INDUSTRIALIZATION OF HOUSING
(Building with systems)

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Abstract

The need for change is market phenomena on a turn of 20th century. As a result of changing life styles the diversity of housing user requirements is increasing and asking for more flexible solutions. This has unavoidable technical implications.
Conventional building structures are not designed for change. For that reason every transformation within a dwelling has to do with demolition of part of a building or sometimes whole built structure. In order to increase buildings transformation capacity building construction should be focused on further systematization of building and development of innovative building methods that will provide flexible structures whose parts could be easily replaced and reused or recycled.

1 / INTRODUCTION

The rate of recent changes in technology and society which is coupled with the changes taking place in lives of users (and in the conditions stimulating market activity) justify the need for new building approaches which are dynamic and flexible. The scope and scale of change of modern society could be seen in the demographic structure of world's society. For example in 50's housing market was dominated by single family home and there was no reason to change the traditional way of designing the houses. However since 1960's rang of buyers has increased and traditional family accounted in some western countries only 17%-20% of all family types[Frie97]. Today we could say that almost quarter of all clients looking to by a home are singles or single parent families. Further more each new stage in life of one individual (from growing up to getting old *figure 1*) brings a set of new requirements on the built environment. Such requirements usually result in physical changes which are related to demolition and time consuming reconstruction processes. Ultimately every adaptation or change within building creates extra load on the environment due to the energy use, dust and noise from demolition activities and building waste.

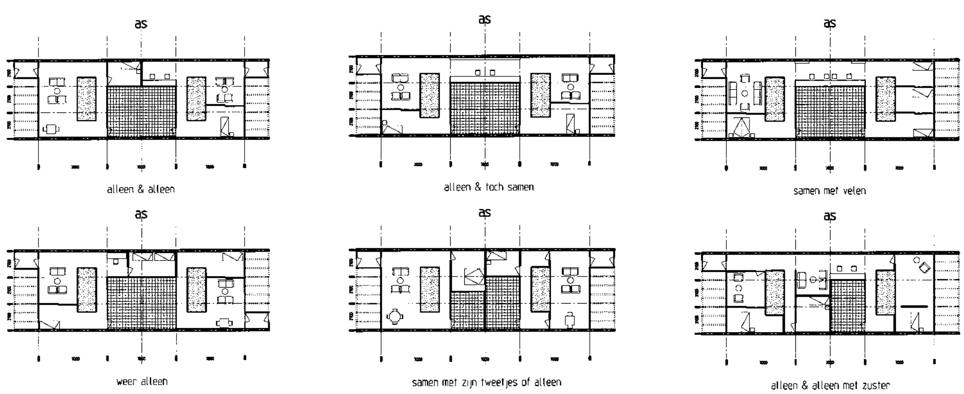


Figure 1: spatial requirements per life cycle phase - from growing up to getting old (Brouwer99)

On the other hand the main aim of building construction today is to contribute towards global sustainability by using energy saving processes, reducing the use of natural resources and reducing the

waste production. Such demands are in contradiction with human prosperity which is related to the consumer-oriented society. The question is how can we lower our consumption of natural resources at the same time as improving our quality of life? and Can the building industry and its systematization, which was seen in 70's as contributing to the "destruction" of the world, offer the key to its "rescue"?
The joint research project of industry Polynorm and Delfts University of technology is dealing with these questions. The project aim at the development of flexible infill system (SMR) that will contribute towards more efficient use of space and building materials wherein the relations are laid between spatial and technical systems within the building. In this paper we will put more light on the advantages of building with systems especially in relation to the flexibility in use, building process. Further on the paper contains the description of the theoretical background for the development of the "SMR" system and the state of the art in its development.

2/ PRESENTATION

2.1 Systems versus system building

"In the course of history, one can recognize certain basic socio-cultural and climatic conditions under which man has sought to standardize and prefabricate dwellings. Developments of this kind usually manifest themselves when demountability and transportability play a role or the economical use of materials is essential. (Adolph Stiller detail99)
Industrialized building has built its reputation in Europe in a first half of twentieth century through mass production of housing. Its reputation was especially based on the trend from 50's and 60's which aimed at construction of low cost housing and improvements of construction process through: enlarging of component size, prefabrication and repetition. It was at that time that mass production was linked with large-scale components what had direct consequences for the architectural expression of industrialized building.
This has created misunderstanding of the system building. Moreover the major pioneering studies of the evolution of industrialized housing comes from the field of economic rather than technological history."
Nevertheless the real meaning of industrialized building should be understood through the definition of "systems building" (which is coming from American building practice)(R.F.Borg82). "Systems building is used to define a <u>method of construction</u> in which use is made of <u>integrated</u> structural, mechanical, electrical, envelop and partitioning systems. The ultimate goal is integration of planning, designing, manufacturing, site operation management and financing into a method for cost effective and high quality industrialized buildings.

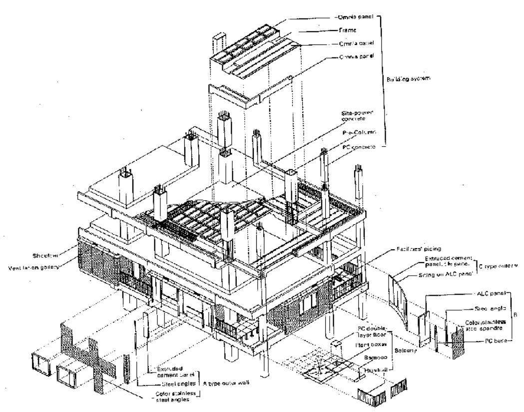


figure 2 (left systems building ; right system building)

Unlike the conventional system buildings which are mostly developed in a form of closed systems, operating independently from other industries and usually for a single building type, systems building can be seen in a form of an open structure which is a result of disciplined integration of independent subsystems. Such structures have form of an open system that permits continuous changes and additions. Flexible buildings of this kind could be solution to the demand for durability. Such structures could last longer because they could be adapted over the time.

Unlike the conventional system building where all building elements were joined together into fixed connections the main characteristic of systems building is in decoupoling of different building's functions and altering them from fixed to less dependent conditions.
Such development stimulates system development and further industrialization of building where in systematization is derived from the fact that different parts of the building have different lifecycle and functional expectancy.

2.2 System development in a context of spatial and technical systems within one flexible dwelling

Each dwelling presents an integration of spatial and technical systems, and one can not exist without another.(figure 3) In that respect if spatial flexibility is defined as ability of building to change its spatial organization than technical flexibility can be defined as ability of the structure to provide these changes through ease of disassembly and repleaceability of its components.
For that reason development of building system can not be taken out of context of a building as a whole. In general flexible system has to provide two main requirements being: spatial flexibility and flexibility of the system itself.

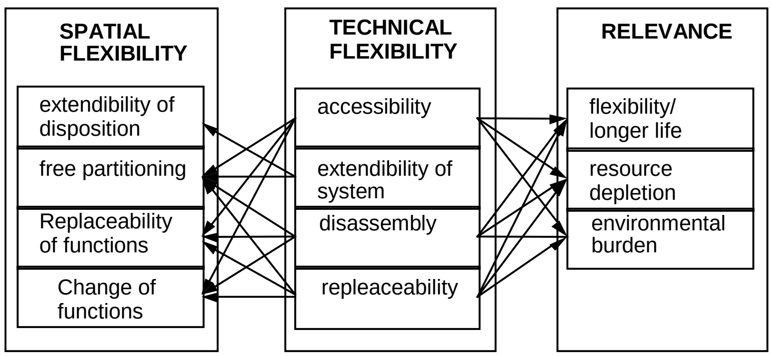


Figure 3: Relations between spatial and technical flexibility

Resent trends in rental housing show that spatial organization of one dwelling is completely changed in a period from 5-25 years. The analyses of these dwellings have shown that the key obstacles for their successful transformation are often related to: inflexible load bearing structure; lack of accessibility to the old installations; lack of space for new installations and in dependent relations between load bearing and non load bearing parts of building.
The fact is that economical duration of a certain phases in the use of a building is generally shorter than the technical life span of most of its components. Thus design life of modern buildings is 75 years yet their service life is unpredictable because their major parts were out at different rates complicating replacement and repair schedules.

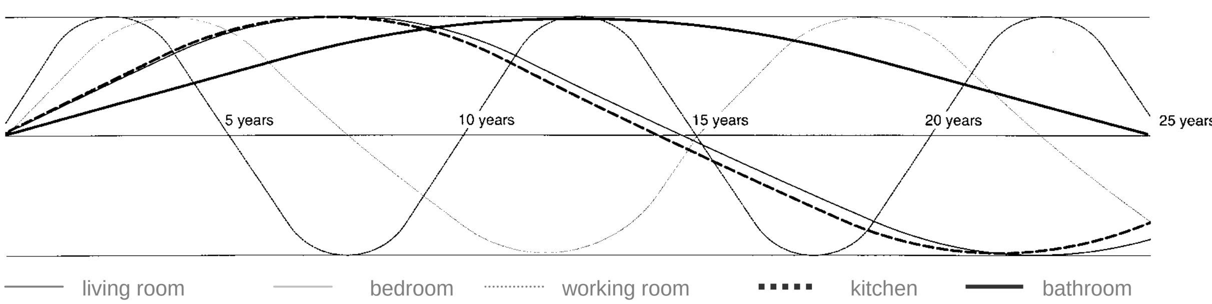


Figure 4 pulse of en dwelling

It is quite usual for example for part with short durability to be fixed in permanently, preventing easy disassembly. Therefore at the end of components service life there is usually little option but for demolition with associated waste disposal. [Crow99] That means that faster cycling elements such as space plan are in conflict with slower cycling element such as structure and cite. For that reason the first step towards managing the temporal tension in building is through decoupling of slow(fixed) and fast(changeable) components.(Kibert00). Such classification determines the hierarchy within the structure which is the main reference for the future systematization of the building and its interfaces. The fixed elements are the elements with high level of flexibility towards spatial and functional changes and high durability. The flexible elements are the elements, which are frequently exposed to changes due to the change of the requirements, and elements with short life cycle. (figure 5)

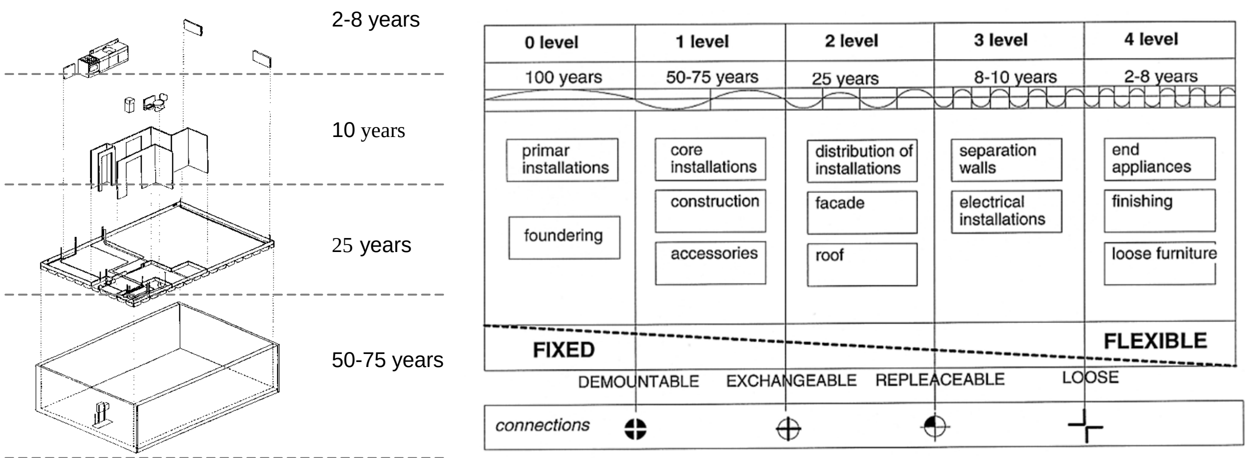


Figure 5 :One proposal for systematization of building systems and their interfaces according to the different life cycles

The most important aspect of flexibility in dwellings is separation and decupling of levels which have different life cycle. Decomposition of one dwelling into independent levels is a top-down process. This process should be developed following the criteria that will help us to recognize and decompose a subsystem from a whole. These criteria ‘s could be defined through two main aspects being spatial and technical aspects of the structure.

The criteria on spatial level are related to the level of flexibility such as:
1. maximal/optimal spatial flexibility
2. maximal/optimal functional flexibility
3. total flexibility (function changes)

The criteria on technical level are related to the :
1. Expected life cycle of the subsystem
3. Separation between subsystems which perform different functions
4. Process of making and its sequences
4. Projects independent subsystems

According to the priorities that are put on each of these criteria the dwelling can be subdivided into different groups of subsystems.(figure6) Figure six shows the difference between the traditional inflexible dwelling with maximal integration of all building components and two possibilities for systematization of building components. One possibility provides maximal spatial flexibility (figure 6 middle) while other presents optimal spatial flexibility (figure6 right).

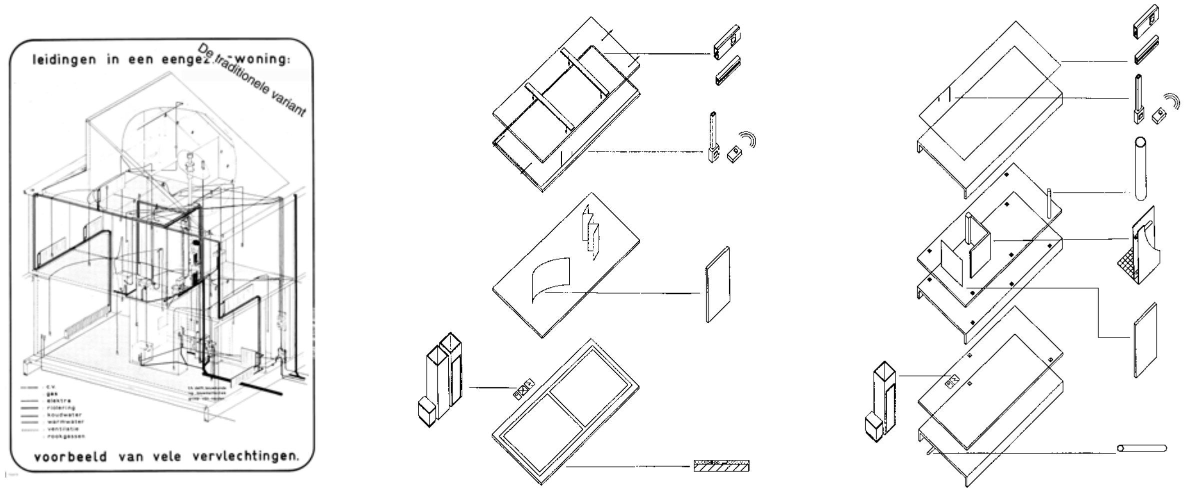


Figure 6: left (traditional house in Holland), middle (maximal spatial flexibility), right (optimal spatial flexibility)

2.3 Interfaces

Through the specification of fixed and flexible components within the building structure the hierarchy is defined, and precondition for further systematization is provided. Once the criteria has been defined on spatial level the focus can be switched to technical level where interfaces play an important role. It is that here the final efforts to achieve flexibility often fail. Therefore one of the most important aspects of design for change is specification of interfaces between independent systems, which has to do with assembly procedures and combination of building materials and their functions at connections.

Following relations have an impact on flexible interfaces:

- Relation between subsystems which have different life cycle

This relation is related to the sequences in assembly (first in –last out principle), level of independence which has to do with hierarchical position of the components in the building and type of connections

- Relation between subsystems which have different assembly processes

This relation has to do with process of making and number of parties which are involved in the process. There are three principle solutions for this relation.

a./two different subsystems are assembled by one contractor,

b./two different subsystems interfere into each other processes which is often the case with installations and load bearing structure or finishing

c./two completely independent systems are assembled in independent time sequences.

- The relation between subsystems which perform different functions

These relations will occur at the connections between the two systems. The major problems here is continuity of the systems. Therefore indirect connection could be more suitable from direct connections.

- Relations between the systems which are project independent

The most important aspect in these relations are agreements about position, dimension (Age van Randen)

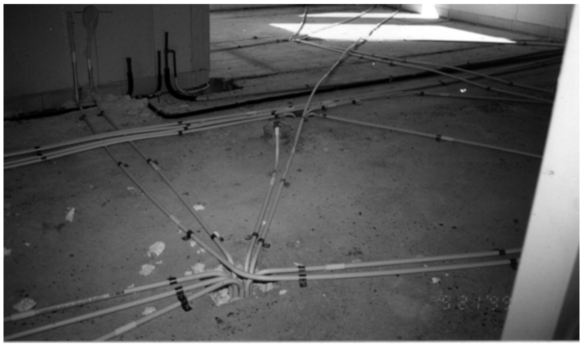
Generally speaking there are two sorts of interfaces : internal and external. The interfaces between different systems and the interfaces within the system . Having in mined above mentioned aspects which have impact on design of building connections five principle guidelines could be defined :

a. create separation between the elements with different functional and life cycle expectances by using separate construction systems
b. parallel assembly should replace sequential assembly in order to allow disassembly of single part without disruption to other parts
c. keep all components separated avoiding penetration into other component or system
d. provide accessibility to the components with shorter life cycle
e. mechanical connections should replace chemical connections

These principles should be use in the design of bought internal and external connections.

3. "SMR" system - case study

As it was already mentioned in the text the development of building system has to take into consideration its spatial application on one side and its technical performance on the other side. For example if we would like to develop infill system for optimal functional flexibility which will offer maximal spatial flexibility, one solution would be to separate the installations with longer technical life cycle from installations with shorter technical life cycle. In this case the units comprising water and sewage system should be accessible for maintenance but not replaceable while other interfaces should be demountable.



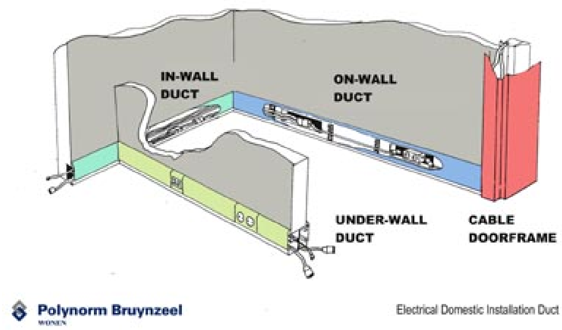


Figure 7: left (traditional concept); right (SMR concept)

The main criterion for development of SMR system was optimal spatial flexibility. For that reason the separation has been made between spatial systems which have longer economical life cycle (such as kitchen bathroom and lavatory) and the once, which have shorter economical life cycle (such as living room, bedroom, working room etc.). The system itself is focused on flexibility of components with shorter life cycle. The main obstacle for change in this category is in lack of accessibility to the electrical installations, lack of space for new installations and fixed connections between load bearing and non load bearing components of one dwelling.
Out of such specification the technical requirements were defined. The main aim of the system is to provide flexible interface between the walls and electrical installations on one side and easy accessibility and repleacebility of its components on the other side.(figure 8)

Unlike the traditional distribution of electrical installation (figure 7 left) SMR introduces circular ring structure for the distribution of electrical and data cables (figure 7 right). The main components of the system are electrical duct which is placed in the lowest zone of the wall. This zone is accessible and its components repleaceble. In order to provide the continuity of installations the doorframe is also designed as the electrical duct. Since it is a project independent system one of important criteria that it has to fulfill is compatibility with other systems within the building .

Figure 8: left(conventional solutions for electricity) ;right (SMR solution)

In order to provide easy repleaceability of partitioning walls the installation duct is combined with Metal Click wall system which is demontable and whose parts are reusable. Evaluation of systems performance has been done in accordance with the criteria which are related to :

- the separation of different functions within the system
- process of making
- assembly and disassembly sequences
- flexibility of connections

Until now two principle solutions for the system are being analyzed. One is made of “under wall duct” (proposal 1) which is totally independent from upper wall and whose dimensions are suitable for use of modular components. This would make assembly procedures of electrical installations simpler and faster.(Figure 9 right) Another concept proposal is made of “on wall duct” (proposal 2). The assembly of “on wall duct” is faster but it creates dependence between the wall and the installations and does not leaves space for use of pre made components.(Figure 9 left)

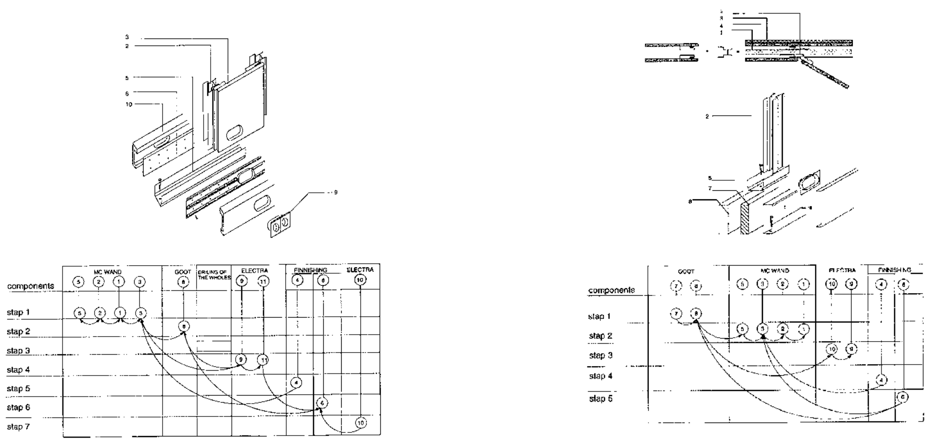


Figure 9: Two proposals and their assembly sequences, left (on wall duct) (proposal 2), right (under wall duct) (proposal 1)

Further more the assembly sequences in proposal 2 have characteristics of sequential assembly. The dependence within such assemblies is proportional to the number of assembled components. In this way all components in proposal 2 are dependent from each other. The assembly sequences in proposal 1 have characteristics of parallel assembly which creates greater independence between the assembled component.

Another aspect of systems flexibility is analyzed through the relations between the components that perform different functions (figure 10)

The diagrams in figure 10 present the relations between fore subsystems which perform different functions within the “SMR” system being : MC wall, steel gutter (interface between the installations and separation wall), electrical installations and finishing.

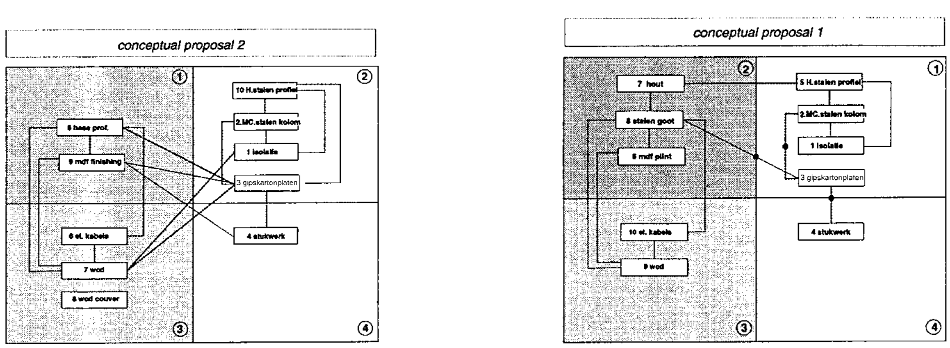


Figure 10:relations between different functions; left (proposal 2), right (proposal1)

It is evident that there are much less relations between different functions in the proposal 1 than in the proposal 2. That means that there is greater level of independence between the components in proposal 1 and therefor the changes could be easily accomplished. For example since the electricity is independent from the wall and its finishing the process of laying down the cables, electricity switches and their finishing could be completed at once without interfering into other processes. All above mentioned analyses have shown that proposal 1 has significant advantage above the proposal 2 when it comes to the flexibility of the system itself and ease of its assembly. Nevertheless bought of the concepts will be developed further in prototypes in a coming year. This will provide a real scale comparison of building processes and put some light on cost specifications.

4. CONCLUSIONS

Though the number of new requirements on the building is increasing on daily base, most of the buildings are still being constructed in a way which ignores the necessity for their adaptation. Very often such situation unable easy changes as well as the reuse and recycling of building products which has economic and environmental consequences. The improvements of buildings flexibility could be achieved by introducing clear separation between components that have different life cycle. The precondition for such separation is in systematization of the building and its interfaces according to four criteria which are mentioned in this paper.

On the example of “SMR” system the advantages of such approach could be clearly depict. Unlike conventional construction procedures which often result in inflexible structures, intervening processes and long lasting construction and reconstruction the “SMR” provides following improvements:

1. accessibility to all electrical installations
2. easy replaceability of systems components with possibility for reuse and recycling
3. faster assembly due to the use of pre made electrical and other components and dry jointing technique
4. independent processes (electrician can work independently from other subcontractors in one time sequence)
5. as project independent system it will be compatible with all types of load bearing and partitioning walls
6. demolition work is replaced with disassembly

Figure 11: disassembly of the “SMR” components

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