

REDUCING FIT-OUT TIME IN A NETHERLANDS HOUSING PROJECT

Ype Cuperus¹, Hans Wamelink² and Glenn Resodihardjo³

ABSTRACT

In the Netherlands the fit-out time of newly built row houses in lots of 50 to 100 units can be eleven weeks. On such projects a large number of subcontractors is common (40 to 50) and this adds to the complexity of the construction process. This paper describes key data of a standard fit-out procedure of a project of 82 dwellings, with an average fit out time of 35 days. Two dwellings were singled out for a pilot project with a target fit-out time of two weeks. This project in general provided for many consumer options; the two dwellings represent different levels of equipment and finishing. In a Last Planner™ System inspired planning session the planned fit-out time was reduced to two weeks. For this pilot the subcontractors created ad hoc team combinations that worked as multi skilled teams in order to reduce the number of decision-making points. Materials were bundled per unit per day. The time planning unit used was two hours. The real fit-out processes are described as cases, with special attention to external interferences and internal non-value adding activities. The fit-out time was reduced from 35 to 11 and 19 days for the respective dwellings.

Although there were many hitches in the process caused by the different way of working the pilot demonstrated that the fit-out time per dwelling could be reduced considerably. The tradesmen from different subcontractors were asked to collaborate crossing the traditional disciplinary borders, this was experienced as positive. The main contractor was positive about planning the work on two-hour time slots and has decided to do a second test with a larger number of units.

KEY WORDS

Last Planner System; Cycle time; Multi-skilled teams; House building.

INTRODUCTION

In the Netherlands the fit-out time of newly built row houses in lots of 50 to 100 units can be eleven weeks. A large number of subcontractors (40 to 50) is not uncommon and adds to the complexity of the construction process. In order to make the houses competitive the buyer can choose from many options of finish and equipment. Introducing a two-tier building process with a separate base building and fit-out as advocated by the concept of Open Building (Cuperus, 2001) would therefore make sense. This however is not in line with prevailing traditions of a construction process organized along lines of disciplines and subcontractors each organization contributing across the boundaries of different levels of intervention: they operate on the base building as well as on the fit-out level. For the subcontractor it is one continuous

¹ Assistant Professor Architectural Engineering, Department Building Technology, Faculty of Architecture, Delft University of Technology, Phone +31 15 278 4646, y.j.cuperus@tudelft.nl;

² Professor Design and Construction Management, Department Real Estate and Housing, Faculty of Architecture, Delft University of Technology, Phone +31 15 278 4159, j.w.f.wamelink@tudelft.nl;

³ Master Candidate Design and Construction Management, Department Real Estate and Housing, Faculty of Architecture, Delft University of Technology, Phone +31 6 2452 2804, glennresodihardjo@casema.nl;

project. Jobs are not subcontracted according to levels of decision-making (one contractor for the base building and one contractor for the fit-out) rather it is done according to traditional disciplines and skills. The effective integration of production and design development of construction systems needs many more skills to complete a dwelling efficiently. This paper is based on the hypothesis that using a multi-skilled team of five for the fit-out would reduce the spaghetti-like complexity of coordination, as coined by Van Randen (1976) which in turn is the first step to reduce waiting time, hand over time and thus fit-out time, and ultimately waste. This study builds on Ballard's presumption that Even Flow Production can be established by introducing multi-craft teams responsible for specific systems and components of a house. The teams should overlap activities, reduce activity durations through time studies and reduce work-in-progress through the development of multi-skilled workers (Ballard, 2001).

THE PROJECT

This paper describes key data of a standard fit-out procedure of a project of 82 dwellings, built for two clients, respectively 44 dwellings and 38 dwellings (Figure 1). Depending on size and finishing the prices range from €275,000 to € 325,000 (US\$ 350,000 to US\$ 400,000). In terms of annual turn over Dura Vermeer Bouw is the seventh largest building contractor in the Netherlands and is the main contractor of this project. For this project 51 contracts with sub-contractors were let. The project consisted of nine rows of detached houses, row sizes varying from eight to twelve dwellings with a total of eight different dwelling types. The buyers had a choice of a series of options in the design and finish of their dwellings. In fact all units were different; this project represented mass customization within a traditionally organized construction process.



Figure 1: artist's impression and construction site

BUILDING METHOD

The dwellings are founded on concrete piles and in-situ poured beams. The ground floor consists of insulated precast floor elements. The load bearing and house dividing walls were made of in-situ poured concrete using tunnel formwork, with embedded plastic conduits for electrical wiring. The floors were finished with self-levelling anhydrite topping, inner partitions were made of sand-lime blocks; the facades were closed with timber frames with a thermal insulation of 10 cm of mineral wool, with an interior finish of two layers of plasterboard and are externally finished with an outer cavity brick skin. The aluminium windows are fitted with double pane glazing. The

buildings have a pitched roof covered with concrete roof tiles. All dwellings are equipped with individual central heating systems with water-filled radiators and mechanical ventilation.

All disciplines moved through the dwellings sequentially. 'Building construction practice reveals the existence of many (...) single-line production systems termed "parades of trades"' (Tommelein et al, 1999). Some disciplines such as the electrician had to return a couple of times, to run the wires through the conduits and then to mount the switches and power-points. Other disciplines delivered work which required curing or drying time (floors, wall rendering, paint), resulting in waiting time for others. This forced small job subcontractors to employ their teams on different projects, creating complex interdependencies with other projects out of the control of the subcontractor. It is not uncommon that subcontractors plan their work a couple of days later than the nominal time that the dwelling is available, thus compensating for the possibility that the an earlier discipline is not ready on time. In this way it took seven weeks or thirty-five days to complete one dwelling. As part of the research project the times of all activities were measured. It became clear that without waiting time there were sixteen days of productive work, rather than the thirty five used, thus there were nineteen days of waiting.

User preferences resulted in different dwellings, this makes it hard to create a routine of repetition. There was no systematic quality check after each subcontractor completed his job. Hence if the next subcontractor found a working environment that did not meet the preconditions to start this generated a report. This method resulted in an average of eight building repair points per dwelling.

Before the final handover check for a dwelling by the client the contractor normally schedules a pre-delivery control check two weeks before the key handover with a representative of the client. This allows the contractor to fix building errors prior to occupancy and prior to the final inspection with the client.

Traditionally a distinction is made between the load-bearing structure and roof construction, this is seen as a split between the work of the rough trades and the other activities by the finer trades, which require a clean and dry environment. These jobs are then subdivided and subcontracted in order to get the lowest price. Table 1 shows that in the traditional construction process eighteen subcontractors were utilized. In the pilot dwellings utilizing multi-skilled teams, the number of different teams was reduced to eleven. For four of the traditional subcontractors whose work was left out of the eleven team's work schedule this made no difference. In their contracts, they placed the aluminum window frames, floors and staircases anyway. The contract for priming the paint- work was eliminated and the loss of income on the two pilot dwellings was compensated. Connecting the new dwelling to the main infrastructure is an essential part of the construction process, needed to make the dwelling work and can only be done after the dwellings are completed.

Table 1: Comparison of the Traditional and the Pilot Way

Elements in finishing a traditional dwelling	Traditional	Pilot
Aluminium facades	X	
Windowsills	X	
Placing timber inner staircases	X	
Self-levelling floors /flow floors	X	
Sand lime block inner partitions	X	X
Inner doors and doorframes	X	X
Rendering (spray work)	X	X
Tile work	X	X
Meter cupboard and meter equipment (gas and electrical)	X	X
Plumbing	X	X
Electrical installations	X	X
Mechanical ventilation	X	X
Hinges and locks	X	
Heating installation	X	X
Kit seals	X	X
Prime paintwork	X	
Paintwork	X	X
Connection to main infrastructure	X	

THE PILOT PROJECT

The main contractor has experimented with lean construction strategies before and was interested in exploring alternative organizational concepts. The initial plan to use a multi-skilled team had to be abandoned, since this conflicted with contracts already signed. It was then decided to simulate a multi skilled team by recruiting the members from the subcontractors. The main expectation of a multi skilled team was to reduce time. However, once arrangements with subcontractors are made, each contractor anticipates fulfilling its role in the traditional way. Any change is potentially a disruption with possible workflow and financial consequences. Both the subcontractors asked to participate and those left out were given financial compensation for any loss due to this experiment. First an analysis was made of which disciplines to include in this fit-out experiment. Legal issues such as previously executed contracts, licenses (an electrician is not qualified to do plumbing) and guarantees on delivered work made it impossible to only deal with five subcontractors. All activities were analysed and it was concluded that the number of subcontract parties could be reduced to eleven.

This reduction from eighteen to eleven subcontractors raises the issue of what to exclude from the collaborative fit-out. The finishing of the concrete floor with a self-levelling anhydrite floor as well as the timber staircases were taken out of the tasks of the multi skilled team. The floor contractor needed a complete dwelling to work in and then the floor needed to cure for three days. This resulted in a natural separation of the floor laying activities both physically and in terms of time. In the case of this project the stairs were considered a part of the base building and were not a consumer option. They were mounted soon after the concrete floors were cured, they could then be used for internal traffic. Damage by building activities and the resulting repair were accepted as a given.

Two adjacent dwellings, one with a high and the other with a low level of consumer options, were selected for the pilot project. Conducting all activities in series it would take sixteen days per dwelling without queuing time. By allowing some overlaps where two or more parties could work in the same dwelling at the same time, a target fit-out time of ten days was set.

THE PREPARATION

First of all a last planner inspired planning session with post-it notes was held in order to understand plan options and to commit the team members to their tasks (Mossman, 2005). 'Ultimately, someone (individual or group) decides what physical, specific work will be done tomorrow. That type of plans has been called "assignments". They are unique because they drive direct work rather than the production of plans. The person or group that produces assignments are called the "Last Planner" (Ballard and Howell 1994)' (Ballard, 2000). It is common practice to plan subcontractor work on a day-by-day basis. Walsh et al. observed in US residential construction: 'Currently, an entire day must be allotted to each specialized activity. As a result, gains in efficiency or productivity in the individual tasks are more than offset by wasted time waiting for the next activity to start. Simulation was used to confirm the intuitive result: reduction of the time gate delay would have significant, positive impacts on the overall construction cycle time for housing.' (Walsh et al. 2003). The planning of the pilot dwellings was based on two-hour time slots, separated by coffee, lunch and tea breaks. The two-hour time slots were based on time measurements done for this study in the dwellings finished the traditional way.

At first the established target of ten days per dwelling created disbelief among those who were used to thirty-five days per dwelling. First it was explained that the traditional way of working could be done in sixteen days by simply eliminating the waste of waiting. Then by suggesting simultaneously working rather than working sequentially the moderator, (who later became the supervisor) was able to convince the *first planners* that the ten days per dwelling was a realistic target.

Finally, for dwelling One eleven working days were planned and for dwelling Two thirteen days were needed due to longer drying times of certain products. It was decided by the main contractor to have the works on the two dwellings overlap with one week, since the painter could not plan his work well if he had to work on one dwelling at a time. In addition this time overlap could be used to ensure that lessons learned on dwelling One were incorporated into dwelling Two. The planning session took three hours.

Two twenty-foot containers equipped with lights were placed in front of the pilot project dwellings with a storage territory for each discipline indicated with lines spray-painted on the floor. During daytime the containers were locked with number coded locks, after working hours with heavy more burglar-proof key padlocks (Figure 2).

At the beginning the main contractor made sure that the dwellings were free of obstacles and clear of dust. It was agreed with all parties that they should always finish their jobs by removing rubbish and leaving the site clean. For this reason the dwellings were equipped with a dustpan and broom.

It was anticipated that since more than one discipline was working at a time, this would result in a higher demand of water and electricity. Hence extra water and power supplies were installed in each dwelling. Although it is common for every subcontractor to bring its own lighting, in this pilot project the head contractor supplied the lights for everyone, in order to reduce cable clutter.



Figure 2: Exterior and Interior of Freight Containers

In the traditional sequence a dwelling is prepared with mounting racks for mechanical ventilation and central heating units. Thus expensive and theft prone equipment can be installed just before the keys are handed over. Due to the high construction speed of these dwellings this equipment had to be installed in one step, hence the dwellings had to be equipped with lockable doors from the outset.

PROBLEMS ENCOUNTERED DURING EXECUTION / CONSTRUCTION

In the week before the start of dwelling One its container was filled with the materials to be used. The space in the containers was limited; therefore they had to be refilled during the construction weeks. This generated unforeseen traffic jams of delivery vans and truck in the narrow space between containers and dwellings.

Connecting the dwellings to the main electricity and sewage did not fit in the fast track organization. The mains service providers do not have a contract relationship with the head contractor and they deliver according to their own rules. This meant that they needed free access to the dwellings for a period of seven weeks starting from the day that the scaffolding was removed. These seven weeks are used for:

Week 1: groundwork

Week 2 and 3: laying ducts and feeding ducts into the dwellings

Week 4: installing street light poles

Week 5 and 6: repairing the pavement

Week 7: connecting, completing and handing over.

This means that if a dwelling is to be completed in two weeks and assuming that the scaffolding has already been removed before the start of the fit-out, the dwellings cannot be occupied till after connection to the mains services. This is hard to explain to the new owner, the builder cannot settle and the dwelling is exposed to damage through theft for which the contractor has to make extra security arrangements.

In dwelling One the sand-limestone team made the bathtub support. Due to bad workmanship this had to be redone three times. This caused a delay of three days. In retrospect and regardless of this reason one can ask if the number of disciplines could have been reduced if the plumber / installer also could have delivered the appropriate bathtub support.

The day before the pre-delivery check of dwelling Two a minor fire broke out during work on the flat roof of an external storage shed. This caused a five days delay.

EVALUATION

All tradesmen directly involved were interviewed based on a questionnaire and their experiences were collated and evaluated. Although there were many hitches in the process caused by the different way of working, the pilot demonstrated that the fit-out time per dwelling could be reduced considerably. The tradesmen from different subcontractors were asked to collaborate across the traditional disciplinary borders this was experienced as positive. The main contractor was positive about planning the work on two-hour time slots and has decided to continue with this planning on a future project with a larger number of units. The three-day delay in dwelling One was caused by rework due to bad workmanship and could have been avoided by a better quality control. The five-day delay in dwelling Two was caused by an external event and was beyond the control of the team working on the dwelling. Expressed as percentages of the planned time the delays were considerable. Compared with the traditional finishing time the total saved time was very encouraging.

This project is an example of an experimental introduction of lean processes into traditional construction. This gradual approach was enforced by the pre-existing contract structures. If subcontractors are frustrated by innovations they become counter productive. The gradual approach involved the selected subcontractors in the planning process and made them responsible for plan achievement; it also introduced them to lean ideas and made them potential candidates to participate in the next lean inspired project. They were compensated for any financial loss, which overcame any reluctance they may have had to participate. The worker's satisfaction was measured through interviews.

Analysis of the traditional process revealed a lot of waiting time. '*Takt* is a German word for rhythm or meter (...) *Takt* can be used to set the pace of production and alert workers whenever they are getting ahead or behind' (Liker, 2004). In the pilot dwellings the waiting time was reduced to almost zero, by applying a *takt* time of two hours as the smallest time unit for planning the work. The almost constant presence of the supervisor may have stimulated smooth hand-over from one discipline to the other. Finished jobs were not signed off on quality grounds after completion. Quality control was done similar to the traditional process. Two weeks before the key hand-over a pre-delivery check was done, with sufficient time to do the necessary repairs. The pilot dwellings counted eight building repair points, which is similar to the traditional process. This may seem disappointing; however the pilot project focussed on reducing waiting time and did not include an analysis of the most common construction failures.

There have been delays that are not pilot-related. Roofers created a fire, with damage to a façade that needed repair and a power shortage also resulted in a delay. Other problems could have been foreseen, such as mini traffic jams on the building site around the two freight containers. Due to poor workmanship a bathtub had to be reinstalled three times. Although this was noticed during the process, obviously there were no measures in place to prevent this.

CONCLUSIONS

The pilot project demonstrated that the fit-out time for dwellings could be reduced from thirty-five to ten days. This was satisfactory to all parties concerned. A tight schedule with a *takt* time of two hours could be achieved since the disciplines derived from different subcontractors communicated well and were not hindered by the traditional resistance of working for their own contract rather than for the project. It

could well be that the continuous presence of the supervisor helped to lubricate the coordination process. This could be a positive side effect of participating research. The supervisor kept a close eye on the time planning.

The peer pressure of the next discipline assured leaving the workspace behind clean, as agreed. There was no formal quality check by the main contractor at hand over from one discipline to the other. The absence of quality checks after completion of jobs may explain why in the end the repair points were not reduced compared to the traditional process, there was only an end control. Two weeks before handing over the keys to the new owner a pre check was done. Despite the delays in the pilot project the results were considered very encouraging, compared with the traditional way of working. The main contractor Dura Vermeer Bouw has already nominated a larger project to be organized in a similar manner to the finishing of the pilot dwellings and they will explore further ways to extend the application of lean construction. Dura Vermeer strongly believes in the practical hands-on approach. Rather than extensively doing theoretical studies it is proposed to explore both the Parade Game (Tommelein et al. 1999) and the management simulation game LEAPCON (Esquenazi et al. 2006). Playing these games will deepen the insights in how to have the subcontractors work in an overlapping fashion as well as better organizing working on single dwellings by reducing batch size, using multi-skilled teams and applying a pull system flow. Finally to improve the quality of the work, and to reduce quality related error it is proposed to implement the lessons learned in the quality handover processes developed by Marosszeky et al (2005). This could well be the next step towards continuous improvement.

REFERENCES

- Ballard, G. (2000). *The Last Planner System of Production control*. Faculty of Engineering, Birmingham, University of Birmingham.
- Ballard, G. (2001). "Cycle time reduction in home building." *IGLC9*. Singapore.
- Cuperus, Y. (2001). "An Introduction to Open Building." *IGLC9*, the Ninth Conference of the International Group for Lean Construction, Singapore, National University of Singapore.
- Esquenazi, A. and R. Sacks (2006). "Evaluation of lean improvements in residential construction using computer simulation." *IGLC-14*. Santiago Chili: 137 - 149.
- Liker, J. K. (2004). *The Toyota Way*. New York, McGraw-Hill.
- Mossman, A. (2005). "Last Planner, Collaborative production planning, Collaborative programme coordination." Lean Construction Institute UK.
- Marosszeky, M., Karim, K., Perera, P. and Davis, S. (2005) "Improving Work Flow Reliability Through Quality Control Mechanisms", Proceedings 13th Conference of the International Group for Lean Construction (Ed: Russel Kenley), Sydney.
- Randen, A. v. (1976). "Nodes and Noodles." Open House international.
- Tommelein, I. D., D. Riley, et al. (1998). "Parade Game: Impact of workflow variability on succeeding trade performance." *IGLC6*. Guarja.
- Walsh, K. D., A. Sawhney, et al. (2003). "Cycle-time contributions of hyper specialization and time-gating strategies in US residential construction." *IGLC11*. Blacksburg, Virginia, USA.