

# INTEGRATING PRODUCTION AND QUALITY CONTROL: MONITORING MAKING-DO AND UNFINISHED WORK

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## ABSTRACT

The lack of integration between production control and quality management has been pointed out as a common problem in the construction sector. This paper discusses the impact of this problem in the generation of waste that are typical in this sector, such as making-do, rework and uncompleted work. Based on that discussion, this paper proposes an integrated production and quality control method, which is focused on the elimination three waste categories: making-do, unfinished work, and work-in-progress. The method is divided in three modules: (a) identification and measurement of making-do events, (b) identification of informal packages, and (c) integrated production and quality control. The main contributions of this study are concerned with the understanding waste in construction, and the relationship between different types of waste.

## KEYWORDS

Performance measurement; waste; making-do; rework; unfinished work; production control

## INTRODUCTION

Ohno (1988), one of the seminal authors on the Toyota Production System, proposed seven categories of waste: unnecessary movement; waiting; defects; overproduction; inventories; unnecessary processing; and unnecessary transportation. It seems that the main role of existing classifications of waste is to call the attention of people to the most likely problems in a specific context, since not all waste is obvious: it “often appears in the guise of useful work” (Shingo, 1988).

Considering Ohno’s (1988) classification of waste as a reference, Koskela (2004) proposed making-do as an eight category of waste, suggesting that this problem is typical of the construction industry, and has not been observed in other industrial sectors. Making-do can be shortly defined as a reduction of performance due to the fact that a task is started or continued even if not all standard inputs are available (Koskela, 2004). This concept was partly inspired by the *complete kit* concept

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proposed by Ronen (1992): the set of components, drawings, documents and information needed to complete a given assembly, subassembly or a process.

Based on the concept of making-do proposed by Koskela (2004), a set of exploratory studies on the incidence of making-do in construction sites was carried out in Brazil (Formoso et al., 2011). Those studies have provided some insights on the limitations of planning systems in avoiding making-do, and also pointed out that this waste category can be considered as the root cause of other wastes, such as reduced safety, quality problems, work in progress and rework.

This paper explores one additional category of waste that seems to be very relevant in construction sites, named unfinished work. Such type of waste emerged from observations made in construction sites, which have attempted to investigate the impact of making-do and the causes of other types of waste, such as rework and work-in-progress. This investigation is part of a research project that aims to devise production control models that integrate quality and task completion control.

## **LITERATURE REVIEW**

According to Koskela (2004), making-do can be regarded as the opposite of buffering, since work starts without the necessary inputs (including inventory) for carrying out a task to completion. The same author points out that the high incidence of making-do in construction is not simply due to a failure of implementing a conventional managerial system, but it is rather due to the underlying concepts adopted: (a) the use of utilization rates as key performance measures; (b) push-type production planning; (c) top-down one-way communication system; and (d) thermostat control model. The potential consequences of making-do are more work-in-progress, and longer lead time, which lead to, among other causes, increase in the share on non value-adding activities, increase complexity of controls, decline in overall productivity, decline in worker's motivation, poor quality, and decline in safety (Ronen, 1992; Koskela, 2004).

In terms of practical results, it has been argued that the Last Planner System is an effective way for protecting production from upstream variability, and therefore avoiding making-do waste. This system is able to increase the reliability of short term planning by shielding planned work from upstream variation, and by seeking conscious and reliable commitment of labour resources by the leaders of the work teams involved (Ballard and Howell, 1998). However, the study of Formoso et al. (2011) indicated that the impact of the Last Planner system was relatively limited in the elimination of making-do. Partly, it was due to flaws in look-ahead planning that have been identified on previous studies on the implementation of the Last Planner system (Formoso and Moura, 2008). However, even when constraint removal was properly done, not all making-do was avoidable, since several making-do situations are caused by the lack of design of specific operations (Formoso et al., 2011)

One important insight that has emerged from the studies and discussions on making-do is the fact that much of the work in construction sites is carried out informally. It means that much of the work that is undertaken by the crews are not properly included in formal operational plans, neither formally released by any other mechanism. In previous studies on the implementation of the Last Planner system (Sukster, 2005; Formoso and Moura, 2008; Formoso et al., 2011), some additional evidences on the importance of informal work have been provided.

Sukster (2005) pointed out that, due to the lack of integration between production planning and control and quality management, part of the short-term plan work packages may not be properly inspected, but are assumed to be completed. For that reason, several fairly small tasks are left for the following week. These are usually related to the need of rework or work completion, and may contribute to the increase of work-in-progress. As a consequence, there may be a distortion in the PPC (percent of plans completed), since some of the packages that are assumed to be completed still need additional work in the following week (Sukster, 2005).

Most work packages included in short-term plans are new packages (Moura and Formoso, 2009). Very rarely, those small rework or finishing tasks are included in short-term plans. These packages tend to be carried out informally, and by nature have a large share of non value-adding activities, such as set up, moving, and removal of residues (Sukster, 2005; Formoso et al., 2011). Even in companies that have successfully implemented the Last Planner System, the total number of workers that are included in short-term plans do not correspond to the total number of workers on site. This is partly due to the fact that some of the crews are performing some of those rework or finishing tasks, or other non value-adding activities.

Surprisingly the literature on rework does not provide useful insights on understanding this type of waste. In fact, Viana et al. (2012) pointed out that a wide range of operational metrics has been used for measuring rework, such as quality deviations, non-conformity, order change by clients, defects, and repairs. Indeed, most papers on this topic do not discuss the cost components of rework.

This paper explores the connection between making-do and other types of waste that are strongly connected to informal work, such as rework, and work-in-progress. It is based on the assumption that those types of waste are strongly connected, and that this type of investigation may contribute to establish a set of waste categories that are useful for guiding the development of production control systems in construction.

## **RESEARCH METHOD**

This investigation involved the development of three empirical studies, carried out in two different companies. The first two studies took place in a large building company (company A), which has been active in the property market in the Metropolitan Region of Porto Alegre, in the South of Brazil for over 30 years. The third study was carried out in a small building company (company B) founded in 1980, located in the same region. Those two companies were chosen for the following reasons: (a) each one of them had a fairly effective production control system, strongly based on the Last Planner system; (b) both companies had well established ISO 9001 certified quality management systems, which comprised routine quality control checks in all their construction sites; and (c) both were interested in improving their production control system, based on Lean concepts and principles.

A Design Science Research approach was adopted, in which an artifact (the proposed method) has been devised, tested and refined along three case studies (Table 1). This method was divided into three modules: (a) identification of making-do waste; (b) identification of informal packages; and (c) integration between production and quality control. The main sources of evidence and data collection procedures are summarized in Table 2.

Table 1 - Description of the projects and scope of each case study

Case Study 1	Case Study 2	Case Study 3
- High-end residential project, two towers, with 19 and 20 floors. Four apartments per floor, ranging from 125 to 146 m <sup>2</sup> .	Mid-to high-end residential project, two 14-floor towers, 8 apartments per floor, ranging from 68 to 74 m <sup>2</sup>	Horizontal condominium, 238 semi-detached houses, divided into 31 blocks, with 6, 8, 10,12, or 14 units, 47,05m <sup>2</sup> or 56,8m <sup>2</sup> per housing unit
- Refine the identification of making-do waste module - Structure the identification of informal packages	- Refine the procedure for data collection and processing for the first two modules - Structure and implement the integration between production and quality control module	- Refine the identification of informal packages - Refine the integration between production and quality control module - Consolidate the development of the method

Table 2 - Main sources of evidence

Case study	1	2	3
Duration	10 weeks	8 weeks	7 weeks
Processes monitored	Structuring, Bricklaying	Bricklaying, internal wall plastering, ceiling plastering	Gypsum plastering,
Participant observation in planning meetings	5 weekly meetings, 1 look-ahead meeting	6 weekly meetings, 1 look-ahead meeting	5 weekly meeting, 1 look-ahead meeting
Analysis of documents	Weekly plans, control charts, quality management procedures, look-ahead plans		
Performance metrics	PPC, causes of planning failures, implementation of planning practices		
Direct observations	50 one to two-hour site visits	40 one to two-hour site visits	21 one to two-hour site visits
Interviews	Informal interviews with workers; Discussion of data with production managers, foremen		

## BRIEF DESCRIPTION OF THE PROPOSED CONTROL METHOD

### MODULE 1: IDENTIFICATION OF MAKING-DO WASTE

The identification of making-do events was based on a protocol that was similar to the one proposed by Formoso et al. (2011). Direct observations of each work package were made by the research team in site visits. If there was any indication of making-do, a set of data was collected, including: (a) a description of the event, (b) identification of the pre-requisites that were missing (or failures in upstream flows); and (c) possible impacts. The main references used for identifying making-do were quality management procedures (available for some of the processes), and health and safety standard requirements. Members of the crews involved in the tasks were questioned about the origin of making-do events, and on possible consequences. In case of doubts, data were shown to site managers and foremen, and their points of view were also considered. Therefore, the assessment of the causes and impacts of making-do was mostly based on the perception of workers and managers. Table 3 presents the categories of making-do considered in this investigation. One additional category was added in relation to the classification proposed by Formoso et al. (2011): changes in the sequence of tasks.

Table 3 – Categories of making-do considered in this study

CATEGORIES	GUIDING QUESTION
Access/movement	Is the space available for the movement of workers adequate, as well as the means or paths used by them to move on site?
Adjustment of components	Are there any unexpected adjustments that are necessary for installing building components or elements?
Working area	Is the working area suitable for performing a task and supporting activities?
Storage of materials or components	Are materials and components properly disposed in places that have been prepared for storing them?
Equipment/tools	Have the equipment and tools used in the task been created or adapted?
Water and electricity supply	Has the water and electricity infrastructure used in the task been created or adapted?
Protection	Are the personal and collective protective equipment available and in good conditions?
Sequencing	Has the sequencing of tasks previously planned been followed?

Regarding the failures in up-stream flows, eight categories were adopted, similar to the work of Formoso et al. (2011): the seven flows proposed by Koskela (2000) plus an additional category, named workspace infrastructure, which was included due to its high impact on this type of waste. Making-do events were also classified as positive or negative improvisations. A positive improvisation happened when the workers introduced some kind of innovation as a way to overcome the lack of resources. The improvisation was negative if it resulted in waste. In that case, there was a brief evaluation of its impact, using a probability versus severity matrix (Figure 1), similar to what is often done in safety management. The assessment of impact was carried out at the weekly short-term planning meetings, when the making-do events were discussed. Only high-risk events were considered in data analysis.

Probability	Severity				
	Very high	high	Moderated	Low	Minor
Extremely remote			1,2		
Remote		4,5			
Unlikely					
Likely	3				
Frequent					

Figure 1 - Probability of occurrence versus severity of the impact matrix

## MODULE 2: IDENTIFICATION OF INFORMAL PACKAGES

This module consisted of monitoring the occurrence of informal work packages, classifying them according to their nature, and measuring the amount of work involved in their execution. An informal package was defined as a package that has not been planned at the weekly meeting, but which ends up being executed during that week. Two metrics were used for measuring the incidence of informal work packages: (a) percentage of informal work-packages in relation to the total number of work-packages; (b) percentage of man-hours spent in informal work-packages in relation to the total number of man-hours – this indicator was based on a rough estimate of man-hours for each work-package, rather than on precise productivity measurements.

Moreover, informal work-packages were classified into three categories:

- Rework: tasks related to the correction of previously executed work;
- Work completion: include tasks that were necessary due to the fact that a work-package had not been completed in the previous week. It includes different types of tasks, such as finishings, cleaning, and set-up;
- New work: consist of new work packages that had not been planned for that week, or batches that were planned but did not follow the planned sequence;

### **MODULE 3: INTEGRATED PRODUCTION AND QUALITY CONTROL**

This module consisted of aligning task completion and quality control, so that when the short-term planning meeting is carried the completed work packages have their quality inspected. This type of integration depends on the way work packages and quality inspection batches are defined. For some tasks, quality control should be allowed independently of the size of the work package. In other cases, the work package should be defined according to the quality control batch. It is also necessary to perform quality inspections (either internal or external) in weekly cycles. This requires a thorough revision of the quality management system, and also the involvement of quality managers or other people directly involved in quality control in look-ahead and short term planning meetings. Their role is to remove quality management related constraints, and also to bring into discussion occasional quality problems to the planning meetings.

The implementation of the integrated production and quality control process starts with the definition of the work package in the weekly plan. As mentioned previously, this package should have an inspection batch associated to it. This definition should be done jointly with team leaders in order to have them committed with the weekly goals. During the week, the team leader informs that the package has been concluded and requests a quality inspection. If the package has not been concluded with quality and there is still time for correction during the week, the same crew will finish it. However, if the package has not been concluded with quality at the end of the week, it should be re-planned, but as a formal rework package.

### **CASE STUDY 1**

Figure 2 presents the relative importance of each category of making-do in case study 1, after the application of the probability versus severity matrix. The change in sequence category represented approximately 20% of the total number of making-do events. It means that a frequent improvisation made by the teams in the absence of prerequisites, to change the sequence of construction tasks. Figure 3 presents the percentage of informal packages in relation to the total number (formal + informal) of work packages. This percentage is highly variable, but it can reach more than 80% of work packages. Of course, informal work packages tend to be much smaller than the formal ones, since they often comprise rework or finishing tasks. A secondary effect of informal work packages is that their constraints are not usually removed systematically, since those packages are not formalized in plans, causing additional making-do. In fact, the informal packages in those two construction stages (structure, and bricklaying) often hindered the planning and control of access to work,

circulation or storage areas for materials, due to dispersion of the teams on site. It is worth pointing out that the effect of rework and finishing (or completion) work packages was very similar. They simply required a crew (or a worker) to move back to a previous workplace, and make a fairly small package, sometimes taking more than one visit, due to the lack of preparation. For this reason, this investigation proposes a general waste category named unfinished work.

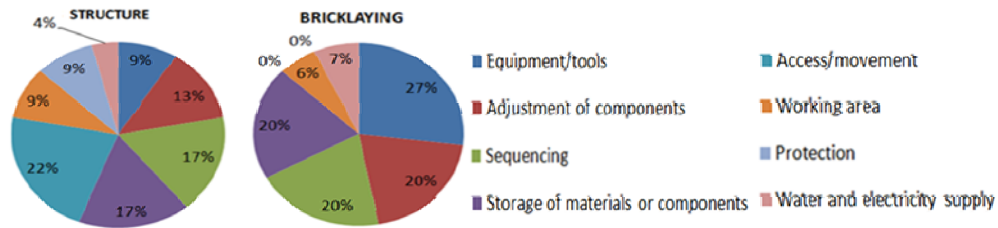


Figure 2 - Frequency of making-do events

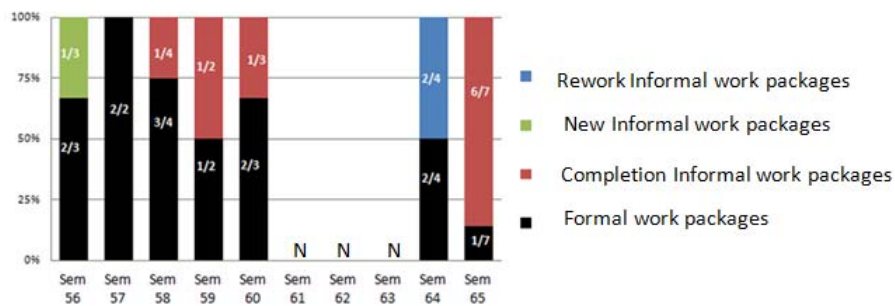


Figure 3 - Percentage of informal packages in the plastering process

## CASE STUDY 2

Figure 4 presents the relative importance of each category of making-do for three processes. In case study 2, the percentage of change in sequence category was again one of the highest ones, particularly in the plastering processes. This is partly due to the fact that finishing activities tend to allow more flexibility in terms of sequencing. Figure 5 presents the distribution of causes of making-do, according to upstream flows. In most cases, there were multiple causes of making do, i.e. this type of waste was caused by failures in more than one upstream flows. Regarding the information category, the team leaders pointed out the absence of information about the quality approval of the preceding activity as one of the most frequent problems.

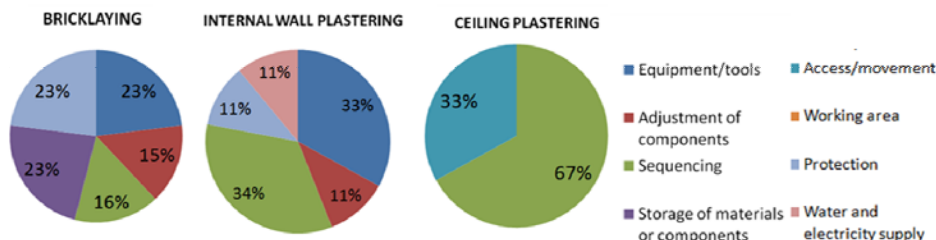


Figure 4- Frequency of making-do events

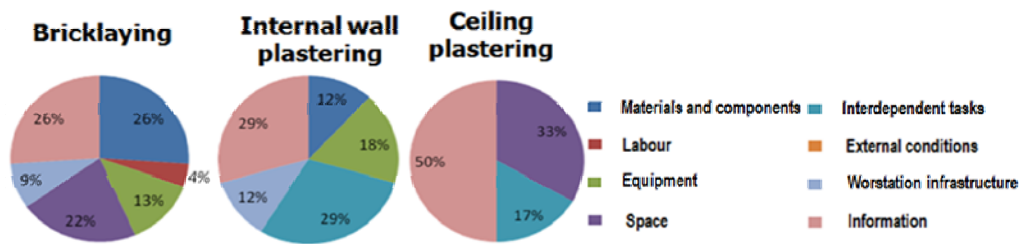


Figure 5- Causes of making-do waste: ineffectiveness of upstream flows

Figure 6 presents the main impacts that making-do waste. Similar to the study by Formoso et al. (2011), material waste was one of the main impacts, especially in the bricklaying process. A large percentage of the impacts, in the perception of crew leaders were problems related to poor quality: quality loss, rework and unfinished work. This is confirmed by the large number of informal packages related to rework and completion of previous work (Figure 7).

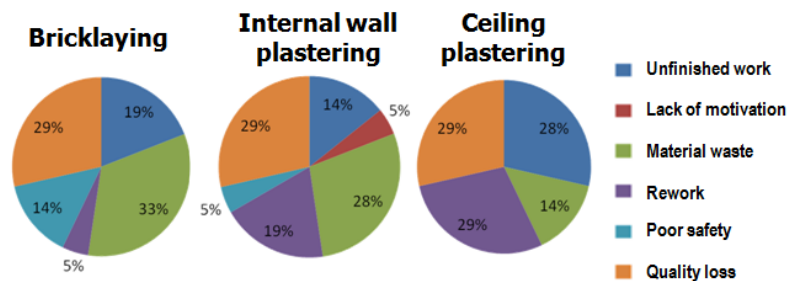


Figure 6- Impacts of making-do

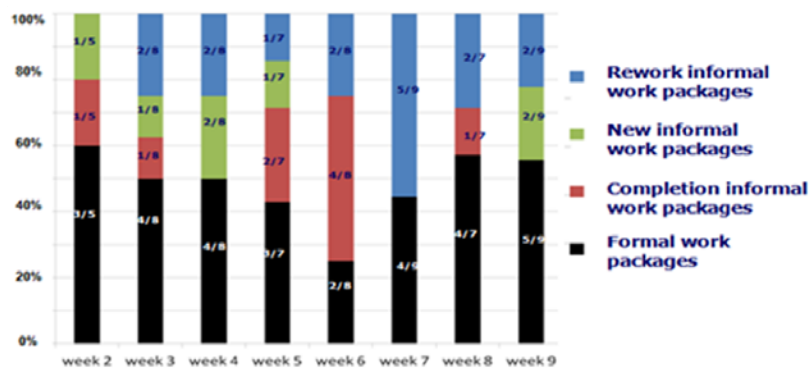


Figure 7- Percentage of informal packages

### CASE STUDY 3

Figure 8 presents the relative importance of each category of making-do for the gypsum plastering processes. Similar to the previous case studies, the “change in sequence” category stood out as the most frequent one. In addition, there was a close connection between that making-do category and the incidence of rework packages and work completion informal packages (Figure 9). It is worth pointing out that, differently from the company involved in Case Studies 1 and 2, in this company most rework and work completion packages were formalized in short term plans. In this



study, it was possible to monitor the amount of working hours spent in different types of work packages. Figure 10 presents that 71% of the man-hours were spent in work packages formally planned, while 19% were spent in rework activities and 10% were distributed between new work packages and work completion packages. Figure 11 presents the root causes for the non-completion of the packages with quality, which were classified into three categories: (a) preceding task, (b) lack of availability of standard inputs, and (c) workforce related problems. The preceding task category comprised cases in which the preceding work had not been concluded, or had been concluded without compliance to quality standards.

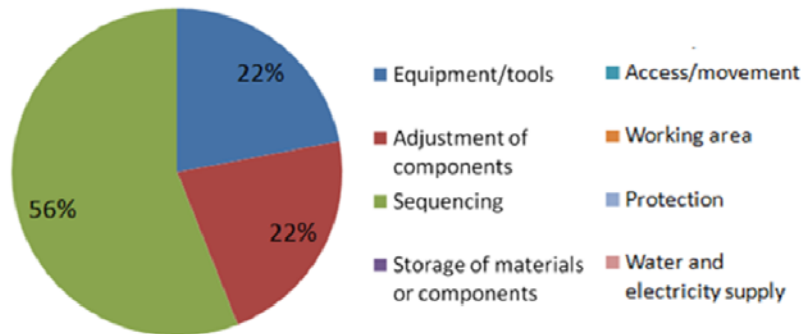


Figure 8- Frequency of making-do events

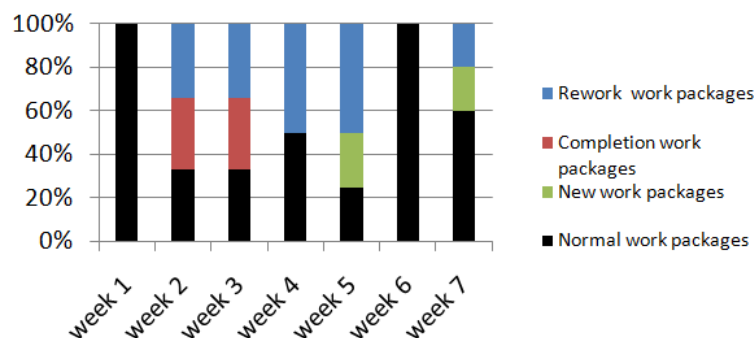


Figure 9- Percentage of informal packages in gypsum plastering process

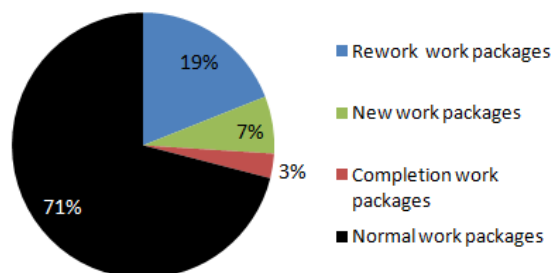


Figure 10- Distribution of labor according to the work packages

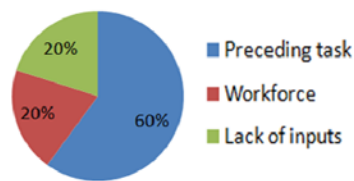


Figure 11- Causes for the non-completion of work packages with quality

## CONCLUSIONS

The main contribution of this case study is to point out the importance of a set of waste events that are strongly related to the lack of quality in construction processes, including rework and uncompleted work packages. Such events are strongly connected to informal work in construction sites, and are often caused by making-do. For devising the method it was necessary to establish a clear operational definition of different types of waste, such as making-do and rework.

An additional category of waste has been proposed, named unfinished work, which includes both rework and small finishing tasks that are left behind when a crew leaves a workstation. Both events bring similar consequences in the construction process: informal work, increase in work-in-progress, increase in the share of non value-adding activities. Those small work packages are usually neglected in medium and short-term planning meetings. As such packages are not formally planned, they tend to cause making-do events, and limit the implementation of systematic quality inspections.

Another important conclusion of the study was the identification of a new category of making-do waste, named “change in the work sequence”. This category seems to be more common in finishing processes (such as plastering). Although this has not been investigated in this research project, it is likely that this category tends to occur more often in traditional construction processes, when no formal standards exist. Moreover, this type of making-do seems to have a strong connection with unfinished work. In fact, it was observed in the case studies that, when there is a lack of standard inputs, the crews often change the task sequence, and leave the workstation without properly finishing the work package. In some situations, changes in the sequence can result in poor quality, which might affect subsequent work. This might create the need for rework at later stages of the project (e.g. painting).

## ACKNOWLEDGEMENTS

The authors would like to acknowledge the contribution from several colleagues that have participated on the 3<sup>rd</sup> Workshop “Understanding Waste in Construction” (see <http://prosjekt.uia.no/uwc/>), carried out in Frankfurt, Germany, on the 4<sup>th</sup> and 5<sup>th</sup> of February 2013, who provided an important feedback for the development of this paper.

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