Study on Parts and Components for Renovation of Multi-family Dwellings

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Abstract

Observations in Japan, Australia and the Netherlands suggest that refurbishment of multi-storey buildings includes a lot of demolition and some damage to the remaining base building, resulting in waste in terms of material as well as process. A challenge as the world inevitably moves towards more sustainable construction practices is how can waste reduced while refurbishing buildings? This paper describes a work in progress and builds on collected data in the three countries mentioned.

The paper draws on the following previously published findings:

1. A comparative analysis of materials and building parts used in newly constructed and refurbished buildings;
2. Potential problems identified from the data mentioned;
3. A classification of materials and parts with regard to newly built and refurbishments.

Recommendations are made with regard to process and product.

It is presumed that refurbishment can gain efficiency if:

1. The differences between new construction and refurbishment are minimised, by focussing on the similarities as production processes rather than the differences in materials used;
2. Replacing outdated techniques and materials to fit the existing buildings by using the latest materials and parts. This needs rethinking of the interfaces between materials and probably a decoupling of interface and appearance.
3. Information about applied building parts should be retrievable in the future, it is therefore necessary that building parts be identified by some form of tag and that the attached information can be interrogated.

1. INTRODUCTION

It is common practice that obsolescence of dwellings, entire buildings or even larger sections of the built environment is solved by demolition and construction of new buildings. The latest innovations in construction technology can be used, such as a large degree of off site (pre-) production. New designs can result in a better fit to new demands that could not have been foreseen in the past. However, sustainability

concerns both in relation to resource depletion and waste generation have put into question the overall effectiveness of demolition and rebuild. Rather than optimizing only on construction costs (demolition and rebuild usually is less expensive) it makes sense to optimize on long term use of the built environment, reducing the waste of building material that still have value, reducing traffic as a result of demolition and reconstruction, reducing the loss on interest during the construction of newly built buildings. (If planned well refurbishment can be done in stages, thus keeping the building partly operational). This needs a rethink of the refurbishment process.

How can we minimize inconveniences such as noise, dust, traffic and pollution of refurbishment, by its own nature taking place in or close to built-up and used environments? All activities, from removing parts, to cleaning up surfaces to rebuild on, to adding new materials and parts need to be measured against these criteria. The international survey has made clear that if the existing structure of the building to be refurbished is not readable, and if the original drawings are not available or do not match the actual construction, destructive research is the only option left to document the starting point of refurbishment after having stripped the building.

If we see the construction process as a chain of events that involves the connection of new parts to the larger whole, we can focus on materials and parts connected by interfaces. This in turns allows us to precisely describe building materials in terms of dimension, quality and capacity (such as shape, texture, weight, colour, fire-resistance, embedded energy, carbon footprint or what else is or will become relevant). Position is important as well, however this is not an entity of the material or part being described rather than the consequence of the building design. Describing the interface (dimension, quality and position) gives clues as to how to refurbish in the future. Although the overall drawings of a building remain very important (how else could we tell a hospital from a residential building?) they should not have to contain much more information than the distribution of space for rooms and space for material, in other words, space plan and material plan complementing each other in the same drawing. The material plan in turn only should contain information about material boxes: space allocated to a certain building part, with certain specifications. The data of the building parts now can be connected to the building part rather than to the traditionally documented building. With this mind set, data on the building parts of twelve projects in three countries were collected and compared and quantified in data sheets for further analysis (Cuperus et al, 2007).

2. METHOD FOR INVESTIGATION

Data were collected in three ways:

1. Site visits to twelve projects in Japan, Australia and the Netherlands, in order to document parts used;
2. Process analysis using questionnaires for designers, builders and institutional clients such as housing corporations;
3. Project analysis using questionnaires, drawings and product information.

2.1 Site visits

The initial intention was to document four apartment buildings in each country, two being refurbishment projects and two newly built projects. This plan was later changed. It was hard to find relevant and representative refurbishment projects in Sydney Australia. In the Netherlands interesting large-scale refurbishments were found that possibly contribute better to this study, these refurbishments included a substantial modification of the base building, change of use and innovations in plumbing and electrical serviced positioned in hollow floors. The site visits took place between August 2004 to August 2006.

The study projects were documented on two data sheets each. On the first sheet some project data were collected, such as the name and address of the building, ownership / rental details, type of construction (refurbishment, newly built) , architect, contractor and numeric details such as site, building and floor area,

number of floors and units. On the second sheet construction data as presented, organized in building part groups, such as external wall, roof, balcony, stairs, mechanical electrical and plumbing installations, inner partitions and finishings. The major constitutive elements and materials are itemised and characterized as project dependent or independent (custom made or standard parts), and also categorised in terms of whether they are used for renovation only or for new construction as well. Finally they are classified in terms of complexity, are they simple elements (single material) or are they units made up of a combination of many parts and materials (composite elements)?

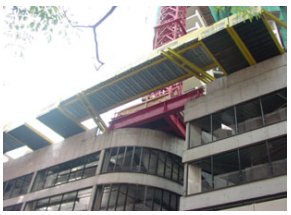
		
Kouyoudai Nagoya	Park City Torimi, Nagoya	Hikarigaoka Hights, Nagoya
		
Syouwa-park2, Nagoya	Lumiere, Sydney	Victoria Garden, Sydney
		
Keyenburg, Rotterdam	La Fenetre, The Hague	Florijn Noord, Amsterdam

Fig.1 Nine out of twelve investigated projects.

This study has its origins in Japan and the first projects selected were renovation projects in Nagoya. They are three renovation projects in residential areas: Condominium Kouyoudai, Park City Torimi, Hikarigaoka Hights and one newly constructed project in an industrial area: Uhouse Syouwa-park2. This selection was used as an example to find comparable projects in Australia and the Netherlands. In contrast to Japan and the Netherlands, the building cycle in Sydney during the time frame of this study was such that there were no comparable refurbishment projects (five years earlier this would have been very different), consequently two new projects were selected: Lumiere in the city of Sydney and Victoria Garden in Chatswood. Two Netherlands projects fit the Japanese examples very closely: Complex 50 and Florijn Noord, in Amsterdam, both representatives of mass housing from the sixties. Keyenburg, Rotterdam was added, since this is one of the icons for Open Building, equipped with facilities for easy future transformation. It was built in 1984 containing 152 small dwellings, and has recently been refitted as 93 dwellings for double handicapped persons. The fourth Dutch project is the recently completed la Fenetre in The Hague and is interesting because of its innovative floor system that accommodates space for plumbing and cabling.

2.2 Collected data

The projects documented in the study differed, some were newly built, others were straight refurbishments

and yet others combined refurbishment with newly built extensions, either adjacent to or on top of the existing buildings. They were labelled as 'n' (new), 'r' (renovation) and 'r-n' (table 1-1,2).

The projects were first of all characterised in terms of the elements used, these were classified in terms of the primary functions performed, such as exterior wall, roof, balcony, stairway, plumbing and cabling and interior finishes. The materials were characterized as 'c' (custom made parts) and 's' (standard parts), In other words, made to order (MTO) and made to stock (MTS) (Ballard et al. 2007). MTS parts usually are of a generic character, and serve as many different situations as possible while still keeping a limited range of stock. Large production runs justify serious product development and a lot of embedded quality. In order to increase their applicability special attention needs to be given to keeping the interfaces simple. MTO products are project dependent, with small productions runs and the possibility to tailor them to the project (table 1-1).

In addition the materials and parts examined were identified as 'u' (unit) or complex parts and 's' (simple), mono-material parts (table 1-2).

Not all materials and parts surveyed have the same degree of complexity. It may not come as a surprise that in all projects

common use space

region of building		**custom**[custom-made parts]:***c*** or **standard**[standard parts]:***s***								
		the Netherlamds			Janan				Australia	
N: New construction R: Renovation		N: La Fenetre	R: Florijn Noord	R: Keyenburg	N: Syouwa	R: Torimi	R: Kouyoudai	R: Hikarigaoka	N: Lumiere	R: Victoria
exterior wall	exterior wall				*c*	*s*	*s*		*c**	*c**
	autoclaved light weight concrete				*s*	*s*			*s**	
	sash and backbend				*c*	*s*				
	exterior wall base				*s*	*s*			*c*	*c*
	vetilation pipe and around it				*s*	*s*			*s**	*c*
	others									
	beams covering									
	verge of a flowerbed									
	plansier									
	outside stairs									
	handrail post									
	concrete grid with balconies									
	timber frame with double glass and closed panels	*c*	*c*							
	inner cavity wall timber frame			*c*						
	outer cavity wall concrete brickwork			*s*						
	auminium window frames			*s*						
	Loovers									*c**
	Aluminium Sliding Doors / Windows									*c**
	Door Panels									*s*
rooftop	roof	*s*	*s*	*s*	*s*	*s*			*c*	*c**
	top rail	*s*	*s*	*s*	*s*	*s*	*s*		*c*	*c**
	penthouse prefab timber frame		*s*		*s*	*s*	*s*		*c*	*c**
	entrance		*s*		*s*	*s*	*s*		*c*	
	waterproofing	*s*	*s*	*s*	*s*	-	*s*		*c*	
	handrail		*s*		*s*	-	*c*		*c*	
	others									
	bicycle parking									
	fence/gate						*c*			
	metal clotheshorse						*c*			
	Concrete balustrade								*c*	
	Color Bond Metal Sheeting									*c**
	Insulation									*s*
	Gyprock Ceiling									*c*
balcony	floor	*s*	*s*	*s*	*s*	*s*	*s*			*c*
	balcony partition	*s*	*s*	*c*	*s*	*s*				*c**
	handrail	*s*	*c*	*c*	*s*	-	*s*			*s**
	handrail wall	*s*			*c*	*s*	*s*			*c*
	others									
	side ditch						*s*			
stairway	exterior (stairway)	*s*	*s*	*s*	*s*	*s*			*c*	*c*
	leader	*s*	*s*		*s*	*s*			*c*	*c*
	floor	*s*	*s*	*s*	*s*	*s*			*c*	*c*
	wall	*s*	*s*	*s*	*s*	*s*			*c*	*c*
	ceiling	*s*	*s*	*s*	*s*	*s*			*c*	*c*
	handrail	*s*	*s*	*s*	*s*	*s*			*c**	*c**
	others									
facilities	tremch for dewatering	*s*	*s*	*s*		*s*			*c*	*c*
	water supply pipe	*s*	*s*	*s*		*s*			*s**	*s**
	drain	*s*	*s*	*s*		*s*	*s*		*c*	*s**
	elevator door	*s*	*s*	*s*		*s*			*c**	*c**
	air conditioner					*s*			*s*	*s*
	others									
	exposed piping									
	leader for dewatering							*s*		
	Sauna									*c*
	Swimming Pool									*c*
	Flower Planter									*c**
indoor	steel fittings	*s*	*s*	*s*	*s*	*s*			*s**	*s**
	wooden fittings	*s*	*s*	*s*	*c*	*s*			*c**	*c**
	floor	*s*	*s*	*s*	*s*			*s*	*c*	*c*
	wall	*s*	*s*	*s*	*s*			*s*	*s**	*c*
	ceiling	*s*	*s*	*s*	*s*	*s*	*c*		*c*	*c*
	others									
	dust outlet				*c*		*s*			
	Vanity unit								*s*	*s*
	Shower Screen								*c**	*c**
	Kitchen cabinets								*c**	*c**

*c** Meaning the item is actually custom designed first, then, manufactured into bulk quantities
*s** Meaning the item comes in off-shelf sizes, then, being manipulated into on-site requirments.

Table 1-1 Usage conditions of parts(1)

region of building		**renovation**[renovation only]:***r*** or **both**[for both renovation and new construction]:***rn***						**unit**[unit construction system]:***u*** or **simple**[simple parts]:***s***									
		the Netherlamds		Japan			Aust--ralia	the Netherlamds			Japan				Australia		
	N: New construction R: Renovation	R: Florijn Noord	R: Keyenburg	R: Torimi	R: Kouyoudai	R: Hikarigaoka	R: Victoria	N: La Fenetre	R: Florijn Noord	R: Keyenburg	N: Syouwa	R: Torimi	R: Kouyoudai	R: Hikarigaoka	N: Lumiere	R: Victoria
exterior wall	exterior wall			*r*	*r*		*n*				*s*	*s*	*s*		*u*	*u*
	autoclaved light weight concrete			*r*							*s*	*s*			*s*	
	sash and backbend			*r*							*s*	*s*				
	exterior wall base			*r*			*rn*				*s*	*s*			*s*	*s*
	vetilation pipe and around it			*r*			*n*				*s*	*s*			*s*	*s*
	others															
	beams covering															
	verge of a flowerbed															
	plansier															
	outside stairs															
	handrail post															
	concrete grid with balconies															
	timber frame with double glass and closed panels	*r*						*s*	*u*							
	inner cavity wall timber frame															
	outer cavity wall concrete brickwork															
	auminium window frames		*r*							*s*						
	Loovers						*n*									*u*
	Aluminium Sliding Doors / Windows						*n*									*u*
	Door Panels						*n*									*u*
rooftop	roof	*r*	*r*	*r*			*n*	*s*	*s*	*s*	*s*	*s*			*s*	*s*
	top rail	*r*	*r*	*r*	*r*		*rn*	*s*	*s*	*s*	*s*	*s*	*s*		*s*	*s*
	penthouse prefab timber frame	*r*		*r*	*r*		*n*		*s*		*s*	*s*	*s*		*s*	*s*
	entrance	*r*		*r*	*r*				*s*		*s*	*s*	*s*		*s*	
	waterproofing	*r*	*r*		*r*			*s*	*s*	*s*	*s*	-	*s*		*s*	
	handrail	*r*			*rn*				*s*		*s*	-	*s*		*s*	
	others															
	bicycle parking															
	fence/gate				*rn*								*u*			
	metal clotheshorse				*rn*								*u*			
	Concrete balustrade														*s*	
	Color Bond Metal Sheeting						*n*									*u*
	Insulation						*n*									*s*
	Gyprock Ceiling						*n*									*s*
balcony	floor	*r*	*r*	*r*	*r*		*n*	*s*	*s*	*s*	*s*	*s*	*s*			*s*
	balcony partition	*r*	*r*	*r*			*n*	*s*	*s*	*s*	*s*	*s*				*s*
	handrail	*r*	*r*	-			*n*	*s*	*s*	*s*	*s*	-	*u*			*s*
	handrail wall			*r*	*r*		*n*	*s*			*s*	*s*	*s*				*s*
	others				*r*											
	side ditch												*s*			
stairway	exterior (stairway)	*r*	*r*	*r*			*n*	*s*	*s*	*s*	*s*	*s*			*s*	*s*
	leader	*r*	*r*	*r*			*n*	*s*	*s*		*s*	*s*			*s*	*s*
	floor	*r*	*r*	*r*			*n*	*s*	*s*	*s*	*s*	*s*			*s*	*s*
	wall	*r*	*r*	*r*			*n*	*s*	*s*	*s*	*s*	*s*			*s*	*s*
	ceiling	*r*	*r*	*r*			*n*	*s*	*s*	*s*	*s*				*s*	*s*
	handrail	*r*	*r*	*r*			*n*	*s*	*s*	*s*	*s*				*s*	*s*
	others															
facilities	tremch for dewatering	*r*	*r*	*rn*			*n*	*s*	*s*	*s*	*s*	*s*			*s*	*s*
	water supply pipe	*r*	*r*	*r*			*n*	*s*	*s*	*s*	*s*	*s*			*s*	*s*
	drain	*r*	*r*	*r*	*r*		*n*	*s*	*s*	*s*	*s*	*s*	*s*		*s*	*s*
	elevator door	*r*	*r*	*r*			*n*	*s*	*s*	*s*	*s*	*s*			*s*	*s*
	air conditioner			*r*			*n*				*s*	*u*			*u*	*u*
	others															
	exposed piping															
	leader for dewatering					*r*								*s*		
	Sauna						*n*									*u*
	Swimming Pool						*n*									*u*
	Flower Planter						*n*									*s*
indoor	steel fittings	*r*	*r*	*r*			*n*	*s*	*s*	*s*	*s*	*s*			*s*	*s*
	wooden fittings	*r*	*r*	*r*			*n*	*s*	*s*	*s*	*s*	*s*			*s*	*s*
	floor	*r*	*r*			*r*	*n*	*s*	*s*	*s*	*s*	-		*s*	*s*	*s*
	wall	*r*	*r*			*r*	*n*	*s*	*s*	*s*	*s*	-		*s*	*s*	*s*
	ceiling	*r*	*r*	*r*	*rn*		*n*	*s*	*s*	*s*	*s*	*s*	*u*		*s*	*s*
	others															
	dust outlet															
	Vanity unit						*n*								*u*	*u*
	Shower Screen						*n*								*s*	*s*
	Kitchen cabinets						*n*								*s*	*u*

Table 1-2 Usage conditions of parts(2)

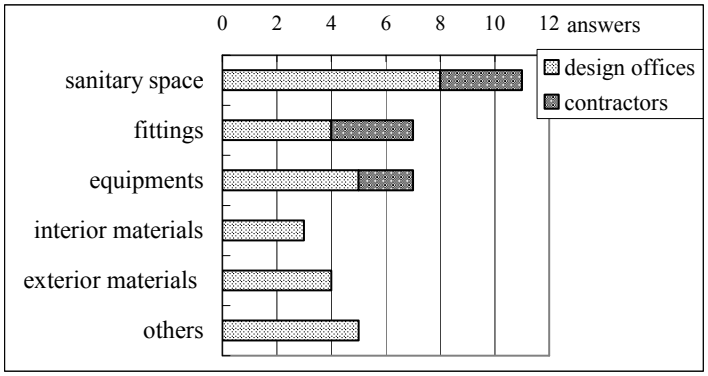
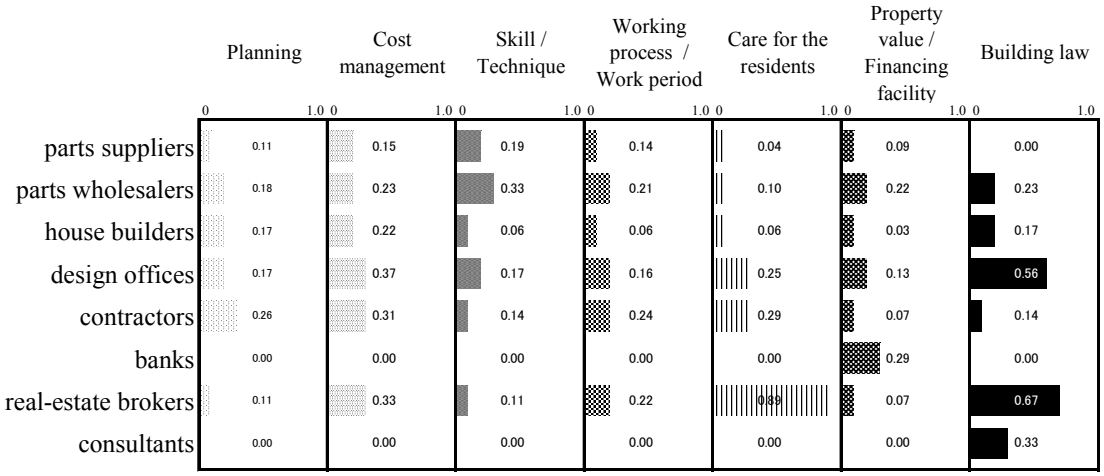


Fig. 2 Difficult spaces of renovation

the bathroom was by far the most complex area, followed by fittings and equipment. This complies with findings of extensive research from the time the buildings to be refurbished were built (van Randen et al).In order to better understand the parties' need for specific information during the complete construction process, a survey was done in the Nagoya region. Besides the obvious (banks are interested in the financial aspects and real estate agents in legal aspects and in communicating with the clients) it was found that some aspects, such as time planning, financial and legal issues are relevant to many of the parties. (fig 3).



Planning	Architects' role is uncertain.
	Investigation /diagnosis methods are not constructed.
	To build residents' consensus is difficult.
Cost management	Poor profits
	Pay doesn't correspond to the workload of each type of work.
	Expecting cost before it starts construction is difficult.
Skill / Technique	Construction system is limited.
	Advanced technique is necessary.
	Workers' skill is various.
Working process / Work period	Managing progress of work is difficult.
	Workable hours is limited.
	Work period is short.
Care for the residents	Considering noises and vibrations for neighboring is hard.
	Securing residents' temporary dwellings is difficult.
	It is difficult for the workers to construct it with the residents live.
Property value / Fnancing facility	Market is uncertain.
	Asset value of used dwellings is vague.
	Financing for renovation is incomplete.
	Money advantage by doing the renovation construction is few.
	Budget for the product development is insufficient.
Building law	Performance in the buildings don't fill a present standard.

Fig. 3 problems of renovation (rate of a company)

3 ANALYSIS

Construction is a rather low-tech industry, processing simple materials and parts or simply connecting complex units, however with a high degree of complexity when it comes to customer satisfaction, organization and quality control. Refurbishment projects have the added complexity that the work has to be built onto existing base building infrastructure rather than on a green-field building site.

3.1 Notes on the process

Many trades in the construction industry are low tech, however this work can only be done by skilled workers. Bricklaying is a skill and installing electrical works, plumbing and mechanical components influence the long-term safety in use of a building.

Building construction is a sequence of low-tech activities with many trades and shared or not well-defined responsibilities. Two recent accidents arising from building failures that caused fatalities in the Netherlands (Kleinman, 2007) were caused by modifications not being communicated upstream, resulting in foundations that did not fit the buildings.

This survey found that information on the building to be refurbished is hard to find, the original drawings often cannot be retrieved or do not represent the actual building. Lack of essential information combined with a complex communication process form the bottleneck in the process. Although this is not typical for refurbishment projects (they are production processes like any production process), the information bottleneck surfaces earlier, since the lack of information on the existing building is clear as a major constraint from the outset.

Since this problem is created by the innate complication of working with insufficient information, it makes sense to look for the solution by simplification rather than installing even more information intensive control mechanisms. Information that is needed should be easy to find, for example by making the building easy to interrogate on matters that are important.

Examples of such strategies include embossed markings in concrete showing where not to drill, non-removable bar code stickers or electronic tags. Embedded computer chips are already ubiquitous, they are used to register pets and cattle, it makes sense to use such electronic coding techniques to identify buildings parts where it is important that other users, downstream of from manufacture, need to know important operational and maintenance details. This helps to manage risks for the life of a facility.

Another way of decreasing the information problem is to reduce the number of parties involved, by subcontracting larger chunks of work, and limiting the practice of pyramid sub contracting. Move to having one multi-skilled team do a larger package of work such as a complete bathroom or kitchen, or even the complete fit-out of a dwelling. They would have better control of quality, fewer chances for ambiguity of responsibility and better assurance of customer satisfaction.

3.2 Notes on materials and products

Based on the above observations it can be said that the complexity of managing the low-tech construction process is related to the simplicity of many activities by many different trades, such as cutting materials to size and connecting them to a larger whole. In order to better understand these processes, we need to look into the nature of connecting materials and parts. Some materials (M) are delivered in bulk, are shapeless and get their final shape after they have been applied, for example paint, glue, mortar and concrete, before curing. Another category of materials (S) has a fixed shape, but needs to be cut to size. Think of timber, sheet materials, bricks. A third category (P) contains parts ready to be installed, made off site, however cannot be modified without damage, such as pre-cast concrete and a window frame. Two category P elements (for example a window frame in a pre-cast concrete panel) only fit if the information of these parts has been communicated well. A P element surrounded by S elements (for example a window frame in a brick wall) requires low tech, however skilled activities to be fitted. The looser dependency between the two parts is

compensated by the skill of the trade. Using an S material (for example a joint filling silicone kit) minimizes the dependencies of the parts mentioned and lowers the required skill level. These examples demonstrate the importance of dependencies between parts, related to their nature (M, S or P) and the available skills to connect parts, in other words the skills to build.

Multi-skilled teams work better if the requisite skills are easier to master, such as using foolproof positive connectors for making electrical and plumbing connections. There is a significant opportunity for product designers to develop complex building parts with a high degree of embedded complexity and quality. For instance, imagine a completely prefabricated wall for bathroom or kitchen. Once it is in place and connected to the mains, the only thing left is to connect the customer chosen appliances.

4 CONCLUSIONS

This paper built on an international survey of twelve refurbishment projects in Japan, Australia and the Netherlands. The study focussed on materials, parts and components used in the documented projects. Although refurbishment of existing buildings is more sustainable than demolish and build, refurbishing buildings can still be a rather wasteful process. In order to explore ways to improve this process, references were made to the building node studies from the early nineties, providing this paper historical bedding and the latest insights in construction management by referring to aspects of Lean Construction, such as creating value, banishing waste and definitions with regard to off-site production.

In the final analysis it can be concluded that:

Refurbishment should be seen as an ordinary production process, rather than a special construction process. This allows us to see the peculiarities of the process (low tech resulting in complex management structure).

Simplifying the information exchange with regard to the remaining parts of the base building as well as the newly added parts contributes to a more transparent and less wasteful process.

In order to make the information retrievable in the future it should be connected to the building parts rather than to a database of drawings that loose their value if they are not constantly updated.

A pyramid of sub contractors should be avoided. Instead multi-skilled team who can handle complex jobs decoupled from other trades and teams, such as doing the complete fit out of a bathroom or kitchen.

These approached demand the use of simple interfaces between the different domains of trade. Many foolproof connectors for wiring and plumbing already exist. At the same time this is a source for new product development.

The next step in this research could be a pilot project in which these recommendations are tested and evaluated and compared with traditional projects.

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