

# QUALITY CONTROL IN LEAN CONSTRUCTION

Esben Misfeldt<sup>1</sup> and Sten Bonke<sup>2</sup>

## ABSTRACT

Quality control (QC) in lean construction is at the moment in an early stage of development. In fact, QC is not yet an integrated part of the overall concept of lean construction. This paper describes the guidelines for a QC system which is coherent with lean construction, and which takes the newest knowledge of lean construction and quality control theory into account.

In the *TrimByg-QC* system [Lean Construction-Quality Control system] a large part of the quality control is executed by the building workers with only limited participation from the site management. When workers are controlling own work their general notion of quality is due to increase, and defects in quality are found and fixed faster than by traditional quality control. In this paper tools and routines for quality control of the site activities “realigning of floor slab panels” and “tamping of concrete elements” are reviewed on the basis of an empirical investigation. The analysis of the data shows that *TrimByg-QC* has a considerable potential for further testing and development.

In connection to such further development six focus areas are identified and described. The future steps should encompass different aspects such as a continued development of the basic tools for worker-based QC and the consideration of legal aspects of building workers’ role when controlling their own work.

## KEY WORDS

Quality Control, lean construction, managerial tools.

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<sup>1</sup> Esben Misfeldt, (CEng) Construction Site Manager, MT Hojgaard a/s, Knud Hojgaards Vej 9, DK2860 Søborg, Denmark, +45 2270 9632, emt@mthojgaard.dk.

<sup>2</sup> Sten Bonke, (Sociologist MA) Associate Professor, Head of Section, Section for Planning and Management of Building Processes, BYG•DTU Department of Civil Engineering, Building 115, DK 2800 Lyngby, Denmark, +45 4525 1648, sb@byg.dtu.dk

## INTRODUCTION

This paper has been written in continuation of a master thesis (Misfeldt 2003) in collaboration between BYG•DTU at The Technical University of Denmark and MT Hojgaard Ltd.

The development of lean construction (LC) into an operational production concept for today's Danish construction sites has come very far. The contracting firm MT Hojgaard Ltd. has by far captured the leadership, considering the development and implementation of LC under the designation *TrimByg*. However, important activities within site management still remain to be integrated into the concept of *TrimByg*. One of the most important of these is quality control (QC), hitherto managed according to separate systems, which have been developed with respect to quite different conceptual premises than those of LC. This twofold situation is causing discontinuity in the site operations, which again leads to low returns on the QC activities.

Based on the latest knowledge concerning *TrimByg* and QC this paper describes a new approach to the QC system, reflecting and in better harmony with the principles of *TrimByg*. For demonstration purposes a small-scale test of this new QC system has been carried out on one of MT Hojgaard's construction sites.

## BACKGROUND

Quality and value for the client are two very crucial notions in *TrimByg*. Quality inspections, however, are not by themselves value-adding activities – consequently they should be reduced or eliminated. Furthermore, the present bureaucratic quality control, applied by most contracting firms, is far from effective as it a. o. is implying a long response time from detection of quality failures. As cited below quality control should therefore always be executed as close to production as ever possible:

*When total elimination is not possible, the financial implications of any error increase as the time between inspection and production lengthens. It therefore follows that those executing a task at the workplace are best placed to control quality and correct defects. This concept is central to the Toyota Production System strategy with regard to quality control (Womack et al. 1990).*

(Marosszky et al. 2002)

In the same work of Marosszky et al. is drawn a list of focus issues, inspired by 'The Last Planner'-system (e.g. Ballard 2000). According to Marosszky two of these are of particular relevance to the production phase in construction:

- Identify the quality failure as close to work execution as possible
- Motivate better quality through work incentives attached to good rather than to poor quality

With the purpose of decentralising more competence of decision-making should be transferred downwards in the organisation hierarchy. Building workers should be given influence to suspend production when observing quality failures. Furthermore workers must themselves be given access to decide on mending minor quality failures.

A decentralisation of decision competences will lead to increased empowerment of construction workers. Through this approach 'higher individual needs'<sup>3</sup> are met in satisfying work conditions, and employees are being motivated to do a better performance. The managerial power, which is then shared with employees, is however not necessarily lost in the traditional management core. Rather, the total managerial capacity of the company can be enlarged for the benefit of the overall productive strength and competitiveness of the company. By transferring part of the more trivial instruction and control tasks to building workers, management can concentrate on more important overriding managerial and planning assignments. Even new or hitherto neglected activities can then be implemented in the organisation. This is also exactly why Daft (1999) - in good accordance with the lean construction philosophy – is arguing that building workers are often most competent in deciding on specific work related questions and in meeting customer needs on site.

Thus, through such delegation of decision-making to workers their skills are being activated for the useful purpose of improving quality. The accumulated site learning processes are directed towards handling of quality failures in building, and proposals for solutions and system improvements are eventually made amenable to all parties in the building process through better knowledge sharing.

#### **ELEMENTS OF A *TRIMBYG* BASED QC-CONCEPT**

Inspired by Marosszky et al. (2002-B) a substantial part of quality control activities are being transferred to building workers themselves with the objectives of early detection and mending of quality failures at minimum costs. It is presupposed that the constellation of client inspection, site management inspection and personal control should be retained. However, these must be integrated into the planning approach of *TrimByg*, making the two activities complementary in an aggregate system of control.

In figure 1 the overall flows of the contractor's QC are illustrated.

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<sup>3</sup> as described in a.o. Maslow's pyramid of needs (Maslow 1954)

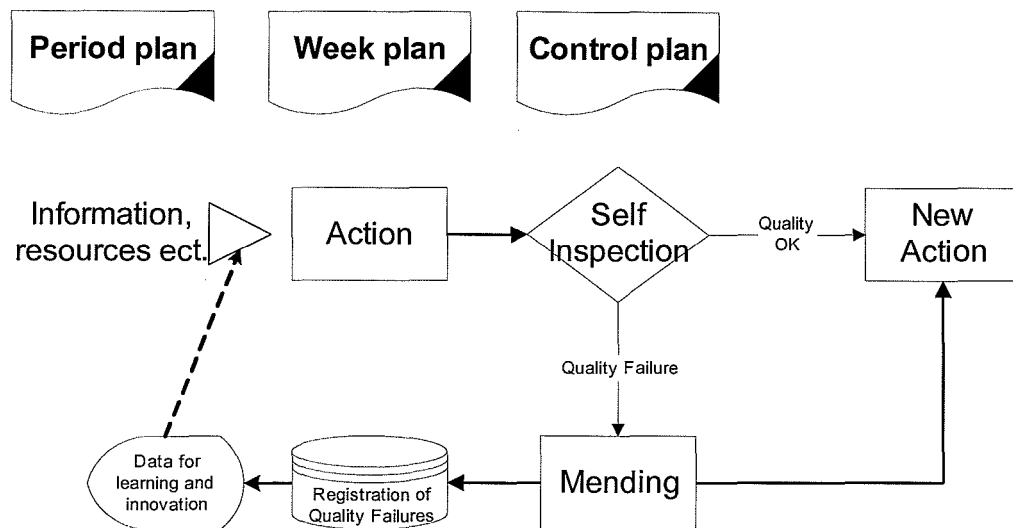


Figure 1: Chart of procedures in a *TrimByg* QC system

In connection with the period plan action must be taken to secure necessary *information, resources* etc. for the production flow. But also the *control plan* and thus existing QC tasks must be activated. Parallel to or immediately after a given production activity (*action*) building workers must carry out a self-inspection of the specific production result. Depending on whether the product quality conforms to specifications or not he may release a subsequent production activity (*new action*) or *mend* the quality failure. Finally, for the purpose of improving future quality control planning, information on relevant types of quality failures must be stored in a central *quality failure registration* (database).

In the following the central elements of this *TrimByg-QC* approach will be reviewed.

Elements in *TrimByg QC*:

- Rolling plans
- Distribution of work functions
- Building workers' quality control
- Ready report
- Quality documentation

## ROLLING PLANS

As a precondition to obtaining efficiency in the production process lean construction theory defines seven flows (Vrijhoef & Koskela 1999); one of these is accurate information given in drawings and specifications etc. at the right time and place. When applied to *TrimByg-QC* also information concerning control and inspection plans for the planning period in question, typically three to six weeks, must be present. This means that the site management in relation to daily planning routines should prepare details in the control plans as these cannot with sufficient accuracy be determined long-range in advance of the building period. On the

contrary, just like other planning issues, they must be dealt with according to the basic principles of rolling plans (Vrijhoef & Koskela 1999).

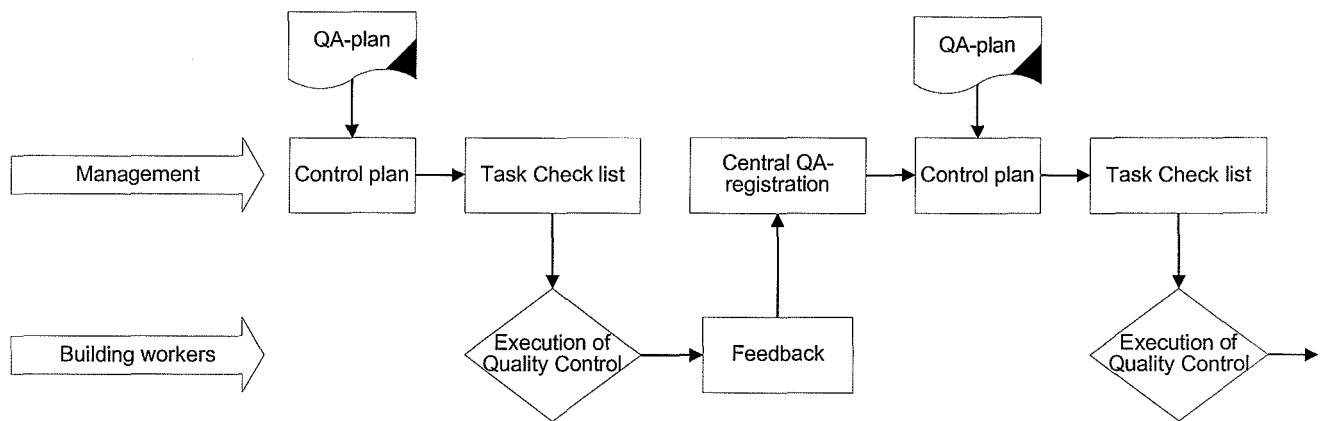


Figure 2: Flowchart of rolling plans-procedures in *TrimByg-QC*

The dynamic approach of rolling plans implies that the continuous assessments, which are underlying the quality control, are executed with a better chronology and localisation in relation to the actual production processes. The trade contractor will be receiving continuous information about where and which operations in production are considered risky by the site management. He then has a better option of tightening the quality control efforts, in particular towards such risk areas. Likewise the trade contractor will inform the site management and the design team about areas considered critical from his point of reference. This openness is of course crucial to the generation of an experience database ('registration of quality failures' in Figure 1).

#### DISTRIBUTION OF WORK FUNCTIONS

The distribution of work functions and responsibilities are shown in the table below.

Table 1: Distribution of work functions and areas of responsibility in connection with *TrimByg QC*

<b>Site Management</b>	Preparation of control plans, allowing for employees' proposals for improvements Preparation of check lists referring to the control plan Instruction of buildings workers in QC procedures Analysing and filing of QC documentation Quality control in relation to specific risk areas
<b>Building workers</b>	Feedback on critical production details before starting execution Execution of daily quality control procedures Documentation of quality control activities Feedback to site management Preparation of improvement proposals concerning quality control

The initial task for the site management is to prepare a control plan. Attached to this should be simple checklists (typically provided as paradigms by the firm organisation). Planning of the quality control activities then has to take place in collaboration with building workers. Checkpoints, which do not make sense for the building workers must either be omitted or clarified. Equally, building workers' proposals for check points should subsequently be integrated in the control plan.

Besides this planning of the building workers' QC activities the management of the trade contractor has the assignment of identifying particular risky production areas where exceptional QC efforts are needed. On these check areas management itself provide supplementary control so that building workers do not stand alone with the on site quality control responsibility.

Check lists, filled in by the building workers, are now collected and analysed by management. In case of quality failures it is the responsibility of both management and building workers to react immediately to these. Taken together, the quality activities of the building workers are of central importance in this system, as a major part of the quality control is executed and documented by the building workers themselves.

#### **BUILDING WORKERS' QUALITY CONTROL**

As indicated, the quality control executed by building workers is based upon the task specific checklists. These are distributed by management and reviewed in collaboration with building workers before the start of the production task. The main purpose of this dialogue of course is to focus the attention of the workers upon any risk area in the production process, thus conducing to higher end-product quality.

Every new production task must be related to a team of building workers, dedicated to exactly this type of activity. One member of the group is then appointed responsible for the task quality – a role, which well may regularly be circulating in the team in order to have competences and motivation of all team members orientated towards the quality issues.

#### **READY REPORT**

The 'last planner' concept of *TrimByg* is operating with seven flows which must all be fulfilled before a 'healthy' activity can be launched (Vrijhoef & Koskela 1999). As indicated none of these are at this point including quality control. In order to comply with this shortcoming one of the flows, normally referred to as 'completion of previous work activities', must be extended with the implementation of *TrimByg-QC*. Quality must then be controlled and approved before an activity can be characterized as 'completed'. In this way it is ensured that the subsequent production activities do not *build* upon defective building parts.

#### **QUALITY DOCUMENTATION**

In the present situation check lists/forms are a well-known feature of most QC systems among contractors. Within the *TrimByg-QC* system more direct and effective forms of

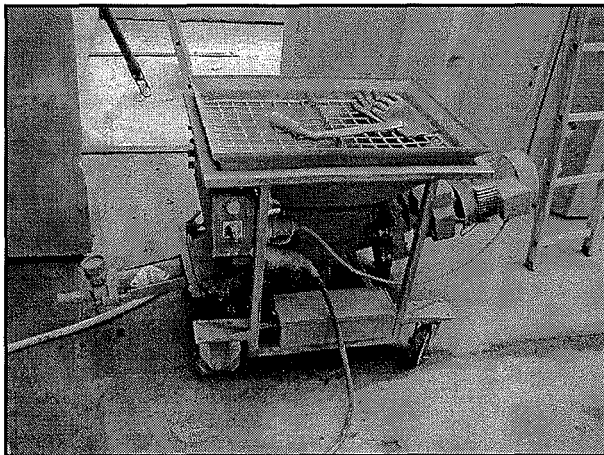
control documentation will be an option. This could for instance be a drawing section, showing a specific work task. With a signature of the quality responsible building worker, indicating that the information is understood, and that time and resources are adequate, such a drawing would be sufficient and relevant documentation. Indeed, the framework for new initiatives concerning quality documentation, for instance from workers, should be kept open as it is exactly one of the aims of the control plan to secure systematism in the documentation through references to the varying forms of documentation, which are suitable to the different conditions on site production level.

### TESTING *TRIMBYG QC*

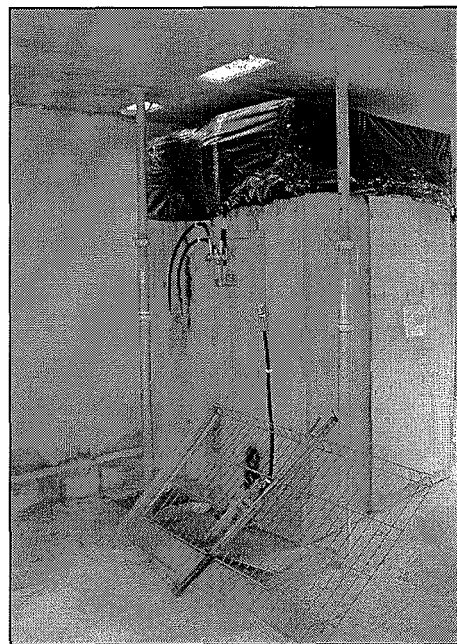
The *TrimByg QC* method has been tested empirically in collaboration with the large Danish contracting company MT Hojgaard Ltd. The testing took place on a building site 'Glyptoteksgaarden' in Copenhagen City. The concept was implemented on the concrete element contract, which then was determining the specific work operations, object to the quality control system. The contract included 55 dwellings plus 350 hotel rooms, totalling to 4,200 concrete elements with a man-time equivalent of 13,000. The testing period had a duration of two weeks from 2003-05-28 until 2003-06-10.

In consultation with project manager, Jacob B. Christensen (JB), two work operations were selected for the system testing:

- Tamping of concrete elements with a joint-machine
- Realigning of floor slab panels



Picture 1: Tamping machine



Picture 2: Realigning of floor slab panels

The selection of these two work operations was based on the principles of 'rolling plans'. The process of tamping of elements with a joint tamping machine implied use of new

technology, which had been causing certain quality problems. Concerning the realigning of the floor slab panels the contract specifications were defining increased demands on arch height tolerances. Consequently, the conditions around the two operations called for a tightening of quality demands, and they were therefore natural candidates for the testing of *TrimByg-QC*.

#### **PROCEDURES IN THE QUALITY CONTROL**

After completion of the work operation but previous to unrigging the work place<sup>4</sup>, the building worker in charge of quality will undertake an inspection of the completed work. This person is responsible on behalf of the team ('gang') that the work operation has been completed without quality failures, when the building workers start unrigging the work place. There should most likely be economic consequences attached to this responsibility, for instance influencing the piecework bonus. However, this is obviously a labour market issue and will need further clarification to become a general option. As mentioned earlier the quality inspection must focus on the risk areas defined in collaboration between the site management and building workers.

If quality failures are identified these should be mended immediately if possible. Thus, no registration in the QC documentation is requested. However, if the failure cannot be mended right away, a note must be made and the mending dealt with at a later moment. When mending then has been done, a note is likewise entered in the quality papers. Not until all quality failures have been mended the team may report ready for subsequent work operation.

This system is aiming to keep down the amount of written documentation in order to facilitate the active contribution from building workers. However, for legal reasons a certain degree of formal documentation will of course prevail.

#### **ATTITUDES TOWARDS THE CONCEPT**

During the two weeks testing period two teams of building workers performed quality inspections on their own work according to the principles in *TrimByg-QC*. Some of the most significant results generated during the period can be identified to the workers' attitudes towards the concept. This important basis for the future development of the concept appear from the empirical information, which was collected in form of the quality documentation produced by workers - and supplemented in a number of interviews with the involved parties.

The information on attitudes is structured on the three levels: building workers, site management and strategic management. As the interviews are few in number these attitudes should be interpreted mainly as input for discussing the features of the QC concept.

#### **Attitudes among the building workers**

One interview was taken in one of the involved teams to collect the attitudes of the building workers towards the *TrimByg-QC* system.

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<sup>4</sup> Work place is defined as the specific location on a building site where building workers have arranged materials, machinery and tools for the execution of a work operation. Work places will constantly be moving during the on-site construction process.



It appeared that, against the principles of the concept, the workers' own quality inspection had not been executed as the prescribed inspection round after the completion of the work operation. This clearly leads to a reduction in the efficiency in quality control. However, the attention on the work quality during the work process had increased (cf. also theories of empowerment, (e.g. Daft 1999)). Taken together the building workers had evidently accepted substantial parts of the *TrimByg-QC* procedures but a further adaptation of these was needed to obtain full implementation.

The building workers are regarding the increased responsibility as an unambiguous advantage of *TrimByg-QC*. Increased responsibility is generating a larger sense of responsibility, which, according to the workers, is also reinforcing the work motivation. As a means to improve quality it is recommended by the workers that work routines should be more precisely specified. An easily read (assembly) instruction for non-experienced workers to consult must be available before operation. In addition to process instructions it must be clearly defined how the members of the gang are individually responsible for the specific work operations. A well-defined quality responsibility in *TrimByg-QC* will reduce doubts and improve transparency in the daily work.

In all the building workers approved of the new concept, and they were particularly happy about the extended responsibility, which was delegated to them. This can be considered a good point of departure for wider implementation of *TrimByg-QC*.

#### **Site management's attitude**

This information is collected through the interview with a project manager, representing the concrete contractor. Again, the generality of data is very limited.

The project manager did not state a clear opinion on whether he was in support of *TrimByg-QC*. He considered it beneficial to delegate a limited number of the quality control activities to the building workers. This delegation should aim at areas in production, where problems of maintaining an acceptable quality level have been demonstrated. Thus, the project manager sees the *TrimByg-QC* system as a supplement to the existing QC approach in the company. According to him, an adequate system cannot do without the quality control executed by the site management. And he is opposed to the idea of letting building workers take over 100%, (which however is not presupposed in *TrimByg-QC*, as it so far is operating with a residual management control in parallel with the building workers' control activities.

The project manager does express an apprehension that building workers will tend to miss or ignore own quality failures thus slipping these through the quality control. This may either happen when the building worker during inspection 'automatically' ticks off the control box on the checklist. Or the building workers may deliberately or unconsciously cover quality failures, thus making it impossible to detect them during a subsequent control procedure.

On the question on whether certain types of quality failures would be more easily caught by the *TrimByg-QC* system it was however acknowledged that positive effects can be ascribed to the social mechanisms argued for within empowerment theories. Exactly this enhanced feeling of responsibility, connected to the delegation of the quality control, is a crucial element in the *TrimByg-QC* system.

### **Attitudes of the strategic management**

The strategic management of MT Hojgaard Ltd. has given a high priority to the development and implementation of its specific company version of lean construction, called *TrimByg*. In support of this strategy the management is also calling for dedicated *TrimByg* tools and methods for health & safety, environmental and quality management. The expression of this need has been the starting point for the development of this test version of *TrimByg-QC*. Subsequently it was natural to have the strategic management assess the characteristics and usefulness of *TrimByg-QC* in relation to the conditions of site production.

Responses have been positive and the strategic management has formulated intentions for a further development of the concept and for its implementation in the company's production system. In parallel also tools for *TrimByg* based management of health & safety and environment are being development.

### **Meeting the scepticism of management**

As demonstrated site management is somewhat sceptical of letting over quality control to building workers. However, this scepticism is mainly due to a lacking understanding of the functionality and intentions of the *TrimByg-QC* system, which indeed does not hand over all QC sovereignty to workers. Site management must also henceforward carry out inspections regularly, but with longer intervals though. At the same time the role of managers are due to change with more emphasis upon communicative aspects related to informing building workers about specifications and quality demands from client. So rather than focussing on the power dimension it will become important for management to think in terms of dialogue and knowledge sharing.

However, it cannot be neglected that part of this management scepticism is deeply rooted in professional attitudes and even psychological mechanisms which it may take a quite substantial educational and training effort to overcome.

### **FUTURE PROSPECTS AND DEVELOPMENTS FOR *TRIMBYG-QC***

In this paper the general conceptual features and operational elements of *TrimByg-QC* has been described and discussed. The future development of *TrimByg-QC* includes a number of issues and dimensions. Below is given an overview of the most urgent areas for further development, based on the empirical experiences reviewed in this paper. They are:

- Development of tools for quality control
- Development of competences for the building workers
- Activating building workers' knowledge and skills
- Integration of QC activities the piecework/bonus wage systems
- Legal aspects of *TrimByg-QC*
- Development of an implementation strategy for *TrimByg-QC*

A substantial task is of course to analyse all important work operations in the construction process for their implementation in the *TrimByg-QC* system, such as it has been indicated in

this paper for the 'tamping' and 'realigning' operations. Furthermore the roles of site management and client must be more explicitly defined within the concept of *TrimByg-QC*.

The competences of the building workers must be developed to include also the assignments concerning quality inspection of own work. This type of human resource development could follow the lines of the company strategy, applied within health & safety (with a 'MTH school bus' visiting MT Hojgaard sites).

In addition to extending the competences of building workers *TrimByg-QC* does also aim at drawing on building workers' extensive (tacit) knowledge concerning appropriate and effective building production techniques. This goal implies collecting experiences and direct involvement of building workers in design questions to the benefit of the whole building process.

In order to establish accordance between efforts (product quality) and reward (piecework wage agreements) the possibilities of integrating quality aspects in the piecework wage system must be evaluated. It is crucial to involve the labour market parties in this development aspect. Another question of regulation in relation to *TrimByg-QC* are concerning the more general legal bindings, which may represent obstacles to for instance building workers' self-inspection. The principle of integrating the roles of the producer and the controller does of course represent a dilemma, as also noted by several interviewees.

Finally, *TrimByg-QC* is lacking a thoroughly prepared implementation strategy, building upon earlier experiences, change management and the qualities and characteristics of the parties at stake. The reflection of such conditions in the planning of the implementation process is of course central to the potential future success of the concept.

Thus, much work involving contributions from several professional disciplines obviously remains before *TrimByg-QC* is ready for widespread use. However, the philosophy of lean thinking in general and *TrimByg* in particular are in support of this effort.

## CONCLUSIONS

At present *TrimByg* in MT Hojgaard Ltd. has come quite far concerning the management of site production. However, the management of quality is one aspect not yet dealt with within the framework of *TrimByg*. In the above the authors of this paper have, considerably inspired by (Marosszeky et al. 2002), been describing ideas for a *TrimByg* tailored quality control system.

Under the designation *TrimByg-QC* the framework of a quality control system has been set up, based on elements of empowerment and rolling plans. The central aim has been to reduce reaction times in connection with registration of quality failures, and to widen the sense of duty among building workers towards the presupposed level of quality (cf. Tranfield et al. 1999). *TrimByg-QC* is supporting the general objective of integrating the experience-based knowledge of building workers in the design process, in order to improve the buildability of the building design. Furthermore, this QC system is operating with a ready report procedure for the dynamic prevention of building on top of defective building parts. This procedure lies in direct parallel with the principles of the last planner system (Ballard 2000).

The paper describes the development of a quality control tool, related to two work operations ('tamping of concrete elements' and 'realigning of floor slab panels'). The tool

was tested empirically on a construction site in Copenhagen City. Subsequent to the testing the involved building workers expressed widespread positive attitudes towards the system, whereas the site management showed more scepticism and argued for a certain level of management authority over quality control. Based on the experiences from this site testing, which has been documented in a master thesis at BYG•DTU, it is assumed that the *TrimByg-QC* system has a potential in general practise, provided that a number of external and internal conditions for its use are analysed and developed. Six of these focus areas have been identified and elaborated in the paper.

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