REUSE OF SECONDARY ELEMENTS: UTOPIA OR REALITY

J. KRISTINSSON, CH. F. HENDRIKS, T. KOWALCZYK, B.J.H. te DORSTHORST

Delft University of Technology, Faculty of Architecture
PO Box 5043, 2600 GA Delft, The Netherlands

ABSTRACT

The Netherlands produces 15 million tons of Demolition and Construction Waste (DCW) a year. For example this amount of DCW can be used for a foundation for a 250 km, six lane highway, 20 meters wide and 2 meters thick. This is an enormous amount of material for a small country like The Netherlands. The Dutch Government has passed a law which states that: “dumping of reusable building waste is prohibited” (short version). However this is easier said then done. Execution of the law can be achieved in three ways: reuse of the buildings, reuse of elements or components and finally reuse of the DCW. About 80-90% of this waste is being reused, for the main part as a road base material. This raises the question: why bothering using it in new constructions?

To make a systematic approach in reuse of elements possible, a scale is distinguished down the following hierarchy: Building → Building part → Components → Elements → Half-Products → Materials → Raw Materials (Eekhout, 1997). Every step down in the hierarchy means that there has been a decreased value of: labour, energy, material and use of equipment. So product reuse should have the advantage over material reuse because less value is lost - provided, of course, dismantling is technically feasible. But what if the building method used doesn’t easily permit dismantling? Are there still advantages then?

At this moment, there are two projects of reuse of buildings and elements in the Netherlands. The first, already realised, is the reuse of elements of an apartment building of eleven floors. The walls and floors have been dismantled and have been reused in two apartment buildings of four floors high and one of three floors. The second project is the reuse of three apartment buildings of four floors high. The two top floors have been removed and the remaining part of the building will be redesigned to become single-family dwellings.

Both projects have generated a lot of technical and financial data, but the environmental data is regrettably lacking. During the realisation of both projects a lot of problems arose which were not foreseen during the planning stage. The generated data and the solutions can be used in future decision-making

In this paper the two projects will be technically, economically and environmentally described and compared with two identical newly-built housing developments. The goal of this analysis is to help ascertain whether reuse of buildings or elements is an utopia or a feasible reality.

KEYWORDS

Reuse, Recycling, Environment, Demolition and Construction Waste, Sustainable Development.

INTRODUCTION

One of the possible contributions to Sustainable Building is to keep the building materials as long as possible in their own cycle (figure 1). This can be done on two occasions: during the design-stage or demolition-stage. In the design-stage a dismantable building system can be chosen, where all the elements and components can easily and directly be re-used after dismantling a building. This design-stage is called Design For Dismantling (DFD). Design For Recycling (DFR) is another building system where, during the design-stage, consideration is given to what to do with the building materials after demolition. The building materials are easy to separate during the demolition process, and after further processing (e.g. crushing) can be used as a raw material for the production of building materials.

The second possibility is to do everything that is possible at the demolition site in order to improve the recycling of materials and elements. This is the most common solution nowadays, because the greater part of the buildings previously built were never built for dismantling. So the present emphasis lies on the demolition process.

The Netherlands produces 15 Million tons of DCW a year. This quantity could create a road basement for a 250 km, six lane highway, 20 meters wide and 2 meters thick. No explanation is needed for saying that this is an enormous amount for a small country like The Netherlands. The Dutch Government passed a law on the first of April 1997 which states: “dumping of reusable building waste is prohibited” (short version).

To deal with the implications of the legislation we consider four possible solutions. Firstly, all new buildings can be built and assembled with reusable elements (Design for Disassembly) and materials (Design for Recycling). Secondly, existing buildings can be upgraded if possible (Object Renovation). Thirdly, if upgrading is not an option, then buildings should be dismantled into elements and components when possible (Re-use of elements). And finally, if dismantling is not an option, buildings should be demolished (selectively) and the materials can be re-used at material level (Re-use of Materials).

LADDER OF LANSINK/DELFT LADDER

In 1980 the Dutch government published an order for waste treatment (Lansink, 1979), which was called the Ladder of Lansink. This ladder was a fixed top-down approach. Since 1980 more waste treatment options have been developed, and so the Ladder of Lansink has been extended with three new options. This new order shouldn’t be a fixed top-down order, it should be flexible. The order can change thanks to the results of two calculation methods: Life Cycle Analysis (LCA), and Eco-cost Value Ratio (Vogtländer, 2000). This new tool is called the Delft Ladder (Hendriks, 2000).

Ladder of Lansink

1. Prevention
2. Element re-use
3. Material re-use
4. Useful application
5. Incineration with energy recovery
6. Incineration
7. Landfill.

Delft Ladder

1. Prevention
2. Object renovation
3. Element re-use
4. Material re-use
5. Useful application
6. Immobilisation with useful application
7. Immobilisation
8. Incineration with energy recovery
9. Incineration
10. Landfill

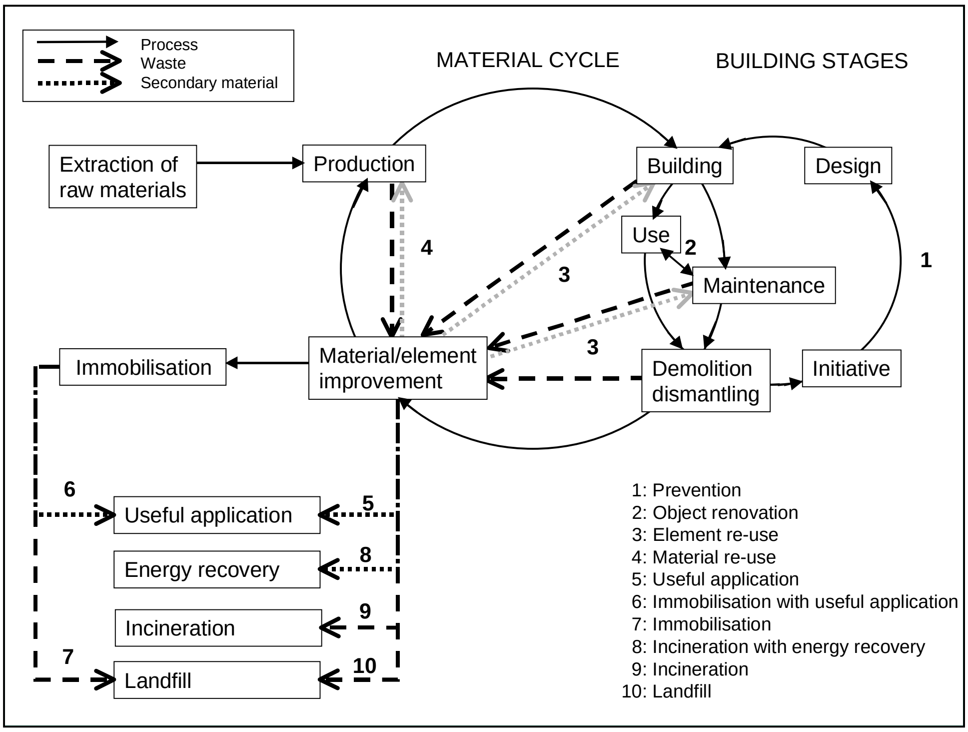


Fig. 1: Integral Chain Management

The Delft Ladder has been clarified in Figure 1: Integral Chain Management (Dorsthorst, 2000). In this figure the material and the building cycle has been added, to give the different stages and the material flows their place, and to explain in which stage which action could be taken to prevent CDW.

The first option of the Delft Ladder tries to prevent the production of waste. This step must be taken before a building is demolished; indeed, it must be taken into account in the design and building stage. This is so called Design For Recycling (DFR). This can be done in two ways: by using a dismantable building system like LEGO, or by using recyclable or renewable materials which are easy to separate and can be used in their own material cycle.

The second option is not to demolish at all but to renovate old buildings and give them a second life (object renovation). This can be done with buildings which fulfil certain conditions, such as perhaps a good technical state, a good location, economical value or monumental significance.

Almost all current constructions were not built using DFD and DFR, and so re-use of these constructions, at all levels, is difficult. Demolition of these constructions results in mixed construction waste, and so almost all of the CDW ends up in road base layers; an useful application (option 5). For use of these materials in the building industry, the waste flows must be separated and washed. With DFR, the demolition waste will be cleaner, so re-use in the building industry will be easier (option 4). With DFD, complete elements can be used again; i.e. recycling at element level (option 3). In spite of two decades of research of these topics, the DFR and DFD building systems have less than 1% market share in the current building industry in the Netherlands. The expectation is that around the year 2040 these present day, newly, built constructions will be dismantled.

Immobilisation with, or immobilisation without, useful application are the next waste treatment options (option 6 and 7). Hazardous waste can be used as a construction material. By incineration with energy recovery (option 8) energy is gained out of the burning of waste. The incineration of materials in a cement-kiln is an example of this option. By incineration without energy recovery (option 9) the material is just burned. The last step is to landfill the materials (option 10). The above mentioned last 5 steps will not be discussed in this paper.

Prevention

This is the first step that could be taken to prevent CDW and it can be taken on two occasions:

- with an existing building. When a building becomes unoccupied, and it can still meet the current standards set by the society, the owner can search for new tenants. It is obvious that this will create less demolition waste. But what if the value of the land is much higher than the value of the building? Or that a newly built building will be friendlier for the environment, e.g. make less use of energy resources in it's lifetime for heating, lighting and cooling than the old building including demolition, building, etc? These are difficult questions to answer, but with a model where all the economical and environmental aspects are taken in account, the choice can be more easily made by a real estate developer or architect.
- at the design stage of the building. In this stage the design becomes real and a building method will be chosen, and this building method will determine what to do with the building at its end of life: demolish, dismantle or recycle the materials.

The last two options are called Design for Dismantling (DFD) and Design for Recycling (DFR). Design for Dismantling is that the building method employed lets the building be easily adjusted to different needs during its lifetime, and at the end of the building's life the building can be dismantled into reusable elements and components. Design for Recycling is almost the same as DFD but with the difference that during the demolition of the building all materials are easy to separate. This will lead to cleaner flows of materials, which can be used in their own material-cycle as a raw material of high quality.

Object renovation

The second option of the Delft Ladder is Object Renovation. When a building is at its end of life, it will not be demolished, but it will be renovated. This can be done if the construction is in good shape and the layout of the building can be changed to address the demands of the new design. It is not necessary that the original function will be continued. The function can be changed (e.g. an office into apartments). This can be done with all buildings, but with constructions that are designed for change it will be much easier. There are many examples: two of the most famous are "de Kop van Zuid" in Rotterdam and "Entrepotdok" in Amsterdam, two warehouses built in the 17th century and renovated in the 1980's. Now they serve as houses, shops and restaurants. Newly built construction can also be prepared for change in the future. An example of such a construction is a building in Schijndel. In this building there are a school (ground floor and first floor) and apartments (second floor). In about 20 years, the school will need less space, and the rooms at the first floor can easily be changed into apartments. Another example, which will be discussed further on, is the case-study in Maassluis.

Element-Reuse

Element-reuse is the third option of the Delft ladder. As pointed out earlier, element-reuse is possible after dismantling a building designed for dismantling. But what is going to happen with all the existing buildings? Can they be dismantled into useful elements? The question arises in what way, and in which order, a building should be dismantled which was never meant to be dismantled? Dismantling a building into elements and components is a way to keep the building materials in their own cycle for as long as possible. The main advantage of this approach is that buildings will not be downgraded to secondary raw materials or building waste but into reusable elements and components. This results in more positive effects than just reducing the building waste. Other results are:

- Less use of raw materials which leads to less reduction of the landscape;
- Less use of energy which leads to a lower greenhouse effect and less acidification;
- Building materials will remain in their own cycle for as long as possible.

Dismantling a building is easier said than done, especially when it has not been built with the intention of regaining the used elements and components. The first thing to do is to establish the building method and the matching details. With this information in hand and the knowledge of dismantling techniques you can determine the success of disassembling the building into elements or components.

If there is no dismantling technique currently available for a certain detail, a new technique could be developed. This new technique will only be developed if it can be economically applied.

One of the greatest bottlenecks, as mentioned above, is that most existing buildings were never meant to be dismantled into reusable elements or components. This means that the thoughts about the building method and details used were only concerned with how the building was to be put together, and not how it could be dismantled. A reinforced concrete structure where every joint is poured together is hard to dismantle. A possible technique could be by sawing the construction. A disadvantage of this method is that the reinforcing steel will be exposed to the air, which could lead to the ‘decay’ of concrete.

For demolishing a building a contractor can choose from a range of methods, such as: balling, impact breakers, hydraulic shears, explosives, gas expansion and solid expansion. They all result in breaking the building into smaller pieces, but not into reusable elements or components. For dismantling a building, methods have to be found which don’t damage the element or component and which will lead to a successful reuse of the element or component. Potentially applicable methods are mechanical cutting and grinding, thermal cutting water jet cutting and laser cutting. These methods make a cut of a width of a few millimetres to a centimetre at most, which is acceptable (Noord, 1998).

Material-Reuse & Useful Application

Re-use of materials is common practice now in the Netherlands. As said before, over 90% of the CDW is re-used nowadays, almost all in the road building industry. Before the stony part of the CDW can be used as a road base material, or as a secondary aggregate in concrete, it has to be crushed. This crushing can be done on site, with a mobile crushing plant, or at a fixed crushing plant. At the crushing plant the material will be cleaned of iron, wood, paper and so on. After crushing the material into the proper size, the material will be sieved in order to get the correct proportions of pellets of different sizes. The crushing companies in the Netherlands have their own certified product, named Korrelmix.

Asphalt

The total amount of asphalt, about 2.8 million tons, is being re-used nowadays in the Netherlands. There are two different ways to re-use it. The first is hot re-use, which can give a recycling rate up to 100%. Old pavements are broken up and heated. A little regeneration oil is added to the old bitumen. This so-called regeneration asphalt is, according to the Dutch regulation (RAW), as good as primary asphalt. For this recycling of materials, special re-pavement equipment has been developed.

The second is cold re-use, which can accommodate all the asphalt that, for different reasons, cannot be hot recycled, like tar-containing asphalt. For this, the material will be broken up and a good road base material created by adding a binding material like cement. This can be called down cycling.

Concrete

In the Netherlands there are three major types of secondary aggregates; concrete aggregates, (about 1 million tons each year), masonry aggregates (0.9 million tons) and mixed aggregates (5.3 million tons). Mixed aggregates contain at least 50% of mass concrete. In order to reduce down-cycling of concrete waste, by using it as a road base material, the Dutch Concrete Platform (cement, gravel, sand and concrete industry) wants to use these secondary (concrete) aggregates in its own cycle again (CoBouw, 1999). Dutch standards now allow use of up to 20% of secondary aggregates in concrete as a replacement of natural aggregates.

Fig 2: Mobile crusher on demolition site

MIDDELBURG

In Middelburg, one of the first projects with reuse of elements has been realised. The apartment building, 11 floors high, was built in 1971 and the dismantling started in 1986 when the building was just over 15 years old. The reason for this was that the apartment building was having different kinds of social problems e.g. pollution, vandalism, drugs, alcohol and prostitution. Therefore the living conditions were not attractive at all, and every year one third of the people moved, and the occupancy varied from 19 % to 32%. In 1981 the Housing Association Middelburg (WVM) realised that the building was unlettable. One year later the idea was brought up to dismantle the apartment building and reuse the secondary elements. A study was carried out to prove the feasibility of the plan. After a few years of planning, designing and calculating, the dismantling of the first of three apartment buildings was started. The plan was to dismantle the top seven floors, renovate the remaining four floors and reuse the elements to build two apartment buildings of three and four floors high.

Fig. 3: The apartment building

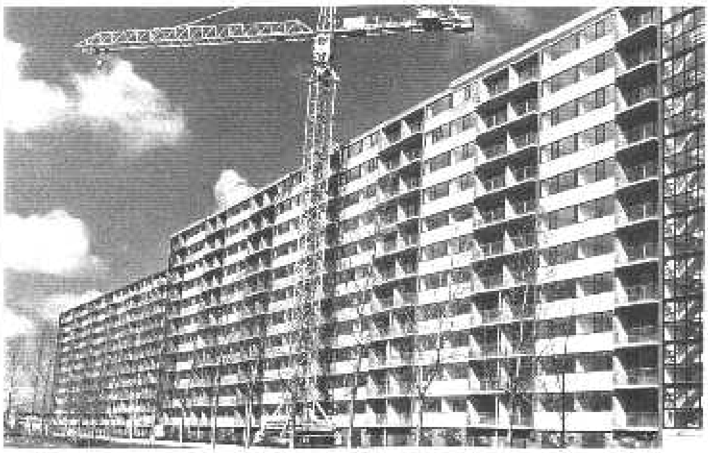
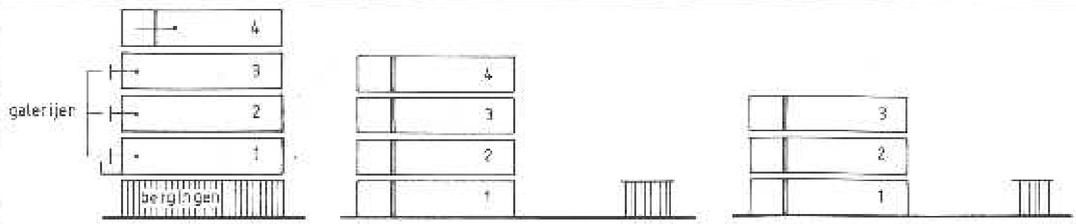


Fig. 4: The plan: dismantling of the top seven floors and rebuilding new apartment buildings of four and three floors.



The dismantling was technically possible because the apartment building was built with the Delta BMB system. The name BMB refers to the mounting method Simplified Brick Construction. The connections between the concrete components are established by means of dry-mounting, such as steel-strips or bolted connections. Grouted connections are avoided as much as possible, but still are applied for connections between floor components to achieve diaphragm-action of the floor surface.

The fact that the concrete structure of this building was constructed mainly with dry-mounting methods had contributed to the decision of dismantling. The walls were lifted so the grouted connections applied at floor-floor connections could easily be detached after 2 saw-cuts had been made with a sawing machine especially developed for this project (Figures 5 and 6). After this a pneumatic hammer could easily break the grout and the prefabricated floor components were disconnected from their support by special hydraulic jackscrew.

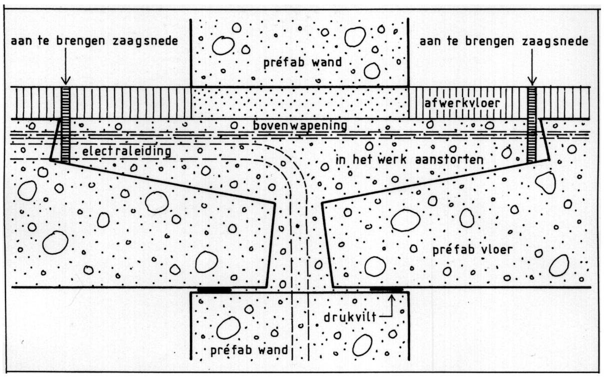


Fig. 5: Detail of the connection between the walls and floor and where to place the two saw-cuts

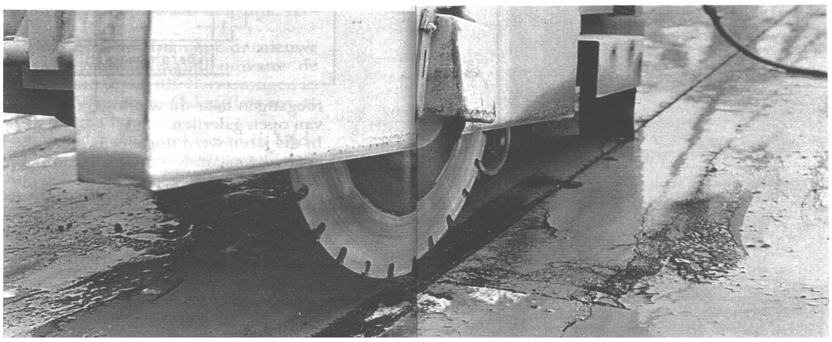


Fig. 6: The machine is making a saw-cut.

Logistics

Directly after the dismantling, several activities were carried out to prepare the components for reuse. Each component was provided with a brand and codes to facilitate the reuse. Subsequently repair work was carried out, and then the components were transported to the storage. To maximize the impact and efficiency of the reuse, the new building site was used as a storage site at the same time. When all the seven floors had been dismantled and transported to this storage site, the construction of the new buildings could start.

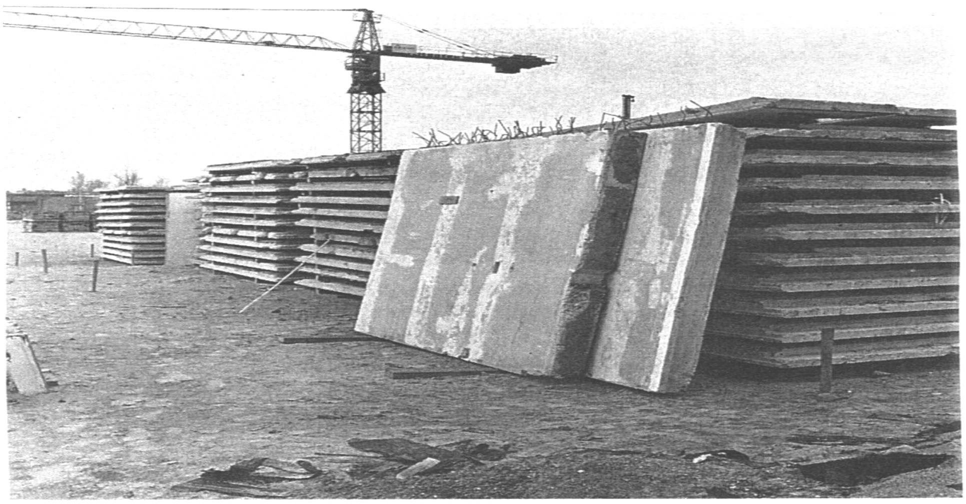


Fig. 7: the storage site of the dismantled elements.

<u>The Results</u>

Did the dismantling of the apartment building into three smaller apartment buildings meet the original goals? The neighbourhood is now a safer place to be and for all three apartment buildings there is a waiting list. But was this a result of the dismantling the building or because the people who caused these social problems were housed in other neighbourhoods? The answer is the second option.

After the whole operation was completed, there was clarity in the financial situation (Coenen 1990):

The total building costs	12.200.000,-	
Dismantling costs	<u>1.495.278,-</u>	-/-
Net building costs	10.704.722,-	
The supposed costs of a newly build building	<u>9.021.092,-</u>	-/-
The costs of the reuse	1.683.630,-	

The reuse of the elements made the building 1.683.630/9.021.092 = 18.7 % more expensive in comparison with a new building. But this figure should be higher because when the comparison is made with a new building then the old building will be demolished instead of dismantled. And the costs of demolition are less then the dismantling costs.

MAASSLUIS

In Maassluis, in the Netherlands, there is currently a re-use project ongoing. It is a project where six apartment buildings of four floors high will be re-used. Two apartment buildings have been renovated and a fifth floor has been added (fig.8). Of three apartment buildings, the two top floors have been removed and the remaining part of the building will be redesigned to become single-family dwellings (fig. 9 & 10). The sixth apartment building has been demolished, only the foundation will be re-used for single-family dwellings.

Fig. 8: The old and renovated apartment building

The dismantling of the three apartment buildings has just been finished and the experience will result in new solutions to the encountered problems, which then can be applied to future projects. One of the first and most important problems encountered is that the apartment building is not quite built as it was designed. During the building the contractor changed the details without giving any notice of it.

Fig. 9: The remaining construction and the artist impression of the single-family dwellings

During the dismantling we came across the different details, which made it more difficult to dismantle without damaging the construction. Firstly, when the project was just in the initiative-stage, the idea was to dismantle the third and fourth floor. These elements would be used to build single-family dwellings just across the street. It was very complex to dismantle and to build synchronically with the same elements. And at this stage it wasn't clear whether the elements were reusable, so the second thought was to dismantle the two upper floors and store them on a nearby location to catalogue and test them.

Realisation of this idea was not possible; two things went wrong during the process. Firstly there wasn't enough time and knowledge available, and secondly the government wasn't intending to subsidise the project so all the risk was for the housing association and the contractor.

Fig. 10: Artist Impression of single family dwellings

The used building method is named after the factory where it was made: "Elementum". It is a precast building system where the connections between the floors and walls should have been filled up with a mixture of sand-cement, but during the construction a much stronger mixture was used. When a floor was removed with more force then initially thought the whole construction moved a bit and it stood out of plumb (fig. 11 & 12). To prevent collapsing more safety supports had to be added.

Fig. 11: The newly settlement of the construction after sawing the wall in two sections. The right section will be removed.

Fig. 12: After removing the floor it is clearly to see that the wall is not standing 90°. This will be fixed during construction

Because this project is still going on and only the first stage (the dismantling) is completed, the financial data is being collated only slowly, and is not yet available. However, even when available, it will need to be used carefully since it is very sensitive in perspective of competitive position of the building company.

This project is the first in its kind in the Netherlands and so it is a learning project. About 2 million of these apartments have been built during the period 1946-1980, and a lot of these apartments cannot now meet today's standards. Because the housing association, the principal in this project, owns 2.500 of these same type apartments in the same condition as this project, it can be expected that more of these projects will follow in the future.

THE ENVIRONMENTAL IMPACT

Establishing the environmental impact of the entire process is similar to calculating the monetary costs. But in contrast to the monetary costs, where for every process there is financial data available, similar environmental data is not available. In particular, the environmental data concerning dismantling- and demolition processes is lacking (Guequierre, 1999a). But this is not the only problem; it is also very difficult to allocate environmental impact to the first and second life cycle. For example, if a concrete floor is reused, how much of the environmental impact is allocated to the first life cycle and how much to the second? These are complicated issues that have to be addressed before the calculation can take place (Guequierre, 1999b). To counter the lack of environmental data we have contacted a few demolition firms and requested information. The acquired information still has to be processed before it can become useful for calculating the environmental impact. A database will be built with this processed information, concerning all the demolition and dismantling processes.

A way to determine the environmental impact is to use a Life Cycle Assessment method (LCA) (Heijungs, 1992). This method is generally accepted as a standard to determine the environmental impact. By using the generally accepted method, information exchange is facilitated and could lead to a more exact database, and this could lead to a more exact outcome in determining the environmental impact.

CONCLUSIONS

The question that is stated in the title of this paper is: “Is reuse of secondary elements a reality or a utopia?” The answer to that question isn’t quite simple - it is a combination of four (technical, environmental, economical and the regulations) different aspects. Almost everything is dismantlable with the current techniques, but will it be economically profitable? Or does it reduce the impact on the environment? A building meets certain regulations dated in time when it has been built, but when these element will be reused after 50 years will they meet the standards valid in that period?

In the cases of both Middelburg and Maassluis the constructions were never built to be dismantled. It was not easy to dismantle those buildings and to reuse them. If we want to re-use building materials or elements, and close the building cycle, much more effort must be put in Design For Dismantling and Design For Recycling. A building constructed using one of those two methods can at the end of its life be re-used or recycled much more easily. This is because the connections are all dry and dismantlable or the materials are used in such a way that they are easy to separate during demolition.

In the case of Middelburg the building was 15 years old and the building method used resulted in construction of the elements for bigger loads, which automatically allowed the elements to easily meet the current regulations. Because it was the first project in its kind, it was very difficult for the people who were involved in this project to anticipate everything.

In the case of Maassluis there were three enthusiastic partners, the housing association, the demolition contractor and the building contractor and all three had their own influence in the process. It was quite clear in the early stage of the dismantling process that the costs were estimated too low. The original drawings were different in crucial points from what was built. Consequently, additional safety measures had to be taken. Also, if there had been more time spent on research on what would be the best way to dismantle the ‘Elementum’ building method, there could have been more reusable elements.

ACKNOWLEDGEMENTS

Thanks to the Science Shop and Research School Bouw who support this Ph.D.-research.

REFERENCES

CoBouw 1999. “ Betonsector schoont eigen stoep ….en zelfs die van de buren”. Betonkrant appendix to Cobouw (issue 31-5-1999). In Dutch.

Coenen M., Lentz G., Prak N. 1990. “De Kop is Eraf”. DUP, Delft. In Dutch.

Dorsthorst B.J.H. 2000. “Building Materials for ‘X’ Life Times”. In “Proceedings, 2000 Integrated Life-Cycle Design of Materials and Structures”. RILEM/CIB/ISO, Helsinki.

Eekhout M. 1997. “Process Organisation for Product Development”. DUP. Delft. In Dutch.

Guequierre N. M. J., Hendriks Ch. F., Kristinsson J. 1999a. “End of life scenario assessment based on product features of building components”. In “proceedings Second International Working Seminar on Re-use”. Eindhoven.

Guequierre, N.M.J., Kristinsson J. 1999b. “Product features that influence the end of a building”. In “Proceedings of the 8th international conference on durability of building materials and components”. Vancouver.

Hendriks Ch.F. 2000, “Nationaal congres Bouw- en Sloopafval, kwaliteit in de keten”. Nederlands Studiecentrum. Rotterdam. In Dutch.

Heijungs R., Guinée J.B., Huppes G., Lankreijer R.M., Udo de Haes H.A., Wegener A.1992. “LCA methodology Guide & Backgrounds documents”. CML Leiden.

Lansink 1979. “Report of parliamentary debates 1979-1980”. SDU, The Hague. In Dutch.

Noord J. de, A.E. van Koppen, Ch.F. Hendriks, T. Kowalczyk, N.M.J. Guequierre. 1998. “Demolition and Construction Wastes in the Netherlands”. Delft University of Technology, Faculty of Architecture, Building Technology Group, Technical Environmental Design.

Vogtländer J.G. 2000, “A LCA based model for the eco-efficiency of product and services: the Eco-cost / Value Ratio” DUP, Delft.