# AN EXPLORATORY STUDY ON THE MEASUREMENT AND ANALYSIS OF MAKING-DO IN CONSTRUCTION SITES

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## ABSTRACT

Making-do has been pointed out as a major cause of waste in the construction industry. It refers to a situation in which a task starts without having available all the inputs required for its completion. Those inputs refer not only to materials, but also to other resources, such as machinery, tools, personnel, external conditions, information, etc. By contrast, the literature points out that improvisation is a ubiquitous human practice even in highly structured business organisations, and play an important role when rules and methods fail. This paper presents the concept of making-do as a form of waste, and proposes a method of measuring it as well as identifying its main causes, and its main impacts in the performance of construction projects. Data from two exploratory case studies carried out in construction sites are used to illustrate the utility of that concept. In those studies, making-do waste was identified, and categorized according to their causes and main impacts. This was done by interviews with construction workers and foremen, direct observation of construction processes on-site, and participant observation in planning meetings. The results provide some insights on the limitations of planning systems in avoiding making-do, and also pointed out the high negative impact of this type of waste in site safety.

## KEY WORDS

Making-do, Improvisation, Waste, Planning and control, Performance measurement

## INTRODUCTION

In general, a very high level of waste is assumed to exist in construction. Although it is difficult to systematically measure all wastes in construction, studies from various countries have confirmed that waste represents a relatively large percentage of production costs. A wide range of measures has been used for monitoring waste, such as excess consumption of materials (Formoso et al. 2002), rework (Hwang et al. 2007), defects (Josephson and Hammarlund 1999), non-productive time (Horman and Kenley 2005), and work-in-progress (Yu et al. 2009; Bashford et al. 2003). Measuring waste is an effective way to assess the performance of production systems, because it usually allows areas of potential improvements to be pointed out, and the main causes

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of inefficiency to be identified (Ohno 1988). 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).

This paper is focused on making-do, a category of waste proposed by Koskela (2004), defined as a reduction of performance that result from the fact that a task is started or continued without all its standard inputs. This concept was partly inspired by the complete kit concept proposed by Ronen (1992): the set of components, drawings, documents and information needed to complete a given assembly, subassembly or a process.

Although no direct measurement of making-do in construction has been reported in the literature, there are some indirect evidences that this type of waste can be very high in construction. Several studies on the implementation of the Last Planner System (Ballard 2000; Moura and Formoso 2008) pointed out that a major cause of planning failures, measured by the PPC (percentage of plans completed) metric, is the poor management of upstream processes, which makes it impossible to complete tasks included in short term plans due to the lack of inputs.

Making-do has a strong relationship with the concept of improvisation, since when people face difficult and uncertain situations they may use whatever resources they have at hand to reach their goals, or even redefine their objectives in line with the resources available (Cunha 2004). The literature points out that improvisation is a ubiquitous human practice even in highly structured business organisations, and that it is an important source of improvements and innovation (Moorman and Minor, 1998; Ciborra 1998; and Verjans 2005).

This paper proposes a method for measuring making-do as a form of waste to be controlled in construction sites. It is based on two exploratory case studies in which making-do events were observed in construction sites, and their main causes and impacts were identified. The data collected in the case studies are used to illustrate different types of analyses that can be carried out.

## MAKING-DO AS THE EIGHTH CATEGORY OF WASTE

Koskela (2004) proposed making-do as an addition to the seven categories of waste proposed by Ohno (1998). In Ohno’s classification, inventories and work-in-progress have been presented as the main types of waste, mostly due to the fact that he had the Toyota Production System in mind, where this type of waste tends to be very important. By contrast, according to Koskela (2004), making-do can be regarded as the opposite of buffering, since work starts without the minimum amount of resources (inventory) for carrying out a task to completion.

Regarding the causes of the lack of inputs for starting a task, Ronen (1992) pointed out three main problems: (i) based on the assumption that overall productivity increases if all workers and equipment have a high utilization rate, managers usually prefer to start a task as soon as possible; (ii) some clients expect the job to start as soon as possible, based on the belief that the task will also be completed earlier. This is usually due to the lack of trust that the supplier will deliver their tasks on time; and (iii) if the number of components to be assembled is very large, and if these are not properly allocated in assembly levels, production control becomes difficult.

By contrast, Koskela (2004) suggests that the high incidence of making-do in construction is not simply the failure of implementing a conventional managerial system, but it is rather due to the underlying concepts adopted: (i) the excessive concern with utilization rate is directly related to the fact that the managerial focus is on value-adding (transformation) activities; (ii) variability in task execution and upstream flows are often neglected and not properly managed; (iii) the thermostat model based on the measurement against a standard performance may provide wrong incentives to managers; and (iv) the conventional one-way top-down communication is not sufficient for managing highly complex production systems.

The potential consequences of making-do are more work-in-progress, and longer lead time, which lead to, among other causes, the 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).

Ronen (1992) provides a set of practical guidelines on how to implement the idea of complete kits. Most of them are concerned with improving production planning and control, especially the management of upstream flows. A fairly simple way of dealing with this problem is to apply completeness checking tools, such as 4M (manpower, machines, materials, and methods), which is often mentioned by the Lean Thinking community as a way of improving predictability and consistent availability of resources (Smalley 2009). However, neither Ronen (1992) not Smalley (2009) emphasise the complexity involved in managing upstream flows. Firstly, the availability of inputs cannot always be assessed by a yes or no question: inputs may be available, but on a non-optimal or non-standard basis (Koskela 2004). Secondly, there seems to be a much larger variety of inputs than pointed out by those two authors. Koskela (2000) stated that construction consists of assembly tasks involving a large number of input flows, and suggested a comprehensive classification of seven types of flow: design, components and materials, workers, equipment, space, connecting works, and external conditions.

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). At the medium term level, the prerequisites of upcoming assignments are systematically identified and proactively made ready, aiming to ensure that the necessary inputs, such as materials, information and equipment, are available (Ballard, 2000).

## IMPROVISATION AS A SOURCE OF INNOVATION

The negative connotation of making-do as a form of waste contrasts with the discussion in the literature about the role of improvisation in the management of organisations. Cunha et al. (1999) defines improvisation as the conception of an action as it unfolds, by an organisation or its members, drawing on available material, cognitive, affective and social resources. According to Ciborra (1998), improvisation is not something only to be used when there is an organizational failure, but it is part of everyday behaviour: it is regularly deployed when there is a gap between standard operating procedures and what is considered to be feasible in daily work. The level of improvisation tends to increase when events are unpredictable or there is a need for fast action (Cunha 2004).

Improvisation is a local, contextual, and sudden process that cannot be thought outside the specific situation where it appears (Cunha 2004). It is the result of the highly situated and fragmentary nature of knowledge, which cannot be efficiently communicated to a central board capable of integrating it before issuing orders (Ciborra 1998). Even written, formal instructions may be interpreted by experienced workers not as a pre-planed way to solve a problem or execute an action, but as an input to an unspecified problem to be addressed (Ciborra 1998).

Improvisation can be performed both at the managerial and operational levels, both individually and by teams of people (Cunha 2004). However, it is very different from regular improvement efforts: in contrast to the idea of slow judicious decision, improvisation is sudden, not expected, nor planned for (Ciborra 1998). Therefore, improvisation has been presented in the literature as something natural to human beings, part of everyday work, as well as an important source of improvement and innovation, provided that it is performed by experienced and qualified people. By contrast, the French word *bricolage* (tinkering in English) is often used to describe a different type of improvisation, which refers to adjusting or repairing damage of mistakes previously made or to solve problems that were caused by bad decisions made earlier (Verjans 2005). Cunha (2004) emphasizes that *bricolage* is about making the best out of the limited resources available at a given moment to solve unanticipated problems.

There is clearly a strong connection between making-do as a form of waste and the concept of *bricolage*. As discussed previously, making-do is a consequence of the poor management of upstream processes, which may result in the execution of tasks under sub-optimal conditions. However, it is also reasonable to expect that there are many situations in which the crew involved devise new ways of carrying out the task, using the limited resources available. People involved may even redefine its objectives according to the existing resources, such as, for instance, downgrading the quality or safety requirements for performing a task.

## RESEARCH METHOD

### RESEARCH DESIGN

This investigation involved the development of two case studies, which were carried out in different companies. Both case studies involved monitoring the production planning and control process, and the direct observation of making-do waste in construction sites. The two companies were both medium-sized construction firms and were chosen mainly because they had a fairly well developed production management system. Moreover, they were interested in the results of this study since they perceived it as an opportunity to eliminate some safety and quality related problems. Their production planning and control system contained several elements of the Last Planner System. Also, they had certified quality management systems, and fairly well structured safety management systems. Consequently, in each of them there was a set of typical planning documents which were expected to be used as references to compare with the actual work on site, in order to identify making-do waste.

The main sources of evidences were: (i) participant observation in look-ahead and short-term planning meetings; (ii) direct observation of making-do events on site; (iii) analysis of project documents, such as production plans, and quality management procedures; and (iv) unstructured interviews with managers, foremen, and workers. Some of these interviews were made at the site with the aim of clarifying the making-do event, in terms of causes and possible impacts. There were also some interviews and discussions with managers with the aim of getting their perceptions on the data collected. Table 1 summarizes the effort involved in data collection.

Case study A was undertaken in a 16-floor, 20,000 m² office-building project. In this study, the direct observation of making do waste started in a fairly unstructured way. Based on the data collected, and on discussions with some of the managers, criteria for categorizing data were gradually devised. At the end of this study, a database of making-do cases was created. The aim case study B was to test the method outlined in the previous study. It was carried on in a 10-floor, 32,000 m² garage-building project during a 5 week period. Data collection was much more structured, based on the criteria defined previously.

Table 1 – Main sources of evidence

| Case study | A | B |
|---|---|---|
| Duration | 17 weeks | 5 weeks |
| Participant observation in planning meetings | 13 weekly meetings and 9 look-ahead-meetings | 4 weekly meetings |
| Analysis of documents | Work-flow plan, Look-ahead plans, weekly plans, control charts, quality management procedures | Look-ahead plans, weekly plans, control charts, quality management procedures |
| Performance metrics | PPC, causes of planning failures | PPC, causes of planning failures |
| Direct observation on site | 15 one to two-hour site visits | 42 one-hour visits |
| Interviews | Informal interviews with work-force<br>Discussion of data with production managers, foremen | Informal interviews with work-force<br>Discussion of data with production managers, foremen |
| Number of making-do cases | 121 | 224 |

## DEVELOPMENT OF THE PROTOCOL FOR OBSERVING MAKING-DO

In the first case study data collection was based simply on making-do events. During the site visits, most crews on site were observed, and, if there was any indication of making-do, a set of data was collected, including (i) a description of the event, (ii) pictures (when possible); (iii) process involved; (iv) possible causes of making-do; (v) person or team responsible for the decision of improvising; and (vi) whether making-do was an isolated event or a continuous situation.

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 in which making-do was observed were questioned about the origin of the problem, and on possible consequences. In case of doubts, data were shown to site managers and foremen, and their point of view was also considered. Additionally, some making-do events were brought for discussion at weekly planning meetings. The data was analysed, taking into account existing performance measures, and production plans, especially the lists of constraints from look-ahead plans. Therefore, the assessment of the origin and impacts of making-do was mostly based on the perception of workers and managers.

Along the first case study, the database of making-do events was revised several times, mainly due to the refinement of the concepts adopted. Before starting Case Study 2, the final version of the protocol for data collection was established. This was divided into three main parts: (i) classification of making-do waste, (ii) investigation of its origin; and (iii) possible impacts. Additionally, the type of feedback provided by the observation of waste was also identified. Table 2 presents the categories of making-do that have been adopted in this study. It excludes making-do situations that are often identified through production control in the Last Planner System, such as the non-completion of work packages due to insufficient material or labour. Table 3 presents the criteria that was adopted for classifying waste, according to upstream flows that are not effective. Such criteria was based on the idea of seven flows proposed by Koskela (2000), but had an additional category, named temporary facilities, included due to its high impact in making-do waste.

In the second case study, this protocol was tested during a period of four weeks. One important different between this and the previous case study was that in the former data collection was based on weekly plan work-packages, rather than simply making-do events. This made it possible to analyse the extension of making do in terms of number of packages affected, and compare the incidence of making do in different processes.

Table 2 – Categories of making-do waste

| 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? |
| **Electricity and water supply** | Have the facilities for electricity and water supply used in the task been created or adapted? |
| **Protection** | Are the personal and collective protective equipment available and in good conditions? |

Table 3 – Categories of making-do according to failures in upstream flows

| PROBLEMS | DESCRIPTION |
|---|---|
| **Information** | Design drawings, plans, studies or procedures that provide the necessary information for the execution of work packages are not available, are not clear, are incomplete or unknown. |
| **Materials and components** | Have not been ordered or delivered, or are not adequate to the task in terms of quality and quantity |
| **Labor** | Is not available in terms of quantity or skills required |
| **Equipment or tools** | Equipment and tools are not available, are not working, or are not adequate to the task |
| **Space** | There is not enough space for working, no access to the working area or to the materials stored. |
| **Interdependent tasks** | Interdependence between tasks makes it impossible to start subsequent activities. |
| **External conditions** | Inclement weather, including wind, rain or extreme temperature |
| **Temporary facilities** | Temporary facilities are not adequate for the execution of work packages, including electricity, plumbing, health and safety equipment, inventory areas, and scaffolding |

## RESULTS

### CASE STUDY 1

Figure 1 presents the relative importance of each category of making-do in each case study. In both, lack of adequate access to the work place should be pointed out that the most frequent type of making do (36% and 33% in cases A and B, respectively). It is also worth pointing out that in Case Study 1 three categories (protection, electricity and water supply, and equipment/tools), which can be related to the necessary infrastructure for the crews on site, corresponded to 44% of making-do cases. In Case Study 2, the inadequacy of working areas was the second most frequent problem (22%).

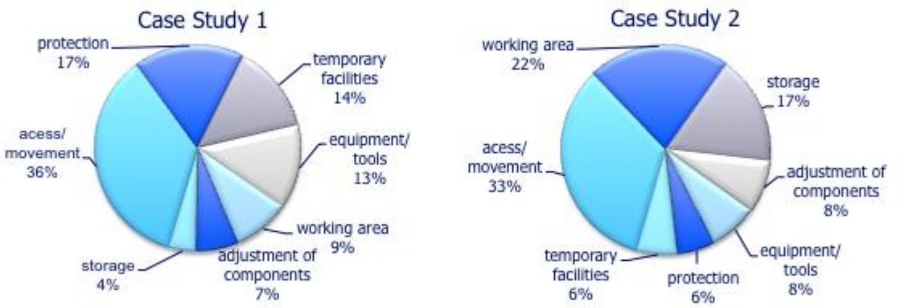


Figure 1 – Total incidence of making-do events

Figure 2 presents the main causes of waste, considering the upstream flows that have not been effective. The sum of percentages is larger than 100%, since each making-do event may have been originated by more than one problem in upstream flows. The two case studies had similar results, since the five main problems were the same, with the same order of importance: (i) temporary facilities, (ii) space, (iii) information, (iv) equipment and tools, and (v) materials and components. Three of these problems (i, ii, and iv) were related to the poor management of physical flows.

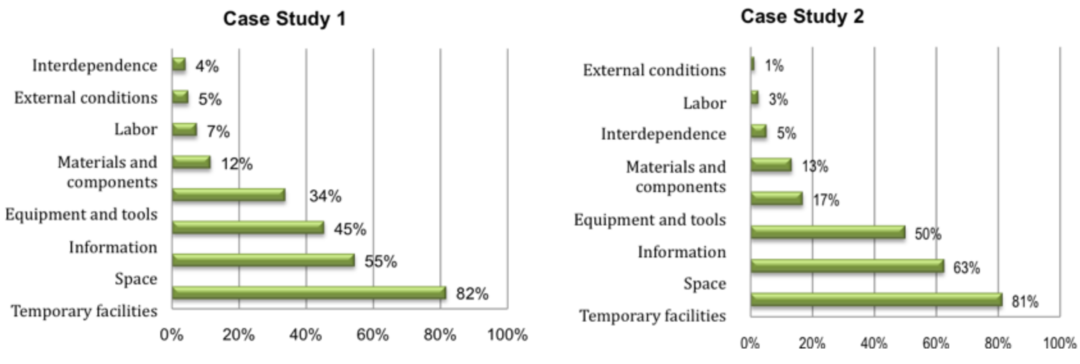


Figure 2 – Causes of making-do waste: ineffectiveness of upstream flows

Figure 3 indicates the main impact caused by making-do events. Again, the sum is larger than 100% since each making-do event may have more than one impact. These results are limited by the fact that they are based on the perception of workers and managers, and limited by the concepts they are used to deal. For instance, none of them mentioned the increase of work-in-progress, pointed by Ronen (1992) as a major consequence of the lack of standard inputs. The three main impacts pointed out in both sites were the same: poor safety, material waste, and reduced motivation. The high impact on safety is clearly due to the improvisations that are made due to poor access to workstations, inadequate working areas, and unsuitable temporary facilities.


Figure 3 – Possible impacts of making-do

In terms of feedback provided (Figure 4), the managerial system that is more capable of preventing the incidence of making-do waste is production planning and control. Although many problems were related to safety, the main improvement opportunities were concerned with improving the effectiveness of constraint analysis at the look-ahead planning level, combined with the systematic application of operations design – that includes 4D modelling, prototyping, and first-run-studies

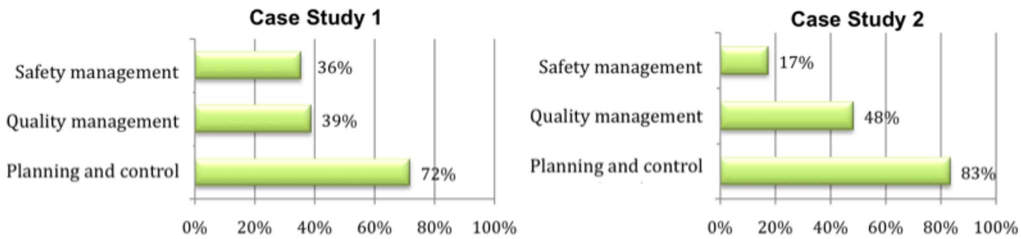


Figure 4 – Improvement opportunities identified in the analysis of making-do cases

Finally, Figures 5 establishes a connection between the incidence of making-do and the number of work packages. It indicates that between 45% and 61% of packages had at least one type of improvisation. This problem was observed both in packages that have and have not been completed. It means that, from one hand, interruptions may be caused in work-packages due to the lack of inputs, but, from the other hand, it seems that improvisation is often used as a mechanism to complete tasks when not all inputs are available. Considering only the packages that had making-do, the average number of these events was 2.5.

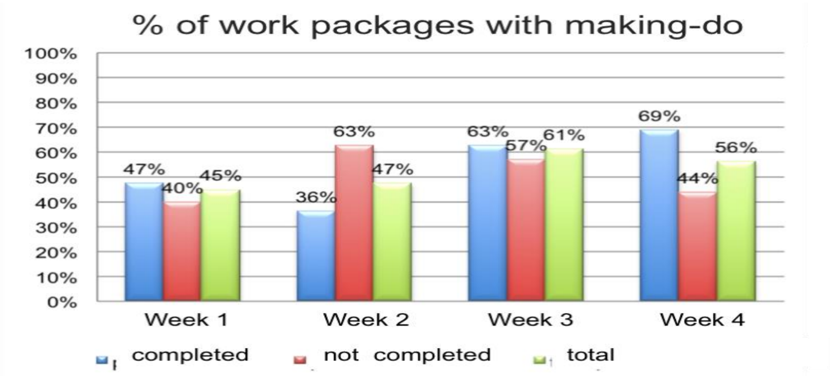


Figure 5 – Number of work packages with improvisations

## CONCLUSIONS

The main conclusions of this exploratory study are concerned with the utility of the concept of making-do, and with some preliminary measures of this type of waste in construction sites. Although, the available data cannot be considered as representative of the construction industry, there are indications that, similarly to other categories of waste that have been measured in this sector, making-do is ubiquitous in construction sites.

In both case studies, the most frequent types of making-do were related to the access and availability of working areas, and to the necessary infrastructure in terms of temporary facilities, protection, and equipment and tools, that need to be provided to the crews. In fact, the main causes of making-do were the ineffectiveness in providing adequate temporary facilities, poor management of working space, and the lack of information. The main impacts were also similar in both sites: material waste, poor safety conditions, and reduced motivation.

Although, both companies were experienced in the application of the Last Planner system, its impact was relatively limited in terms of eliminating making-do. Partly, it was due to flaws in look-ahead planning. Similar to what has been pointed out in previous studies (Moura and Formoso (2008), both companies have had only partial success in the implementation of constraint removal. 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, which could be effectively done through process improvement initiatives, including 4D modelling, prototyping, and first-run-studies.

Finally, it is important pointed out the limitations of the protocol that was proposed. It still needs to be further developed, and used in combination with other indications of making-do, such as planning failures, and measures of work-in-progress.

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