „Department of Building Technologies, TU Delft“ (DUT, Netherlands) for the development of the Real Time System (the research work packages WP1 to WP3). The software development and testing (WP4) will be headed by „Synectics Ltd“ (SYN, Cyprus). The participating SMEs of Cyprus, the Netherlands and Germany are directly integrated into the project in so called SME-Meetings, where the research results are intensively discussed. The abbreviations correspond to Figure 1 representing the WP-structure and their responsibilities within the project.

The focus of IAGB within this project is the development of a consistent quality model for the building of residential houses. This quality model will distinguish between quality of products and of processes; the characteristics will be concretized with parameters as well as quality indexes. If the actual and target states of the required building and construction processes are compared in real time, this model is able to calculate the quality assurance indexes.

3. QUALITY MODELS IN DIFFERENT SCIENCES

According to DIN EN ISO 9000 quality is the "degree to which a set of inherent characteristics fulfils the requirements" (DIN EN ISO 9000, 2005). Therefore, requirements for the process and for the product are needed to draw conclusions on the quality.

In general a quality model should fulfill the following requirements. A fixed set of inherent quality characteristics is used to describe the quality of a phenomenon. It is essential to use the same quality characteristics to obtain a uniform quality description. Concretization of the quality characteristics is effected by means of variable quality parameters. The quality parameters are needed to obtain flexibility for the description of heterogeneous data types. Each quality parameter is filled with a numerical value. On the one side it is the recent actual value that may be measured or obtained in another way. On the other side a target value has to be given for the respective parameter. The required quality is achieved, if the actual (measured) value fulfils the requirement (the target value).

The analysis of available quality models presented in the following is essentially based on QuCon (2009a).

3.1 Civil Engineering

For civil engineering in general and for construction processes in particular no complete and concluded quality model exists. Some recent research projects deal indirectly with the topic quality. For example the Bavarian research cooperation "Virtual Construction Site – Digital Tools for Planning and Execution of the Construction Work" (ForBAU) was launched on January 1st, 2008 (Bafo, 2010). The central idea of the research cooperation is the integrated simulation of a complex construction project in a digital model of a construction site. This should serve as a central data medium to all project partners involved and over all phases of the project, from the design to the execution of works. It should take into consideration all data regarding planning, surveying, project scheduling, accounting, and progress of the construction work. By this procedure the quality of the construction work is improved, but no real quality modeling issues are treated within the project. The same is valid for the project "industrialised, integrated and intelligent construction" (i3Con) granted by the European

Commission since 2006 under the 6th European Framework Program that deals with the current situation of the quality and interface problems within the housing industry (i3con, 2010). The project will deliver technologies for an integrated smart building services system using distributed control systems with embedded sensors, wireless connections, ambient user interfaces and autonomous controllers. Additionally a new industrial business model will be developed.

Currently quality is mainly defined and described by tolerances that are quality parameters for the quality characteristic “accuracy”. These tolerances are defined within norms, standards and general recognized codes of practice. E.g. in Germany more than 4000 DIN standards are used in the construction of buildings. More than 1000 of them are relevant for housing construction (e.g. DIN EN 13914-2, 2005 and DIN EN 14992, 2007). Additionally on the European level the nine Eurocodes (Eurocodes, 2010) including different number of parts are available. Despite the high number of accuracy parameters no concluded quality model exists.

3.2 Geodesy

In the field of geodesy, quality is generally determined for measurements and evaluations based on these measurements. For many geodetic evaluations least squares adjustment is used. A comprehensive description of different parameters is state-of-the-art and described for geodetic networks in many textbooks (e.g. Niemeier, 2001). Most quality characteristics and parameters are related to accuracy; additional reliability parameters (which may be named as controllability as well) are part of many network adjustment analyses. The different parameters may be used for the optimal design of networks (e.g. Grafarend & Sanso, 1985).

Typical well-known accuracy parameters derived from error theory as well as from statistics are

- standard deviations and variances for coordinates,
- trace or determinant of covariance matrices as well as covariance sub-matrices for a whole network, or a more-dimensional point or even a point group respectively,
- confidence ellipses or ellipsoids for 2- resp. 3-dimensional points
- confidence hyper-ellipsoids for a whole network.

Typical parameters for the reliability analysis of geodetic networks are:

- degrees of freedom or redundancy,
- redundancy numbers or partial redundancy and
- marginally detectable blunder

For monitoring networks a special quality characteristic, the sensitivity against movements and deformations of the object to be monitored, has been introduced. Here, the parameter is the minimal detectable movement. So for the special case of geodetic networks a quality model outclassing the “accuracy-only-model” in the construction sector exists, but it is still related to a product only: the geodetic network.

3.3 Geodata and Traffic Telematics

In the following an example for an already existing quality model is demonstrated. The quality model has been developed within the EuroRoadS project. The EuroRoadS quality model is used to describe the quality of spatial data such as a digital map for car navigation or driver assistance systems. Generally it is based on ISO 19113 (DIN EN ISO 19113, 2005) and Wiltschko (2004). The following descriptions and definitions follow Witschko & Kaufmann (2004). The quality characteristics are given in the following.

- *Availability* is defined as degree to which geographic data are available in a certain place and at a defined time. For example, if in case of an application the geographic data is available in the intranet, but due to a communication error it cannot be transferred to the internet or to an external user, availability is not given.
- *Up-to-dateness* describes the degree of adherence of geographic data to the time changing universe of discourse. This is dependent on the dynamic of reality and the rate of update. For example, flow regulation at a junction was changed on 12th August 2009 from traffic sign to traffic light. But up to now the regulation of the junction has not been changed in the geographic dataset. As a result of changes in the course of time the information does not reproduce the reality correctly.
- *Completeness* is only fulfilled, if all required features, attributes and relationships of the universe of discourse are included in the geographic dataset. For example, if the feature "Point of Interest" has a Y-value but no X-value, the dataset is incomplete.
- *Consistency* is defined as the degree of accordance of geographic data (data structure, their geographic attributes and relationships) to the models and schemata. The consequence of consistency errors are incorrectness and non-availability.
- *Correctness* means the extent of conformity of geographic data in relation to the universe of discourse. The gross and systematic errors will be considered. These errors are depending on the required accuracy. For example the digitalization is correct, if the digitized street is inside the required accuracy interval.
- *Accuracy* is defined as the degree of adherence of geographic data to the most plausible or the true value respectively. Typical parameters are in accordance to section 3.2.

In parallel the PAS (publicly availability specification) 1071 "Quality model for geodata specifications" was developed and is available now (PAS, 2007). It deals with the description of geodata and is therefore to a large extent similar to the results of EuroRoadS. Here the quality characteristics are *position accuracy*, *thematic accuracy*, *completeness*, *consistency* and *time accuracy*. Characteristics like availability and correctness that are typical e.g. for mechanical engineering are omitted. In general both quality models are complete for the respective domain, but they are product related.

3.4 Conclusion

The proceeding analysis of all available quality models and characteristics within construction processes as well as neighbouring disciplines show the following results.

- A quality model that includes characteristics and parameters is required to describe the quality of a phenomenon.

- Several projects have investigated the construction process. The main objective of these projects was to improve processes, technology and communication. The improvement of quality was an intermediate goal.
- A complete quality model for the construction process does not exist.
- In neighbouring disciplines several complete quality models exist. These can be used as an indication for a quality model for the construction process.
- All analyzed quality models are product oriented. A model which is at the same time product- and process-oriented has to be developed.

4. CONSTRUCTION PROCESS FOR RESIDENTIAL HOUSES

A consistent quality model for construction processes does not exist, since there are different task groups working together on the same project. On the one hand, they have different points of view on quality issues of the parties, on the other hand the modelling of different processes carried out by different partners especially the interactions between them are difficult. The other reason is the unique character of each building and therefore the respective construction processes impede the quality modelling. But this character is reduced to a certain extent with regard to residential houses construction processes. Many of the processes (first level) as well as sub-processes (second level) and activities (third level) follow in general a certain sequence and are repeated in a similar way for different houses, that means the construction processes of residential houses can be described and standardized to a certain extent. But the level of detail has to be chosen according to the possible amount of standardization. If many deviations from the standard process occur on a more detailed level e.g. activities, it is more easy to describe the process less detailed and omit the activity level.

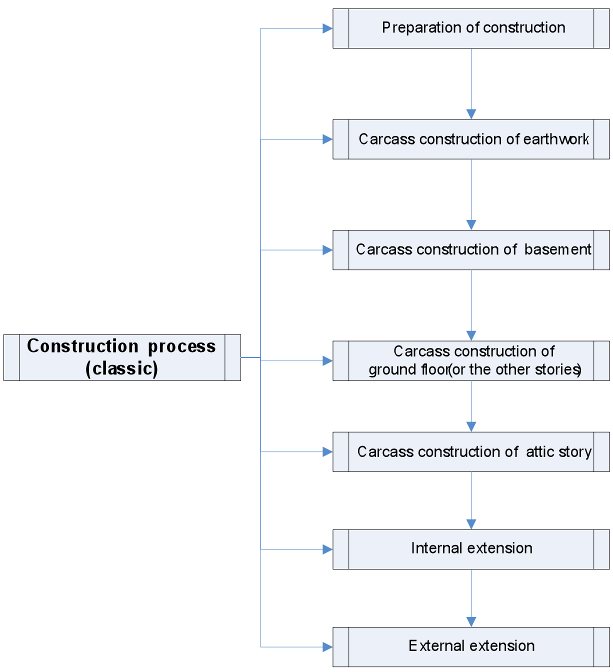

Fig. 2: Total construction process for residential house (Wengert & Schwieger 2010)

We have generated a construction model with about 100 sub-processes. However, the scientists and the SMEs from Cyprus have another view on the process. They have designed a more detailed construction process model, which contains more than 500 sub-processes and activities. In comparison to the exsiting quality model which is introduced in section 3, the processes optimization is more important than the product quality in our quality model. After the discussions with the SMEs and using Meyer (1996) and Meyer (1997), the German team has decided for a construction model including 100 sub-processes. The total construction process is split into 7 main processes, which are shown in Figure 2. Figure 3 presents the flowchart of one main process: the carcass construction of earthwork with the sub-processes and some exemplary checkpoints (compare section 5.3).

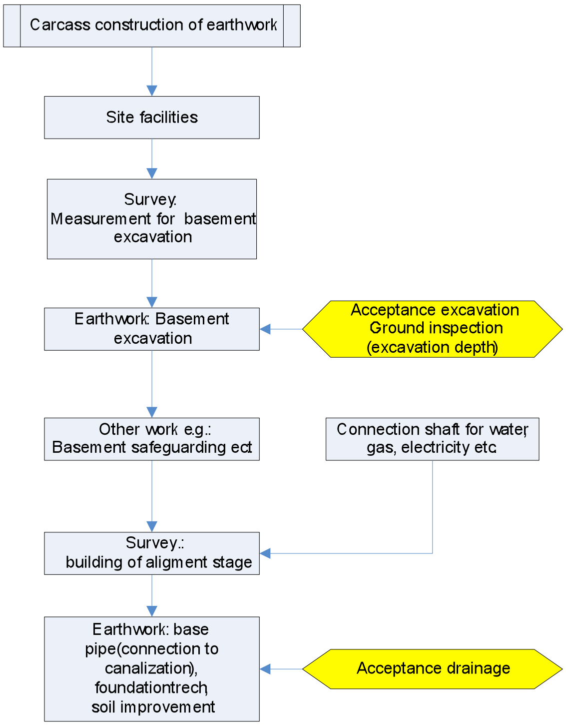

Fig. 3: Example for sub-processes of residential houses: carcass construction of earth work (Wengert & Schwieger 2010)

Figure 4 is the visualization of the construction process in MS-project as a Gantt chart, the sub-processes are chronologically displayed and relationships among the sub-processes and processes are shown too. As shown in Figure 4, most of the processes have to be carried out in a defined order and some of them at the same time. Many task groups take an active part in the construction process, for example the brickwork, woodwork, metalwork, mechanical and electrical work painting work and so on. It is a complex network among the partners and a good communication is needed. For example nowadays many prefabricated components like prefabricated walls and ceilings are used in residential houses. They have to be prefabricated, their dimensions must be checked and delivered to the building site on time. All of this needs a good cooperation among the partners. If the different tasks and partners are in good coordination with each other, the process will be optimal.

It is much easier to arrange the work with this Gantt chart as a project overview. The recent project state should be documented, reported and visualized for the partners. It will be compared to budget, schedule and, if modelled, to requirements from the contract as well as standards (compare to section 5). The reasonable decision and remedial actions will be initiated, if budget or schedule issues are violated or if the quality does not meet the requirements. By doing so, the total process will be optimized in real time.

The other lightspots are the checkpoints for the process (yellow boxes in Figure 3) which are important to avoid damage or financial deficits caused by premature proceeding with the next construction step. Those checkpoints can be draw from the needs and requirements of the contract, standards, guidelines, general recognized code of practice as well laws (compare section 5.3). One example is the acceptance of the excavation (see Figure 3). Here the excavation depth is measured carefully with the levelling instrument. Later on the acceptance of the drainage has to be realized. It is important that both is done before starting with the basement construction, since afterwards corrective work is very expensive. Another example is the isolation and waterproofing of the basement wall in basement construction. This must be assured, as the rebuilding operation is much more expensive and leads to a loss of company reputation.

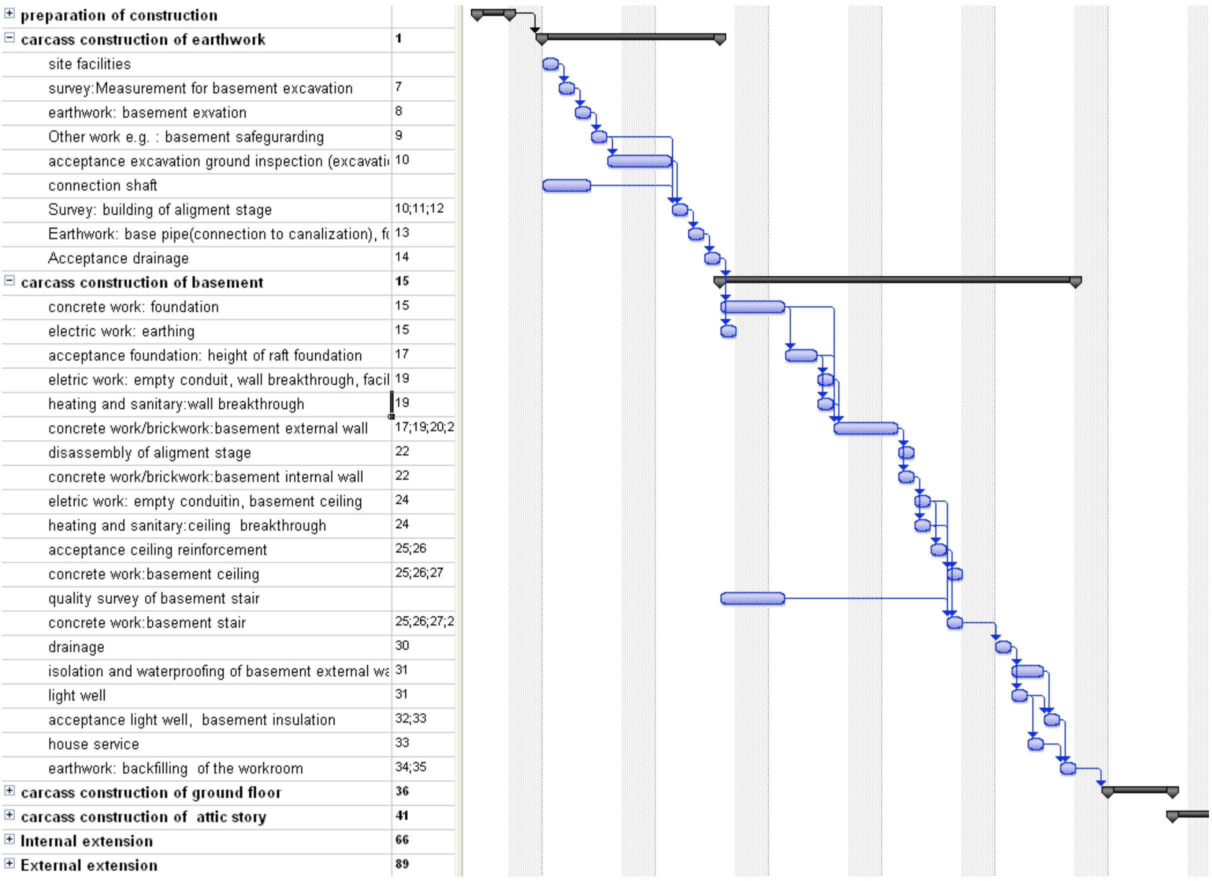

Fig. 4: Visualization of the construction process in MS-project, Gantt Chart

5. QUALITY MODEL

5.1 General Structure

The developed tool of QuCon should help the SMEs not only to improve the final product but also the quality of their work (processes). Therefore our quality model contains process and product related quality characteristics. Figure 5 presents all characteristics and their general relationships at a glance. In the following the process- and the product-related characteristics are defined and described briefly. For more details, especially possible concretizations using parameters, please refer to QuCon (2009b).

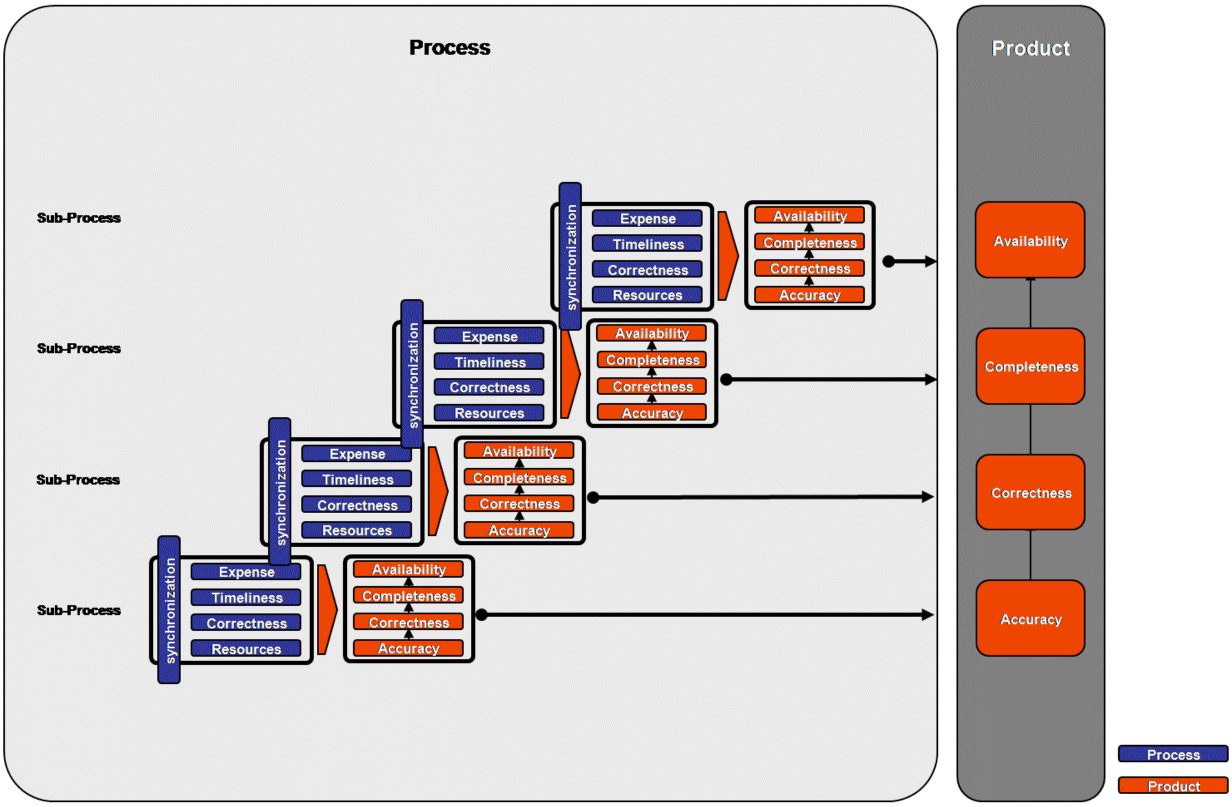

Fig. 5: Structure of the quality model for the construction of residential houses (Wengert & Schwieger 2010)

5.1.1 Process related quality characteristics

Expense: *Adherence to the expense plan*. The (sub-) process is carried out within / exceeds / falls below the budget.

Timeliness: *Adherence to the time schedule*. The (sub-) process begins and ends at the scheduled points of time / shows a time delay / is ahead the time schedule.

Process-Correctness: *Adherence to the predetermined procedure*. The predetermined procedure regarding the correctness can be deduced from laws, standards, the generally recognised codes of practice and the technical demands written in the contract. Correctness is regarded with respect to the technical demands; e.g. correct sequence of working steps or of compliance with all regulations. These criteria may be fulfilled, partly fulfilled or not fulfilled.

Resources: *Adherence to the predetermined resources*. The (sub-) process is carried out within/ exceeds / falls below the predetermined resources. In any case the resource rate has an influence on the timeliness and on the expense, since any lack in resources lead to an increase of expenses or of the time spent, or of both.

Synchronization: *Adherence to the overall predetermined inter-process workflow*. This quality characteristic addresses different processes that depend on each other. These (sub) processes begins and ends at the scheduled points of time / show a time delay / are ahead the time schedule with respect to the related processes.

5.1.2 Product related quality characteristics

Availability: *Overall quality characteristic that takes into account all other definitions*. Product is completed at the required point of time within the budget using the planned resources. The characteristic is not purely product related. It is the combination of process and product related characteristics.

Completeness: *Adherence to defined completeness of product.* Product is completed correctly as defined and planned or it is fragmentary.
Condition: only correctly realized products are counted as completed.

Product-Correctness: *Adherence to demands, requirements, standards, generally recognised codes of practice and technical demands written in the contact.* The demands, requirements, standards, etc. are fulfilled or not fulfilled. Two variants have to be distinguished:

a) The correctness of the product is measurable. These characteristics can be parameterized using accuracy parameters. If their accuracy exceeds the tolerance from the standards, demands, etc., the product is incorrect.
b) Some characteristics are not measurable. In these cases there are checks only, e.g. visual controls. If requirements are not fulfilled, the product is incorrect.

Accuracy: *Degree of adherence to demands, requirements, standards, generally recognised codes of practice and technical demands written in the contract.* Accuracy is the basis for correctness decisions of variant a) of product-correctness. In general it takes into account random deviations only.

5.2 Exemplary Realization

In the following the characteristics described are put into concrete terms by exemplary parameters related to sub-processes of the construction process for residential houses. The process related quality characteristics *process-correctness* and the product related quality characteristics *product-correctness* and *accuracy* are described together with the example from the ISO standard (ISO 4463-1, 1989) that will be discussed more in detail in section 5.3. For the characteristic *availability* no further concretization will be given, since it will be understood as a general quality index that will be the main target of QuCon. It is not yet defined and discussion about this index is still going on.

5.2.1 Process related quality characteristics

Expense *for earthwork:*

- relative expense rate $ER = \frac{E_a}{E_b} \cdot 100$ [%], E_a actual expenses and E_b budget (planned expenses):
  95% of the predetermined costs for earthwork have been expended.
- absolute expense difference $\Delta E = E_b - E_a$ [€]:
  150€ have been economized for earthwork.

Timeliness *for earthwork:*

- relative time rate $TR = \frac{T_a}{T_b} \cdot 100$ [%], T_a actual time consumption and T_b planned time consumption:
  105% of the predetermined time for earthwork have been expended.
- Absolute time difference $\Delta T = T_b - T_a$ [days]:
  2 days more have been expended for earthwork.

Process-Correctness:
An example regarding this characteristic is explained in section 5.3. In the following the typical parameters are given.

- correctness CA: true/false [0, 1].
- correctness rate CR [%]: $CR = \frac{c}{n_c} \cdot 100$ [%], c fulfilled and n_c all process steps / requirements.

Resources *for building alignment stage measuring procedure:*
Planned Resources:

- Personal: 2 site surveyors
- Material: 16 ground marks
- Tools: 1 EDM, 2 30m-tapes, theodolite reading directly to 10 mgon (1') or better

If e.g. there is only a theodolite reading directly to 100mgon instead of 10mgon, the resource rate $RR = \frac{R_a}{R_b} \cdot 100$ with R_a actual consumed resources and R_b planned resources consumption will be 0%, because the used resource is not adhered to the predetermined resources. If e.g. there are only 12 ground marks, the resource rate RR will be 75%, since a number of 16 would be the optimum, but 12 are still enough marks.

Synchronization *for earthwork sub-processes, especially building alignment stage:*
Before starting the survey work for the building of aligment stage, many other processes have to be realized, for example the "site facilities" must be build up, "excavation" and its measurement and "acceptance of excavation" as well as "connection shaft" (see figure 6) have to be done. These processes need different time spans, most of them must be carried out in a defined order and some of them can be carried out in parallel, but all of them have to be finalized, when the building of aligment stage starts. E.g. the realization of the "connection

shaft” is realized in parallel to the site facilities, it may be carried through later, but has to be finalized before ”building of alignment stage” starts. The last process before ”building of alignment stage” is ”acceptance of excavation”, so finally the first has to be finalized not later than the second. The maximum time difference $\Delta TS = \max\left(T_{bi} - T_{ai}\right)$ will be minimized. Here T_{ai} is the actual time span and T_{bi} the planned time span to start the follow-up-process, both for process i, including n processes i that are important for the follow-up-process.

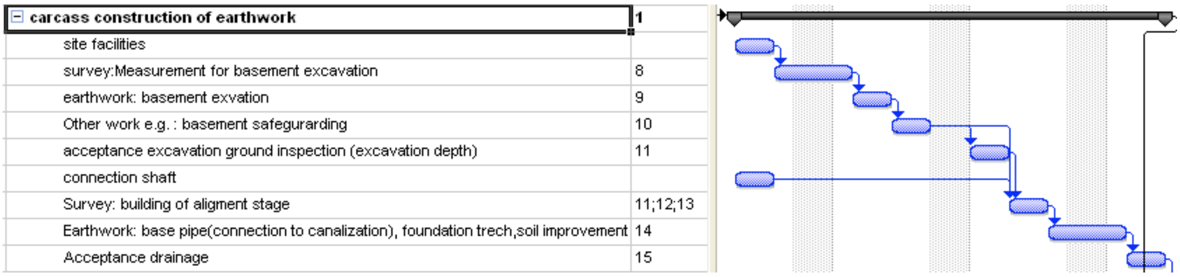

Fig. 6: Extract of the construction process: carcass construction earthwork

5.2.2 Product related quality characteristics

***Completeness** for building alignment stage measuring procedure:*
CRR = 75% (12 from 16) ground marks were correctly marked according to the plan, with $CPR = \frac{CP_a}{CP_b} \cdot 100$ [%] with CP_a actual completed product parts and CP_b product parts in case of 100% completion.

Product-Correctness:
An example regarding this characteristic is explained in section 5.3. In the following the typical parameter is given.
- correctness CB: true/false [0, 1]

Accuracy:
An example regarding this characteristic is explained in section 5.3. In the following the typical parameters are given. The definitions and equations are well-known and therefore not repeated at this place.
- RMS (root mean square), standard deviation, average or maximum deviation,
- the maximum deviation MD.

5.3 Measuring Quality

It was suggested by the German SMEs, that the surveyor should independently control correctness and accury. This suggestion is also mentioned in the standard. This means that measurements will play an important role in the quality control of building construction. The following sentences are quoted from ISO 4463-1 (ISO 4463-1, 1989).

4 Definitions
4.1 site surveyor : Person entrusted with the carrying out of one or more of the different measuring operations in the building process.
As practice tan differ from country to country, the term site surveyor is intended to refer to a competent operator in this field irrespective of his formal qualifications.
4.2 compliance measurement
...
4.3 check measurement: Independent informal measurement to check the correctness and accuracy of a previous measurement.

As described in section 4, checkpoints help construction managers to control the construction process. The more check points, the more the process can be checked in detail, but it is not possible and necessary to check for all details. It is just necessary to check some of the critical points which are important to avoid waste and failures. ISO 3443-8 "dimensional inspection and control of construction" (ISO 3443-8, 1989) gives us a list of items to be checked. There is a checklist in practice as well (Metzger, 2007). For the construction process model within QuCon both of them will be combined. The work is not yet finished up to now. To give the readers an impression, the following text blocks are extracted from the ISO standard. The authors focus on process-correctness, product-corrcetness and accuracy as typical characteristics related to surveying and measurement techniques. In practice, the position of the house corner (building of aligment stage) and the depth of excavation will be carefully checked. This is emphazised in the standard too (see the following extract).

A.1 Obejects and characteristics which it is important to check
Among others, the following important objects and their characteristics should be checked:
- *a) Primary, secondary and postion points, and possible transfer and protection points, horizontally and vertically, checked according to ISO 4463;*
- *b) The dimensions and level of foundation;*
- *...*

The process of measurement procedures and accuracy table for different instruments and different dimensions are given in the named ISO standards. For this reason, the process-correctness and product-correctness as well as product accuracy will be described in the following using examples of measurement for setting-out a house corner in construction.

Process-Correctness:

As it is well-known, a network for the determination of the accurate positioning and level of houses and house elements is needed, so in the following an extract from ISO 4463-1 is given as an example for measuring procedures for requirements defined on the process level. In earthwork it is important to set out the position of the house corner. There is a three-stage order of reference systems or networks respectively which are commonly required for large and complex building projects: primary system, secondary systems and position points. These stages are the base for the setting-out procedure. Since the processes and the requirements of each of the three stages are quite similar, only the procedure for the secondary system is extracted from the standard.

15.4 Setting-out of secondary Points
The setting-out of secondary Points should be carried out with redundant measurements and in such a way as to allow for Cross-checking.
15.4.1 Distance measurement
There are two alternatives:
a) Using an EDM
...
b) Using a tape
All distances should be measured at least twice, preferably in opposite directions. The values measured should be corrected for temperature, sag, slope and tension. A tension device shall be used with the tape.
Distances to be measured should not be greater than twice the length of the measuring tape to be used.
.....
15.4.2 Angular measurement
Angles should be measured and set-out with a theodolite reading directly to 10 mgon (1') or better. The measurements shall be made in at least one set. A set is formed by two observations, one on each face of the instrument.

In this case, the total process can be subdivided into two steps: distance and angular measurement, then $n_c = 2$. If both of the two steps are carried out according to the standard, the correctness rate CR will be 100%, if only one of them is correct, the correctness rate CR will be 50 %.

Product-Correctness:

a) Position of the house corner, measurable parameter, accuracy parameter has to be taken into account, the correctness CB may be zero or one.
b) Color of the internal plastering of the wall: if grey is demanded in the contract, and white is actually realized, the correctness CB is zero.

Accuracy:

The following are acceptance criteria for the position of secondary points extracted from ISO 4463-1:

15.5 Acceptance criteria for the Position of secondary Points
Secondary Points should be subjected to two stages of acceptance, namely:
- *Stage one, in relation to key primary Points; and*
- *Stage two, in relation to other secondary points controlling the same building or the same section of the building*

15.5.1 Stage one
15.5.1.1 Distances
The difference between a given or calculated distance and a compliance distance shall not exceed the following permitted deviations:
Distances up to 7 m: ± 4 mm
Distances greater than7m: $\pm 1.5\sqrt{L}$ mm
where L is the distance in metres
15.5.1.2 Angles
The difference between a given or calculated angle and a compliance angle shall not exceed the following permitted deviations:
in degrees: $\pm \frac{0.09}{\sqrt{L}}$ (or $\pm \frac{5'24''}{\sqrt{L}}$)

in gon: $\pm\frac{0.1}{\sqrt{L}}$
or as offset : $\pm 1.5\sqrt{L}$ mm
where L is the length in metres of the shorter side of the angle
15.5.2 Stage two
……

If e.g. the measurements of the angles between two points are carried out with a theodolite and made in two sets, the RMS can be calculated If the shorter side of the angle equals 100m, for the angle the permitted deviation is ± 0.01 gon. If $\sqrt{rms} < 0.01gon$, the angle is regarded as correct otherwise it is incorrect. Thus a strong relationship between accuracy and correctness is obvious.

The depth of the exvacation as well as the height of the foundation can be measured and checked using the levelling instrument. The application of further measurement instruments to check the size, squareness, straightness, flatness and further geometric features of the components is defined in the ISO standard as well. The respective accurancy table is given there as well. The readers are recommended to have a look in this standard to get more information.

6. CONCLUSION AND OUTLOOK

Within this article an approach was made to define a new quality model for the construction of residential houses. The advantage is its consistency through out the whole process and the consideration of process and product quality. Additionally it is not restricted to accuracy, but deals with additional parameters as availability, correctness, timeliness, synchronization, completeness, expenses and resources. The works are realized within the EU-project QuCon that aims at a cost-effective quality assurance software-tool for SMEs. One important part of each quality assurance is, besides the modeling, the measurement of actual and recent achieved quality parameter values. For this task a surveyor is the right person. He may control most of the quality parameters and thus gives the input for an effective project management of the whole construction process.
The project team will continue to develop a tool for accessing the overall quality of the construction process at all stages of the process. For this a general quality assurance index has to be computed on the base of all the different parameters. This will be a challenging task for the future.

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