



TEKNOLOGISK  
INSTITUT

# **BUILDING IN KNOWLEDGE SOCIETY**

**Erabuild: Plug&Play project**

*1. report, June 2007*

by Ivar Moltke, Danish Technological Institute

# Index

Index .....	2
Preface .....	3
Acknowledgements .....	4
1. Building in knowledge society.....	5
1.1 Human centred.....	5
1.2 Multi media .....	6
1.3 Being present .....	7
1.4 Interactive architecture .....	8
1.5 Inspiration.....	8
1.6 Multi media art .....	9
1.7 Sustainability .....	10
1.8 Branding .....	11
1.9 Building = information x material.....	11
1.10 Man as biological creature.....	12
2. Adaptable house.....	15
3. Erabuild Plug&Play project .....	19
4. Examples and experience economy designs .....	22
5. Plug&Play issues map.....	24
6. Plugin and play scenario .....	25
7. Design and ordering scenario.....	28
8. Production scenario.....	30
9. Discussion .....	32
10. Plug&Play project vs. Manubuild.....	33
11. Learning from the kitchen industry.....	34
12. Learning from the car industry?.....	35
12.1 What is the difference between cars and houses?.....	35
12.2 Life length .....	37
12.3 Legislation .....	37
12.4 Discussion.....	37
13. Value chain .....	38
14. Business models.....	43
Appendix 1: Mobile home definition from wikipedia.....	46
Appendix 2: MIT House N project.....	51

# Preface

This report aims to put the Plug&Play project into the context of knowledge society and experience economy. This is an entirely new paradigm in the construction sector and the full impact of the new mindset is profound, yet hard to imagine.

Einstein said “You can’t solve a problem within the mindset that created it”. This is why I headed straight for the mindset behind present efforts to industrialise the construction sector. The old mindset is entirely producer centred and completely within the paradigm of industrialisation. The building construction industry has been slow in catching up with industrialisation and unfortunately is has been so much behind the other sectors that it was still in the middle of starting the industrial revolution when other industries advanced to the next paradigm of knowledge society and experience economy.

The present effort to industrialise the sector offers the consumers nothing. Not even inexpensive housing as the market forces immediately absorbs the savings. On the contrary, the consumers are offered reduced choices, poor architecture, and rooms restricted by transportation limitations. No wonder the consumers are far from enthusiastic.

So, this report is about the next paradigm, a mindset within which you can solve the problems and overcome the barriers the building industry obviously could not solve within the old paradigm. Fasten seatbelts and join me in this turbulent transformation into the next paradigm.

Illustrations from my own design on page 22 prove that I take the “medication” myself.

Ivar Moltke  
Architect  
Danish Technological Institute  
+45 25322518

# Acknowledgements

This is not the official output of the ERABUILD Plug&Play project. However, it would never have been possible without the valuable input, feed back and support from the project group and its consultants. Thank You

## ERABUILD Plug&Play group

- Alain Zarli, CSBT
- Marc Bourdeau
- Esa Nykänen, VTT
- Jyri Nieminen, VTT
- Jenni Jahn, VTT
- Miklós Molnár, Lund University
- Philipp Hartl, Profactor
- Ronny Andersson Cementa
- Anders Thomsen, Danish Technological Institute

## Consultants

- Jens Gulbæk, E-loop
- Henning Sejer, Danish Technological Institute

## Erabuild project manager

- Gustav Christoffer Jensen, EBST

# 1. Building in knowledge society

Throughout history we have built and perceived the world through the paradigm of the prevailing value creating process. Farmers built farms from organic materials and lived in the nature. Industrialisation brought us high-rise buildings, cities, modularisation, industrial construction. What will knowledge society bring us?

Most profoundly the measure is changed from the physical m<sup>2</sup>, kg, °C, lux of the industrial age to the measure of knowledge: “a difference that makes a difference”. Our senses react to differences. Changes stimulate our nerves. We are blind to continuous stimulus. The brain reacts to something that is different to that which we knew before. Knowledge is a model structure in the brain. Familiar information makes no impression because it is already there within the model. It is the new and surprising that counts. It’s all about importance, focusing on the sender and receiver instead of bits and bytes. Information is increased when the sender has structured and compressed his message (difference no.1) to have a meaning and value for the receiver (difference no. 2) and when the receiver cares. An enthusiastic sender and a curious open minded receiver is the ideal situation preferably in two way communication.

It is as when Galilei moved the co-ordinate system from the earth to the sun and pow! Kepler explained the motions of the planets in terms of elliptical orbits and Newton followed up with the rest of the universal laws of physics that became the basis for the industrial revolution.

This new paradigm will create holism out of chaos and structure our interaction with each other, our surroundings, as well as with ourselves. So let us take a look at the ten new commandments about differences that make a difference in buildings:

## 1.1 Human centred

**The aim for architecture is for man to enjoy, flourish, thrive, prosper and develop**

This human centred knowledge society focus on the user is profoundly different from the present paradigm where the building as such is in focus. Architects have always cared for the users but the rest of the actors on the construction arena have urged everybody to concentrate on the practical task of erecting a building.

Buildings become a multi media in relations between:

- Users
- User and building
- Users and their environment

We users are all different. This difference is a resource driving evolution from the biological and genetic development of species to the development of new ideas. Difference is particularly important in this knowledge society era when the building becomes a multi media. There would be no need for communication or even information without differences. It makes no difference to learn something you knew already.

Darwin found that evolution proved “Survival of the most adaptable species”. Adaptable means those who flourish with the new conditions, while flexibility is about coping short term

with new conditions. We need to develop an architecture that flourish with difference and complexity.

Valuation of difference means of course that buildings should never be produces from the “one size fits all” concept of Ford T. “You can have any colour as long as you choose black”. Architecture in the knowledge society is all about customisation, configuration, rapid manufacturing a building that fits the user perfectly and adapts to changes.

Most architectural reviews shows pictures of beautiful deserted buildings without users. A kind of “After Tjernoby1” pictures. In the knowledge society era, buildings are more beautiful when love, friendship and collaboration are manifested between the users. Human development and interaction is both the starting point and the objective.

The concept of multi media communication involves all senses. Sight, sound, smell, touch, taste and sixth senses too because it is a difference that makes a difference in your brain that counts. In this multi media paradigm, a successful building provides a higher quality communication than any other media. Better pictures, sounds etc.

A candlelit dinner is a metaphor and an example of a situation where all senses are stimulated in the brain. The city is an example of a situation where we are choosing which senses we wish to stimulate and where to go for that wish to be fulfilled. To stimulate the sight and sound we go to a cinema. To stimulate human contact we go to a café. To stimulate our taste senses we go to a restaurant.

## 1.2 Multi media

### **A common language**

Communication through multi media becomes the common denominator for all disciplines and all knowledge in the knowledge society. There is no longer a separation between the hard analytical world of the physicist and the soft of the humanities. All knowledge disciplines have a common language –“ a difference making a difference”- just as HTML is the language of the internet.

Each year sees the birth of new disciplines, increasing specialisation and deeper understanding, but we miss something to tie all of this together. A common language, a universal relationship. The common denominator is: “we create for human benefit”. We humans have senses and thinking in common. Our common language is that of information, a difference that makes a difference. The condition for a holistic parallel representation within an equal and concurrent process is the use of a common language. Not just an actual language as in English, or a digital language, but something that can compare both hard and soft data and something, that can be used to find a win-win formula when conflicting interests confront one another.

We can already view the world through many kinds of physical and virtual optics. Through our spoken language, our profession, our roles as parents, as colleagues, through our national culture and our sub-culture. We recognise directly through our senses, but also through TV, the Internet, books, films and forms of art. They are collectively a kind of multi media that reinforces certain impressions whilst repressing others.

Creative thinking and an increase in knowledge can be furthered through conceptual understanding. Group creativity and collective intelligence is increased through communication. Communication through concepts, pictures, metaphors, graphical communication, mimicry, sound impressions, smells, feelings etc. that everybody within a group understands and can communicate to each other enhances the creative outcome of the processing. Since the purpose behind meeting each other in our knowledge society (instead of working from home) is precisely to create something in collaboration with others, this more efficient communication is of paramount importance.

We play a role and have roles. A conscious attitude towards communication as improvised theatre can increase the bandwidth within communication.

We want to create an architecture inspired by the theatre, where it is easy to play a role, make new scenes, and create new performances.

### 1.3 Being present

#### **Concentrating on those you share the room with**

If the building is the ultimate multi media experience, you should use this opportunity to be together with the people you share the room with.

Some people 'solve' their social problems through isolation and retreat. Turn off the flow of information completely. They sit in their own space and work alone. This seems more a problem than a solution and raises questions as to the importance of contact between people and the nature of that contact.

Some people share rooms with those they do not collaborate with and do not share room with those they actually collaborate with. In knowledge society, the workplace is also a multi media where you move to stay in project rooms together with those you actually collaborate with. And we do not need private silent offices. We can be silent together like in the reading room at libraries. We can be together without being uniform.

When you think creatively the brain has to be in 'flow'. Your challenge should be demanding enough to catch your full concentration yet not so tough that it is impossible to succeed. Most people know this feeling of flow from their hobbies. Flow can be shared among groups that try hard to accomplish great stuff. Flow is about focus and it is disrupted by everything which is out of focus. So we need confined, protected, undisturbed space to keep focused.

Space does not necessarily require a building. When sitting around the fire in the dark of the woods, the room experience is created by a single source of light. Such a trick is often employed within the theatre where the seen and unseen are achieved through the treatment of light and darkness. You can create private rooms without a building by being in some place at an odd hour or walking in the woods.

## 1.4 Interactive architecture

### Connecting people and their minds

We are often too shy to contact others. Architecture in the experience economy of the knowledge society is meant to break this barrier. If there is something exciting to see, people move automatically slower and thus have a greater chance of contact. Places which promise experience through sign, facade and architecture attract people. Cafés, chairs, merchandise etc. causes people to sit and interact. The possibility for contact is increased when we plan towns with:

- Open spaces alongside a pavement to make people stop and talk .

Places where people can sit with their back protected, raised a little above the pavement in eye level with the pedestrians passing by .

We can zoom in on situations where people thrive when they:

- Look happy
- Have a body language that is as light and pliable as a soft rubber ball
- Radiate an engaged concentration
- Relax in security

Such situations can be play, sport, dance, discussions, co-operation, flirtation and is often both “hands on” and in touch.

We have moved on from the office landscape of the industrial age, the white collar sweat shop, to the office of knowledge society, where everybody is working in networks and alliances in spaces, where the network is alive, people communicating and knowledge developed.

This new office ecology is about the interaction of people with each other and their environment. You choose the setup you want, choose your own furniture, and create the kind of results that make a difference. And in the multi media concept the building is without boundaries. You need a quick response to an idea and walk over to the videophone window looking at and talking to your colleague in the London office.

One of the preconditions is an IT mobility that liberates work from a single place.

## 1.5 Inspiration

### Changing optics, wild associations

Innovation is a key challenge in the knowledge society and experience economy. Multi media architecture with inspiring ever changing spaces can enhance creativity.

Changing optics, perception, figure ground, scale, good and bad, up and down is the basis for all creativity tools.

Associations are another creativity tool. A lot of different story telling artefacts, a scent of cinnamon from the bakery, cacao reminding you of childhoods birthday parties, a cosy fireplace, an ice bear like in the movie ”Same procedure every year”. The most crazy associations yields usually the best results.

Space, shape, the way natural light enhances the shapes as well as changing perspectives in true 3D rooms are the strongest tools in architecture.

Multi media can also be digital, large displays, colour changing LED, and surprising effects. It is easy to amaze and inspire first time visitors, but more difficult to keep amazing. The settings must be easy to change and update, just like other news in the multi media world.

Keeping in mind “a difference making a difference” multi media architecture should communicate to all senses, to Gardner’s 7 intelligences (language, mathematical, physiological, social, spatial, musical, body kinetic), to the introvert and extrovert, to right and left brainers etc. You obviously need quite a few advanced tools to do this.

Innovation is creativity turned into products and services you can sell successfully. First step is the worthwhile challenge, or the brilliant idea whatever comes first. Next step is experiments, prototypes, interaction with the users. And then the circle starts over and over when you spiral your way through the value chain. Any innovative place should have a hands on workshop to make prototypes of whatever they need to make prototypes of, virtually or physical.

Learning processes can be integrated in buildings. Knowledge is developed in a spiral form around a problem-theory-practice loop through time, ever growing towards the sublime. Each part of such a process becomes indispensable. Practice is the prerequisite for new problems to be recognised and for the process to develop. Prototyping, testing and simulation are phases of this creative process.

The industrial society’s model for working and learning is mechanical. Wheels turning, round they go. In the administrative era you sit behind your computer and write until your hand and shoulders hurt. In a knowledge society however, creation of knowledge is valuable, and that is not at all based upon regular routine. You take a lead in its development when you are both object and subject.

## **1.6 Multi media art**

Art is the sublime transaction from one subconscious mind to another subconscious mind of a difference that makes a difference. Art was unexplainable in the mechanical paradigm. Information integrates metaphors, symbols and language in a completely new way compared to a building/physical understanding of architecture. Art is thus a precursor to a break through perception.

Buildings communicate like any other art through a direct appeal to the subconscious. When the architect has performed well in her creation of space, form and choice of materials, our experience can be intense and surprising. A fantastic architecture can even change our lives. The best stories are often told through the subconscious of the architect relying upon instinct and intuition. But spatial design is as static as sculptures. In the multi media paradigm of knowledge society design must develop from the static to the interactive, like a shift from photographic to interactive multi media. Life is dynamic, and architecture becomes alive when the vision is to enhance users knowledge and quality of life.

Architectonic artistic quality is measured as experience through the senses. Things can be psychologically hot and cold. Nice to the touch, pleasant to behold. Safe and secure. The senses of a difference that make a difference. The ideal is a balance between calm harmony and a kind of dynamic disharmony. Both the safe, familiar and the challenging. The art is enhancing experience of material, nature, light, the city and not least the people: us. A building is to be experienced again and again. We quickly tire of the fashionable and the mannered. A 'cult' film is more of a role model than an advertisement trailer.

Architecture can indeed be dynamic. Alive. Something that changes according to the needs of the user. Something that can open and close. The mechanical paradigm from our industrial heritage is replaced by an organised consciousness born out of the information age. The users make the building become something organic, changing over time and changing itself according to purpose, and at the same time it becomes a theatre to the dramas of life.

The breakthrough is when the audience becomes the actors. When you yourself decide what it is you want to do, how it should be done and what kind of interaction is necessary to set the scene. To tell stories and show inspirational images are one way of telling others about who you are, what you do, and invite to teamwork. Such "advertisement" could also be a real inspiration for creating new working relationships. It is an invitation interactive exchange of ideas and methods where you become a catalyst for innovation. All the levels of an organisation from the individual to the corporate can be visualised working in this fashion. The organisation can visualise strategies and appropriate actions, maybe even through the use of images and sounds that reinforce conceptual development.

Our working culture is facing both internal and external market forces. In a knowledge society the motivation to take an active part in those market forces becomes essential. Work is a bazaar and ought to be considered as such in its appearance and workings. A place where you can 'shop' between individuals and departments/specialities.

The space, the shapes the materials should be such a strong story that it cannot be flooded by the chaotic items of the users. They should be so strong that they actually flourish with the users, their pluralism, ornament and decoration. When the steel doors open in the bazaar of Jerusalem and the shopkeepers display their merchandise the stage is set for objects and subjects to mix in an intoxicating whirl that continues and changes irrespective of the individual transactions of which it is composed. Some shops have a siesta whilst others continue the ply of their trade by spreading themselves across the territory of their neighbours. The overall picture is incredibly alive and dynamic even though the buildings in the bazaar can appear shabby and worn.

The result is dynamic and exciting, a kind of order out of chaos that contributes to the business at hand. Something beautiful emerging from something ugly. This is especially interesting when we consider that architects often live in anxiety that the user ruin the beauty of their creation. It could just as well be the opposite.

## 1.7 Sustainability

### **Architecture is a multi media between people and natural resources**

The building is an extra skin to our body. Even in this well known and very basic functionality the knowledge society paradigm makes a difference because this skin is

interacting with the environment. It is not only protecting us from the weather but also receiving solar energy. The focus is no longer on the power train of the industrial age: Energy, but on the human centred comfort, which can be provided without energy in passive solar buildings.

We need to develop skills and ways to create synergy with nature without harming the environment. Something that is concurrent to the process of natural growth. Heating could become multi media, being available to individuals on demand - just as we know it from cars - rather than ambient in the entire building,

Ecology is an essential design consideration creating sustainable buildings. This is not just about heat loss and the effect upon the environment, but also a consideration of activity, office equipment, lighting, everything to be considered from a total life cycle energy perspective, even the effects of increasing production is to be taken into account. A more expensive building could have an increased negative effect upon the environment, even though its energy consumption may well represent an improvement over standard practice. Such considerations are very complex and needs systems thinking.

## 1.8 Branding

### A knowledge icon

The building is an important part of your company branding if your building full fill this list:

1. Unique, distinct, easy to remember
2. Passing the postcard test. Attracting visitors and tourism. Putting your building on the map of architecture
3. Being even better in real life 3D than on the photos
4. Enhancing the visitor's life

Buildings are measured by size in the industrial paradigm. But how does that make sense in a world where people buy property in "Second Life" virtual worlds. In the knowledge society paradigm value comes from branding as well as from whatever the building does to its inhabitants. Imagine that the building could change the life of the users, make them more happy, more creative, more entrepreneurial?

## 1.9 Building = information x material

LEGO has patented its own interface. A precise geometrical relationship, interface, has suddenly become a by-word for child creativity. Interface in the building industry is also the key to utilising new technology that contributes to a dynamic and creative existence. If we could follow the lead of LEGO, we could build without the need for special training or tools, because the necessary knowledge has already been integrated in the design of the product. We have merely to use our creativity. LEGO have their own CAD system, where children can design in virtual space, in a way that we only dream of in the building industry.

Industrial age culture focuses upon linear design and linear thinking. In a knowledge society the paradigm shifts to feed back free form, from the mechanical to the systematic, from a building as a physical thing to a building as multi media within which we communicate, and

the cubic will suddenly be obsolete. Just as when a car became something entirely different from a horse carriage with a small petrol engine mounted at the front.

It is no longer necessary to build in x and y directions because that was the way the engineer and architect of yesteryear had to draw them. It was easier to design when one could use a T-square and angle to do the work. Even though we have the tools to do otherwise, we still continue familiar practice. Gehry's contribution to architecture is in taking a lead in showing a paradigm shift. Like it or love it, he has shown it is possible to use human creativity and the computer as concurrent means unto an end. Visit the Guggenheim museum of modern art in Bilbao and try to deny that your senses are stimulated.

Even the physical building process is redefined in the knowledge society. Information is the result of the design process. In the production phase the material is transformed into the building. Information tells how. The building process is becoming a 'black box' between the digital model and the user. Input becomes a reduction of the gap between the virtual and the physical. The design process is the human part, the creative, sensual part of the process. When complete, one has merely to press 'enter' and the digital model is automatically sent, payment demanded and confirmed within a click. Your dream has been translated into a living reality you can soon enter and engage.

The building process will become totally automatic. Modules will be produced through robot technology as we see in the car industry, only more agile and mass customized. Cutting as we know from the textile industry, and printed from the three-dimensional printer as we know from rapid prototyping. Rapid manufacturing has come of age. And just as your printer is just as fast when the message you print is complex and complicated, so will the rapid manufacturing of tomorrow be indifferent to the complexity of you design. More complex design might even reduce the material and resources needed.

The important difference between buildings and other automatically produced industrial products is the difficulty of transporting them to the particular place they belong to. Our vision is the automatic and efficient production of buildings partly through the manufacture of standard performance components and partly through non-standardised materials that expand and stiffen to form the wished-for shape. With a continuous rather than discontinuous shape virtually all of those precious details between the junctions of the building disappear. It will be as easy as putting up a tent, only you got to decide what it looks like. An ecological house should also be able to expand and contract. Be added to and have taken away. Even be transported from one place to the next. And be taken apart and reused.

## **1.10 Man as biological creature**

Information expand, increases and encompass the entirety of human existence. This includes our biological existence too. We need sunshine to create vitamins and relieve the depression of winter (SAD). And we have a need for safety and comfort. Here too, the interface/filter theory can be considered in terms of something physical with an informational condition.

The interface between the building and man as a biological creature is usually described within the context of sick building syndrome. The other side of the coin is regarding this relationship in a positive sense. Health, healing and holism.

Ecology is all about the relationship between the organism and its environment. Our relationship with our environment, each other and things. This leads us to a new architectural concept with the garden as a metaphor for spatial experience, user influence and flexibility as well as a metaphor for fruitful sustainable growth. The starting point is an examination of our social and biological requirements. Only through an understanding of ourselves as human beings and our biological needs can we understand how to live in symbiosis with our environment.

Man developed from ape to prehistoric man in approx. 10 million years. The development from prehistoric man to modern man took a mere 200,000 years. Until 100 years ago, the majority of people lived outdoors for most of their working time. It will take an additional 200,000 years before we will notice any significant difference in our evolutionary development. It is therefore biologically necessary to reproduce the natural qualities the human body has evolved to fit. We are not evolved to sit for hours in front of a computer. We need to move, change position, talk, relax, switch off, switch on. Outdoor qualities such as daylight, birdsong, the sound of a water fountain, aroma, fresh air – as in the garden – but within our micro-system within the macro-system.

As a biological creature, we have an instinctive subconscious need that has been refined over a period of millions of years. We are not aware of it in a direct sense, but it is there nevertheless. It is hardwired like ROM in the *amygdala* of the brain, the place where we decide whether something is good or bad. We have a key to powerful positive human perception if we can tap such a basic force. Likewise, our genes are a kind of biological memory. If we do something that is biologically positive, then the outcome is a healthier existence. Both physical and psychological health is connected to a historical memory that has accompanied us for thousands of generations. It is quite an overwhelming perspective. The Japanese recognise them and absorb them into their culture. Such qualities can be beautiful and poetic and among them we can mention:

- Flowers and fruit as a signal for food and scent
- Falling water, spring water and warm water
- Daylight
- View and sunset
- Fire/hearth
- Birdsong
- Earth, gravel, stone
- Air, breeze, wind

If we add all these ingredients we have a powerful means of expression. They have been our constant companion throughout the last 200,000 years and they ought to be a part of our continued existence.

People return to their ancestral occupations when they are off duty. Fishing, gardening, walking, hunting, baking bread, sitting around a fire, sitting in company, standing alone with a back to a wall. These activities are counted with little weight in architecture until we consider the importance of psychological well being as being a large part of our physical health. Such considerations are generally ignored apart from those of an artistic or theatrical persuasion. In an effort to battle through a stressed existence, a lot of us are forgetting what the meaning of life is all about.

We all know that light is important in order to see, and architects, painters, photographers, theatrical directors and film crew are often aware of light as being a medium to mould. Even though we are not as dependent on light as plants for example, our biology and psyche is never-the-less affected by light. One of the effects is that our biological immune system is strengthened through the presence of an abundance of light, we become less sleepy, more alive and our abuse of narcotics, alcohol, tobacco and sugar decreases. This is as much through psychological well being as physical health. Researchers worldwide prove a connection between daylight, serotonin hormone and wellbeing. The blind do not possess the same symptoms. Research also shows that a day lighting level of between 2000-3000 Lux is sufficient to avoid SAD (winter depression). In this respect material technologies that filter direct sunlight and admit daylight is a part of the multi media paradigm. It is by the way the same light preferred by artists in their atelier.

## 2. Adaptable house

Building operates like everything else within a cost/benefit market. So far building research has been obsessed with cost reduction. It is however of decreasing importance with the present levels of land property cost. The benefit, the value part of the equation, the focus on users and experience economy is of growing importance.

Many partners in this ERABUILD were also participants in the Nordic Innovation sponsored project “Adaptable house” which focussed on the benefits, the value creation. The result is the following definition value of future housing:

Imagine buildings:

- That really make a difference to the user
- Supporting your optimal performance
- You can influence, shape, develop
- That learn from your life.
- That make you feel better every morning you wake up
- Cure winter depression with plenty of daylight
- With perfect indoor climate, no noise, fresh air
- Cleaning automatically
- Perceived from the interior rather than the exterior

Designed with

- Sensual shapes and amazing daylight.
- With a continuous rather than discontinuous shape without troublesome junctions
- A theatre like large empty volume divided and screened by removable walls and filled with artefacts
- A small area but a large volume you can fill with decks and extend with additions
- The old alcove concept (recess in a room, screened off by pillars, balustrade or drapery) creates a “pull down menu” functionality when needed
- A room which is beautiful when empty as well as when gradually divided by partitions
- Multi media art expressing what home is all about
- Composed from a variety of facade components and systems like balconies, terraces, sunshades, solar heating, photovoltaic, bay windows, windows, walls etc.
- Reflective surfaces that can mirror clouds, sky, sunsets and surroundings
- A fruitful garden-like interior, with fountains and flowers
- Encouraging us to break out of the box and achieve greatness
- Supporting, encouraging and developing diversity

In dialog with the users

- A kind of “20 questions to the professor game” sampling good architecture in a dialog with expert systems and experts
- An ICT expert system preventing solutions that do not fulfil building regulations and functional demands

### Financed

- With a pay back time based on realistic evaluation of life time of the particular building encouraging more durable, healthy and sustainable buildings
- Using leased transportable modules
- Based on a self assembly montage system as simple as the self assembly IKEA furniture

### Sustainable

- Absorbing CO2 through green plants
- Producing more energy than consumed
- Collecting rainwater and use it to substitute drinking water
- With super insulating transparent materials and components that filter excessive sunlight and convert it to electrical energy
- Dynamic heat supply exactly where it is required right next to your body instead of general space heating
- Automation based on self organising biological thinking, and genetic evolutionary algorithms
- With materials that change shape and properties creating new opportunities for filter/interfaces with nature and the eco-system
- With new energy converters like fuel cells making the buildings autonomous, producing both heat and electricity in symbiosis with solar heating and photovoltaic
- A system of reusable recyclable modular Plug&Play components dramatically increasing the components' life span and reducing the embodied energy and waste from building materials
- a building structure that is so general it can basically be used by different users, for different purposes, at different times

### Living for ever because it is

- An attractive house
- Adaptable to new functionality and new users
- Easy and inexpensive to repair and maintain
- 0-energy

### With a new kind of rooms

- A (refrigerated) E-business locker accessible by the delivery man
- A theatre room utilising the height of the room to store furniture and artifacts not in use – much like IKEA's 3D thinking
- Theatre like flexibility
- Large doors connecting indoor with outdoor
- Feng Shui, meditation like rooms for brain still, silence
- A bounty land tropical beach paradise bathroom, wellness room
- Multipurpose Swiss army knife like room and furniture
- Pervasive computer and media presence
- Co creation slow food BBQ like kitchen merging cooking and eating to make the entire process social

### Improving the environment

- Make low-value sites and buildings attractive
- A hierarchy of domains to create social interaction and social life
- Public areas like streets and squares, preferably covered and protected in severe weather conditions and open when the weather permits it
- Semi private areas between the public and the private area. In the office buildings, the meeting room, canteen and auditorium could be such semi private areas. In a home it could be the porch, terrace, balcony facing the street as well as a welcoming entrance hall. Places to stop and talk when you have met someone
- Private areas in the office, home and garden where people can sit with their back protected, raised a little above the pavement in order to have eye contact with passers by
- Places with experiences that attract people. Cafés, chairs, merchandise etc. causes people to sit and interact
- Reintegration of work and residential areas taking advantage of the workplace facilities like conference room (for parties and cinema), cantina (for restaurants) and visa versa. It also saves a lot of parking places and ad activity and life to the streets
- Space for sport and play
- Workplaces in an suburban area where people want to live like in Silicon valley
- Removing commuting barriers by increasing speed, regularity and frequency of public transportation in order to reduce car traffic
- And/or to substitute commuting some days with ICT
- With manmade landscapes, parks, lakes, beaches instead of an asphalt jungle
- Planned for more house with a view

### Built by an industry offering

- Value as perceived by users
- Adaptability
- Out of the box architecture
- Mass customisation
- 20 year service agreement and warranty like Toyotas factory made houses in Japan
- Open Plug&Play system for architectural design
- Adapting to any European building code
- E-business and one stop shopping
- Design, co-design and dialog with customers
- User community
- Facility management taking care of the house, keeping it safe and sound
- Updates to software in home automation
- Hotline support for “do it yourself” maintenance and updates
- Financial partners’ interest in a positive development of property value
- Holistic concept where a building is “sliced” in transportable modules combined with a milling robot that can produce with great accuracy without limitations to design.
- Scanning technology will have a large potential in reconstructions and retrofits

### Using one or more of these innovative integrated design and production tools

- Keeping the entire model in-house like NCC Komplet
- An open source model adding modular components ordered from the internet, adding up to a complete house

- A kind a docking-station concept where you add entire prefab rooms, even stacked on shelves (like Open house)
- A kind of New York loft model where you build a void space, a store room, and fill it with highly adaptable modular self assembly Plug&Play furniture like partition elements, bathroom units
- A holistic approach where you design whatever shapes you want and slice the design in units transportable within the 40 feet container volume
- On site production with robots

#### Produced with

- More industrial robots in production
- The present human process of building could be mimicked by humanoid robots only without mistakes and errors
- Plug&Play components
- Alliances with subcontractors
- Test, quality, extended warranty, service contract
- A life cycle perspective: 0-energy, renewable materials & energy, sustainable architecture
- Universal Adaptable Standardised Interface between components
- All HVAC installations, bathroom, kitchen etc. in one 40' Container unit to be sold worldwide
- ICT making the house and home understand you

#### Including new technologies like

- (Self-) cleaning and repairing nano surfaces
- Pervasive augmented fulfilling your every need without in any way being visible or noticeable
- Fuel cells and photovoltaic

### 3. Erabuild Plug&Play project

The background for this Erabuild Plug&Play project is that the building component industry has succeeded in the industrialisation process where the building construction industry has failed. Some of the building component producers have even successfully transcended into the experience economy, particularly the sector selling kitchens and bathrooms. The same industries have been very successful in e-business and web based configurators.

The paramount challenge is to shift to experience economy, focus on benefits and produce something extraordinary. To produce an industrialised product the consumers will prefer because it is better rather than cheaper.

The idea is that the easy road to knowledge based construction business could be to produce the entire house from industrial components.

The missing link in this process is:

- Not all parts of the building is available as components
- Not all components are parametrically scalable to be ordered in any size and particularly not in any shape
- The interface between the components is missing except for the glazing industry

The vision in the Plug&Play project is that in the future, the largest part of the built environment (new or existing) will rely on the concept of open building system characterised by the following properties:

- An entire building can be assembled from industrial parts or sub-systems, and all (or at least most) of the building can be disassembled (with any part having the potential to be assembled elsewhere) according to a well-defined contract (set of formalised rules & constraints);
- Any individual industrial part can be transported and functionally bound to the system without cutting, milling or any other transformation, provided that it comes with the right interfaces compliant with the rules & constraints put on the parts. At the extreme, the system should be designed for self-assembly;
- The concept must rely on an adaptive model for creating built environments and places of living that are 1) tailored to living individuals according to their requirements and personalised needs, 2) tailored to manufacturers/suppliers so as to ease their tasks in specialising their existing products or to create a new manufacturing line, and 3) tailored to developers/builders to assemble and integrate
- The design system should be able to transform a design into systems components based on a common interface. The e-business order software and the production should be parametric, scaleable, and open to non-linear geometry. The production should be mass customisation open to different performance criteria and building codes. It should be designed to be disassembled, replaced and recycled.

To achieve such a desired state, it is required that:

- The concept of open building system integrates (most of the time heterogeneous) points of view of various actors (architects, manufacturers, developers...). Moreover, it has to target new as well as existing buildings, as well as maintenance and

rebuilding, besides construction; it should be open to any kind of material, suppliers and nationalities;

- The concept of open building system is adapted to production relating to mass customisation relying on off-the-shelf part / component catalogues, as well as creative (architectural) open to different performance criteria and building codes;
- The production dealing with open building systems should be parametric, scalable, and open to non-linear geometry;
- The development of open building systems must strongly rely on ICT, especially at level of semantic modelling of interfaces and constraints. E.g. a design system should be able to transform a design into systems components based on a common interface;
- All actors, especially manufacturers, agree on standardised interfaces / ports to be further developed for components / parts;
- An open building system must fulfil building codes in the 5 ERABUILD countries.

The focus has been exclusively on production within an industrialised paradigm. There are already a lot of system deliveries where the components are “Plug&Play” for instance for steel construction (Lindab) and profile systems for glazing (Schüco).

If you want right away to build a house from the Plug&Play concept the status at present is:

At building scale

- The house can only be assembled, not disassembled and recombined
- The house can only be delivered in flat elements
- The link between design process and production is only available in very closed proprietary systems
- The choices of customisation is very limited

At system scale

- Steel building can be configured
- Glazing and windows can be configured
- Kitchens and bathrooms can be configured
- HVAC systems can be configured

At component scale most suppliers have a web site ordering module with configuration options. However only few can provide those configured components in 3D objects with attached BIM information related to the order.

The potential benefits in Plug&Play production should be examined in the following context

	Industrial paradigm	Experience economy
User	<ul style="list-style-type: none"> <li>• Price is fixed</li> <li>• Lower price</li> <li>• Minimal energy consumption due to</li> <li>• Better quality control</li> </ul>	<ul style="list-style-type: none"> <li>• Multi media design</li> <li>• User centred functionality</li> <li>• Adaptability</li> <li>• Easy maintenance</li> <li>• Recyclable</li> <li>• Free form 3D objects</li> <li>• Beautiful interfaces</li> </ul>
Producer	<ul style="list-style-type: none"> <li>• Industrial montage</li> <li>• Faster process</li> <li>• Less waste</li> </ul>	<ul style="list-style-type: none"> <li>• Paramtric design</li> </ul>

The benefits from indoor production is

	Industrial paradigm	Experience economy
User	<ul style="list-style-type: none"> <li>• Better quality</li> </ul>	
Producer	<ul style="list-style-type: none"> <li>• No weather problems</li> <li>• Close dialog between designer and producer</li> <li>• All materials are in house (as long as the assortment is limited)</li> <li>• Same team</li> <li>• Standard for all details makes the process fluent</li> </ul>	

Quite a lot of producers like NCC komplett, Myresjøhus, Smålandsvillan, Danhaus etc. can already produce the left column industrialisation but:

- Architecture is at best very basic and without experience
- Choices are very limited
- Only new houses can be produced

Very few can produce the right column experience economy kind of products. They can however be produced by hand.

## 4. Examples and experience economy designs

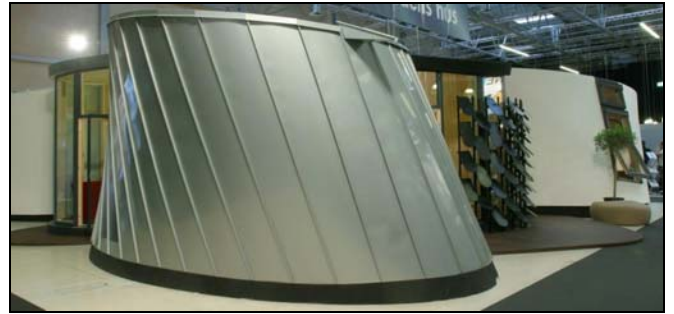
Gehry technologies and Arup broke this complex stadium for the Beijing Olympics down into modular parametric components and cut the cost with 50%.



This building in Chicago was made from automated machines capable of milling components in 3D shapes.



VillAlive is assembled from room size modules just like BoKlok modules from Skanske except that the modules are double curved, lighter and full of experience and adventure.



## 5. Plug&Play issues map

<b>Component</b>	<b>Interface</b>
<b>Size</b> <ul style="list-style-type: none"> <li>• Handheld</li> <li>• Surface</li> <li>• Room</li> <li>• Container</li> <li>• Max transportation</li> <li>• Building</li> </ul>	<b>Structure</b> <ul style="list-style-type: none"> <li>• Load bearing frame or wall</li> <li>• Component &lt;=&gt;Frame</li> <li>• Component&lt;=&gt;component</li> <li>• Slicing</li> </ul>
<b>Made to measure</b> <ul style="list-style-type: none"> <li>• Zero tolerance</li> <li>• Any geometry</li> <li>• Digital scanning on site</li> <li>• Parametric modularity</li> <li>• Parametric free form</li> <li>• 3D parametric modularity</li> <li>• 3D printer</li> </ul>	<b>Assembly-disassembly</b> <ul style="list-style-type: none"> <li>• Dry sealed without glue, plaster and sealant</li> <li>• Bolted and clipped rather than nailed</li> <li>• Self-assembly mindset</li> <li>• Same joint, corners, interfaces</li> <li>• Same combined open and closed business model</li> <li>• Same materials</li> <li>• Same tools controlled by more sophisticated ICT</li> </ul>
<b>Directly from digital model to component</b> <ul style="list-style-type: none"> <li>• Robot production</li> <li>• Mass customisation</li> <li>• Rapid manufacturing</li> </ul>	<b>Digital interface</b> <ul style="list-style-type: none"> <li>• Assembling in digital 3D model</li> <li>• RFID</li> <li>• Digital, electrical connectivity (USB)</li> </ul>
<b>Business model</b> <ul style="list-style-type: none"> <li>• Component industry</li> <li>• E-business</li> <li>• User co-design</li> </ul>	<b>Business model</b> <ul style="list-style-type: none"> <li>• Component industry</li> <li>• Interface industry?</li> <li>• Montage industry?</li> <li>• Self assembly</li> <li>• Contractors and subcontractors</li> </ul>
<b>Organisation</b>	
<b>Open Plug 'n play alliance</b> <ul style="list-style-type: none"> <li>• B2B</li> <li>• B2C</li> <li>• Digital models</li> <li>• Marketing</li> <li>• Service</li> </ul>	<b>Open USB like standard for</b> <ul style="list-style-type: none"> <li>• Components</li> <li>• Dimensions</li> <li>• Digital information</li> <li>• Assembly</li> <li>• Test</li> </ul>
<b>Success criteria</b>	
<b>Love your building more</b>	<b>Hate your building less</b>
<b>Sensuality</b> <ul style="list-style-type: none"> <li>• Visual</li> <li>• Tactile</li> <li>• Acoustic</li> <li>• Scents</li> </ul>	<b>Economical</b> <ul style="list-style-type: none"> <li>• Reduced construction cost</li> <li>• Reduced maintenance cost</li> <li>• Reduced energy cost</li> </ul>
<b>Architecture</b> <ul style="list-style-type: none"> <li>• Shape</li> <li>• Space</li> <li>• Functionality</li> </ul>	<b>Durable</b> <ul style="list-style-type: none"> <li>• Durable surfaces</li> <li>• Durable materials</li> <li>• Compatibility available after many years</li> </ul>
<b>Personal home</b> <ul style="list-style-type: none"> <li>• Decoration</li> <li>• Colour</li> <li>• Art</li> <li>• Souvenirs</li> </ul>	<b>Less and easier maintenance</b> <ul style="list-style-type: none"> <li>• Accessibility</li> <li>• Plug 'n play replacement</li> <li>• Digital diagnosis and hotline support</li> </ul>
<b>Healthy</b> <ul style="list-style-type: none"> <li>• Daylight</li> <li>• Fresh air</li> <li>• Hygienic</li> </ul>	<b>Adaptability to changes</b> <ul style="list-style-type: none"> <li>• During the day</li> <li>• Seasons</li> <li>• Life phases</li> <li>• Upgrading to new technology</li> <li>• Multipurpose</li> </ul>
<b>Learning</b> <ul style="list-style-type: none"> <li>• Learning home automation</li> <li>• Flexible</li> <li>• Mobile</li> </ul>	<b>Sustainable</b> <ul style="list-style-type: none"> <li>• Zero energy</li> <li>• CO<sup>2</sup> absorbing</li> <li>• Minimal pollution</li> <li>• Recycling</li> </ul>

## 6. Plugin and play scenario

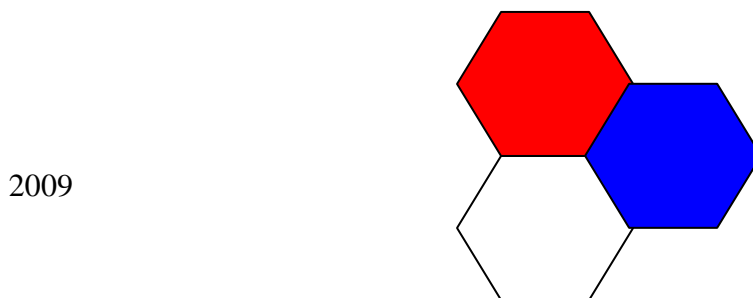
In the IT-world a plug-in is software adding new functionality to your computer. Something you download, install and suddenly you can hear MP3 music, use your computer as on a Skype telephone, play DVD's etc. New functionality without new computer.

This scenario is based on the same idea:

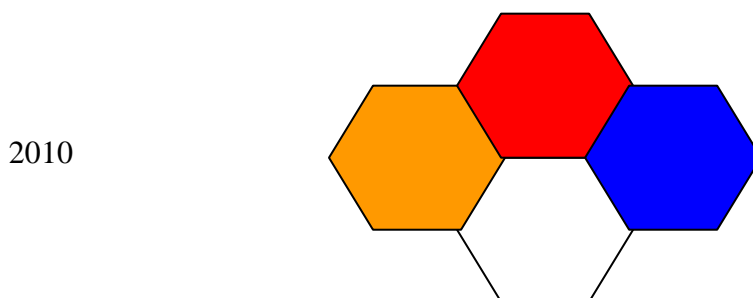


20 years ago back in 2007 when I was a bachelor I bought a nice building site and bought a basic docking station house with a bathroom attached.

As you know, a docking station house is a basic house with potential for growth. When I was alone, this basic house with kitchen/living room and a corner for my king size bed was all I needed.

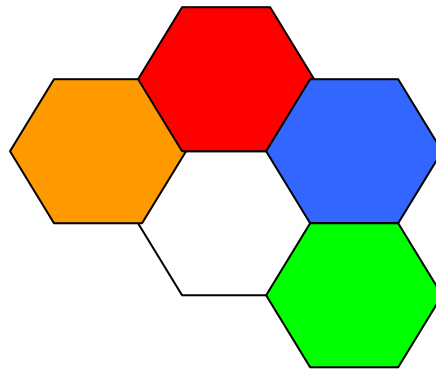


A few years late I was married, my wife moved in and we went through the offers on the internet and ordered a really fantastic bedroom. It was delivered and attached to the docking station, plugged in and a few minutes later the truck left and next day we had a housewarming party.



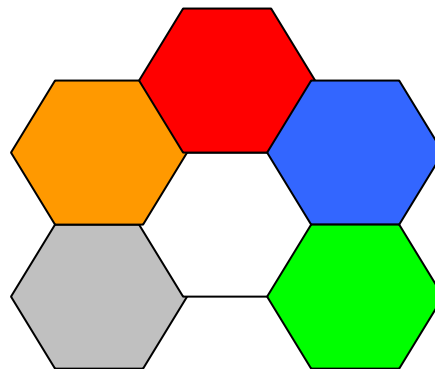
We surfed for the best wellness room and found a very exotic Japanese offer. A month later it arrived.

2011



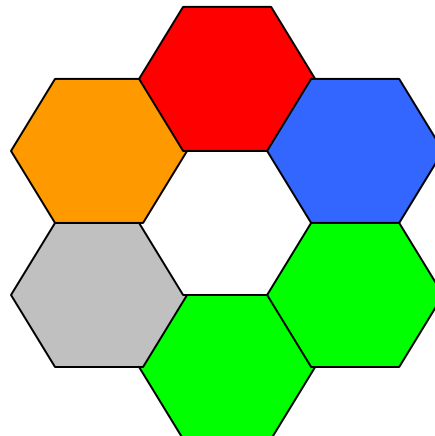
A few years later we had our first baby and we needed another bedroom and more space in the living room. We bought an additional bedroom doubling as a playroom

2012



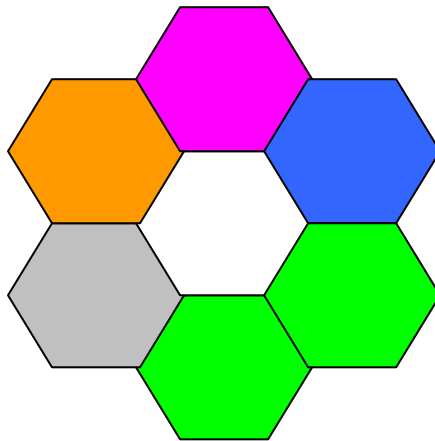
We evidently needed more space and bought an additional living room module with the most fantastic kitchen.

2013



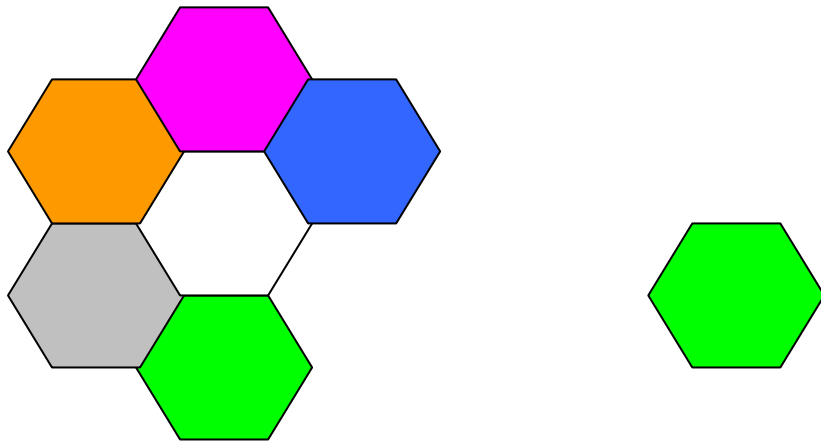
When our second child was born it was time for another child module. We upgraded all the windows to super-insulating windows. This was also a Plug&Play operation done in one day.

2015



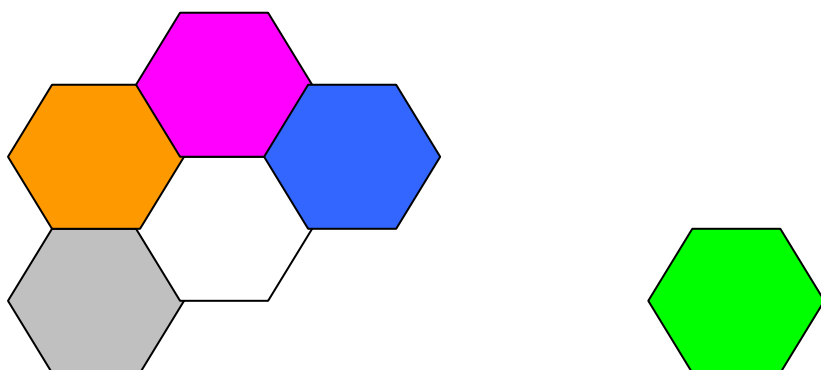
The old bathroom was very outdated so we exchanged it for a much more intelligent and energy saving one with solar heating on the roof. We got a good price for our old bathroom which is now serving in Poland. We upgraded all the roofs to photovoltaic.

2032



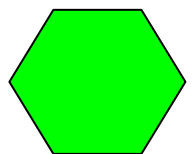
The first kid left home and brought along her module.

2035



The second kid left home

2036



We decided to move from Denmark to Cote d'azur and brought along the house.

## 7. Design and ordering scenario

“We wanted to build our own new house and opened the new Artificial Intelligence (AI) design web page”.

You know the kind of software where you can compose a face to fit someone you have seen. AI design is a little like that. You are shown a lot of bathrooms and frame the design details you like in each of the pictures. The software put all these clues into a favourite list of pictures you can compose in a drag and drop mode until you have a visualisation of your favourite bathroom. This visualisation is then processed by the computer into several scenarios. Again you can frame the solutions you want and this way your personal bathroom emerges. All along you have a price meter running based on the actual components and size of bathroom you have selected. You continue the same process with kitchens, bedrooms, living rooms etc and finally with the entire house. All along the process you know the price tag of your new building.

When you have decided that this is your favourite building you move on to the authorities approval module. All your choices are uploaded to this official website where all building code demands to energy conservation, indoor climate, structural strength, acoustics, accessibility, fire safety, environmental loads etc is calculated and any un-conditional results are flashing in red until the problem is solved. The building application is mailed directly from the website to your mailbox.

You move on to the ordering module. This module is based on a structured system for ordering of the different kinds of component for the building. You move through ordering the deck, floor, facades, windows, ceiling, roof, HVAC installations, electrical installations etc. In each order module you can choose different suppliers who are capable of delivering the parametric scalable components. You can compare cost, warranty, service agreement, delivery time etc and choose the most favourable. You are guided through this procedure until you have ordered everything for the building.

You move on to the montage part of the web site. Each component you have previously ordered has attached a number of montage “points” depending on size, weight, shape, height over ground, number of bolts, joints etc. Using the total number of “points” as entry you search the montage company with the best offer in relation to price and your delivery schedule.

When the house is designed, approved, ordered and montage is scheduled the software takes you through a recalculation process to make sure that logistics are correct and prices are accurate and you are now ready to enter the finance part of the website to finalise your ordering with the best financing available.

All these “made to measure” components are produced on automatic factories by robots and rapid manufacturing machinery. The rest of the components are more standardised.

Within a short time the montage crew arrives at your site, and start assembling your new house. The assembly process starts with the roof and is followed by walls, windows, doors and deck in order to close the building within the first day. Later all the interior components and installations are mounted in a Plug&Play system and the house is ready.

Throughout the entire process the information flow is 100% digital. And the house is made 100% from “made to measure” components. Nothing is cut, glued, filled or processed on site. All montage is dry. All components can be attached and detached in a simple way. This also means that all kind of maintenance, repair, refurbishment and reconstruction work can be carried out with Plug&Play components ordered from the same web site.

## 8. Production scenario

Once upon a time a text was dictated to someone who steno graphed in, typed it, had it corrected, retyped it, negotiated a price with the print shop, send it to the print shop, had a typographer set it in led types, had the preprint corrected and then finally had it printed. Today you type, have misspellings corrected by the computer and click on “print”.

Printers are also available for 3D objects. The Dutch company [www.materialise.com](http://www.materialise.com) can produce man size objects in polymer. The American company [www.zcorp.com](http://www.zcorp.com) can produce somewhat smaller objects in gypsum material and cure them in polymer.

The building size 3D printer is shortcutting the construction process in the building sector in a similar way. The days will be over when

- You destroyed the 3D information in you CAD model as you printed drawings and descriptions
- Had a tender among construction companies, negotiated the price and contract
- Had the construction company analysing your drawings for flaws that can justify extra bills
- Had the worker interpret approximately what you construction look like
- Make wood or steel casts with poor accuracy
- Poor the concrete into these casts with similarly poor accuracy
- Followed by building meetings and eventually arbitrage to sort out the disputes

When the concept of 3D printer is fully implemented, the conventional process is obsolete. You click “print” and software will control a robot to build whatever can be build from concrete composite.

Most 3D printers add thin layers horizontally supported by a media. It is not feasible to build a containment around a house and fill it with polymer or gypsum powder like it is done in 3D printers.

The advantage of this 3D printer process is:

- Almost all expenses of man power is saved
- Form work for casting concrete is saved and no waste generated
- Any architecture, style, shape, surface structure, pattern etc. can be build
- Concrete can be cast in an intelligently distributed density variable (0-100%) saving material and minimising thermal bridges
- The building process can be fast as the robot can compose concrete with fast curing
- The robot builds exactly like designed with minimal tolerances allowing use of prefab components later in the process
- The building is stronger, airtight and water tight as the process is continuous without joints
- Special surface material can be added with the same robot

One concept is to produce the desired shape in polystyrene insulation foam, mill it to the desired shape with a robot and coat it with shotcrete.

The ultimate perspective is that you can build whatever you want where you want it. The robot can be used in new buildings, even high rise, and it can be used within existing rooms. It can build whatever shapes you fancy. You can even 3D scan Gaudi’s Sagrada Familia in

Barcelona and Michelangelo's David statue and copy it to any scale (respecting intellectual property).

The perspective is furthermore to extend this concrete technology to include a metal technology for electric cabling and a polymer technology for pipes. This way you could build anything but real wood.

## 9. Discussion

The new challenges of the Plug&Play concept is:

- Somebody must take the responsibility for the total result, that is air tightness, energy consumption, durability, etc.
- Putting thousands of P&P components together increases the risk for leaks.

For this reason this work group proposes a hierarchic concept where:

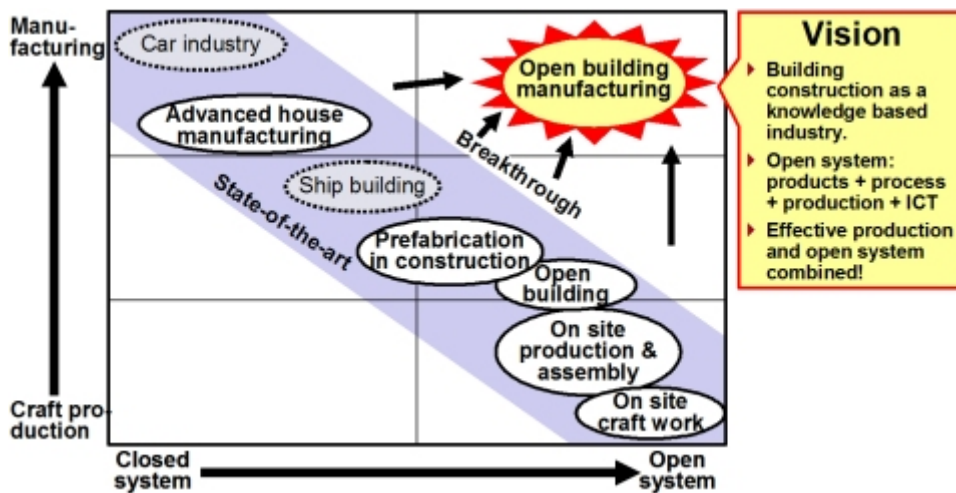
- A company takes responsibility for room size modules.
- These modules can be configured and assembled for potential disassembly entirely within the responsibility of the company

## 10. Plug&Play project vs. Manubuild

When you look through the comprehensive list of objectives of Manubuild it looks very much like our project. They have already produced convincing results and presented them in books and conferences. Manubuild present itself as follows:

The ManuBuild vision is of a future where customers will be able to purchase high quality, manufactured buildings having a high degree of design flexibility and at low cost compared to today. For the first time, inspirational unconstrained building design will be combined with highly efficient industrialised production.

ManuBuild targets a radical breakthrough from the current "craft and resource-based construction" to "Open Building Manufacturing", combining ultra-efficient (ambient) manufacturing in factories and on sites with an open system for products and components offering diversity of supply in the market.



Enabling business processes, ICT systems, new materials and technologies and smart components etc will underpin this.

Potential impacts include significant reductions in the number of construction industry accidents, waste and the costs and time to construct buildings. This will allow Europe to improve it's building stock, whilst also releasing resources that can be allocated to other income generating industrial sectors.

***The BIG PROBLEM with Manubuild is that the results of the process somehow look exactly like the buildings from the sixties which has already proved unpopular. The operation was successful but the patient died. Manubuild is almost entirely within the industrialised society paradigm using the optics of the producers and focusing on the benefits for the producers.***

## 11. Learning from the kitchen industry

The kitchen industry is so far the most advanced in the building sector.

You can walk into a kitchen shop and configure almost any kitchen with a little help from their interior architect.

Some plain industrial society modular components are assembled to all the cupboards. They are covered with tables parametrically cut to fit your specific kitchen. And you can have them free form parametrically directly from your CAD model in any material: wood, Formica, Corian, composite and even glass.

Then you add whatever fronts, handles, accessories and decorations you want.

The system is also an open system. You can replace a cupboard with one from another supplier. The system is furthermore open to any kind of white goods, refrigerators, ovens, dishwasher etc. You can also install any kind of light, faucet, sink etc.

The kitchen industry is an example that you can actually do all the things we propose in this Plug&Play concept.

## 12. Learning from the car industry?

The building construction industry is often compared to the car industry. Why don't we build houses the way we build cars? The question is often asked within a production paradigm. Why don't we produce houses the way we produce cars? This distinction is important because few people actually want houses to be like cars. You can tell that because they actually sell mobile homes in USA, houses built with the technology and materials from campers. They happen to be low status slum like buildings. And think about it. The kind of material we know from cars are not very durable and they are very difficult to repair. In the appendix quotation from Wikipedia the development from a car like product to a house like product is described. The significant difference is that car materials are abandoned and substituted by house like materials, primary wood and plasterboard.

### 12.1 What is the difference between cars and houses?

Transportation is one significant condition for a product to enter the global market. Ordinary houses cannot be transported, only their components.

#### Road transport

The transportation is no issue for cars. The entire infrastructure is designed for cars. But is not exactly designed for houses. In USA you can transport houses 16 feet wide. That is almost 5 m. You can do that in Europe as well, but it is very restricted. Objects more than 4 meters wide are difficult to fit into the transport infrastructure. Bridges in Europe has a free height of 4,15-4,25 meters making transport of houses taller than 3,6 meters very difficult. In USA the bridges are about 30 cm higher allowing houses to be transported with sloping roofs on the modules. The American mobile homes assembled from 2 units takes advantage of this situation.

#### Rail transport

Rail transport is an interesting alternative. Rails can transport much larger objects. In USA rail transport can hold two containers on top of each other and those containers are even higher (and longer) than in Europe. A total of 17 feet (5,1 m) height is possible. In Europe the max height of train transportation is about 1 meter higher than the roads but the width is more limited and the cross section is reduced the higher you get.



### Air transport

Air transport has been tried with this 3 tons heavy Futuro house. Today the max weight is around 20 t with no limitations to the dimensions. It would be possible to move a complete house by helicopter if it was build in composite technology. It is technically possible to build even larger helicopters. See <http://www.berting.nl/futuro/>



Boeing fly very large objects but only between airports.



The traditional Boeing planes, 737 series can be transported by rail.

The new 787 wing and body can be airlifted within a modified 747 (above). Airbus can fly their sections of the small 320 but none of the bigger ones. Being able to transport components is a competitive advantage. Airbus 380, the new jumbo has large problems with transportation.

The finished airplane can of course be transported.

### **Sea transport**

Transport by sea is practically unlimited. This means that complete houses can be finished on factory and floated to their new position. The largest such structure is an office building for a tug company in Holland.

The smaller version is houseboats.

The problem with houseboats has so far been that legislation was unclear. Now new legislation has opened new opportunities and houseboats might flourish in the future.

### **Slicing the house for road transport**

The opposite mindset would be to chop any house up in slices fitting to the max road transport dimensions of 2,65 x 12,5 x 4,25 meter.

## **12.2 Life length**

Cars last for a decade, houses for centuries. That is a significant difference:

- Cars are a fixed product with some build in flexibility but little or no adaptability. You cannot change a car design.
- The materials in the car usually do not last very long.
- Cars are inexpensive to build and very expensive to maintain.

## **12.3 Legislation**

Cars and airplanes are build according to the same legislation globally, while houses are build to local building code.

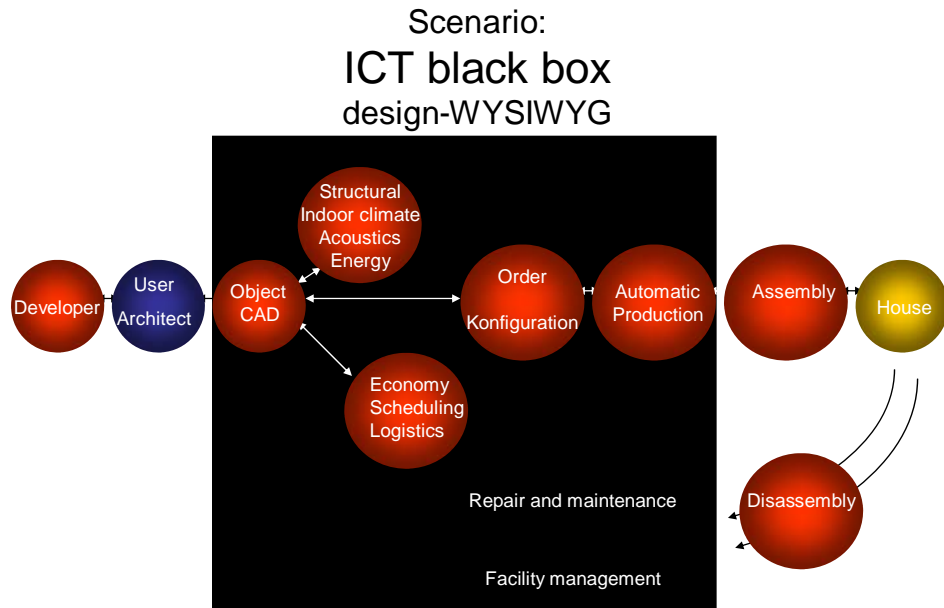
## **12.4 Discussion**

The 3 innovative solutions tunnelling through the barrier are:

- Producing the house from super light composites with insulation core and transport them by helicopter. The main objection is that it would neither look nor feel like a real home.
- Chop the house up in transportable slices . This solution is tested by for instance Temporent [www.temporent.dk](http://www.temporent.dk) but could be developed to something less container like.
- Houseboats, Quite a number of houseboats have been build. Houseboats have however not this “my home is my castle” experience.

These options should be further investigated within this project.

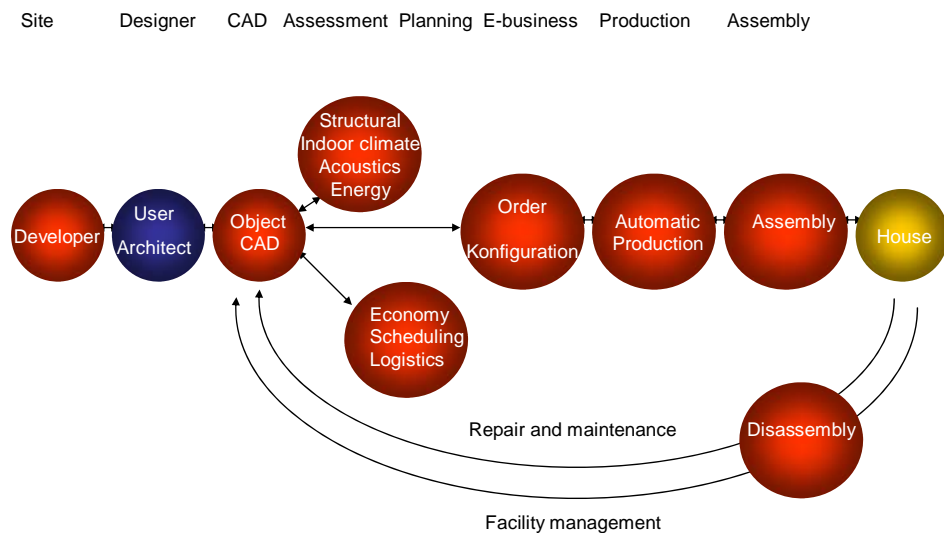
# 13. Value chain



What you design on your computer is what you get as assembly kit

This is the users view on a knowledge society building construction value chain model. The users do not care about the production. She just wants the house tailor made in good quality without faults delivered on schedule at no extra cost. The assembly process is outside the black box because the user might want to assemble the house, particularly the more adaptable parts.

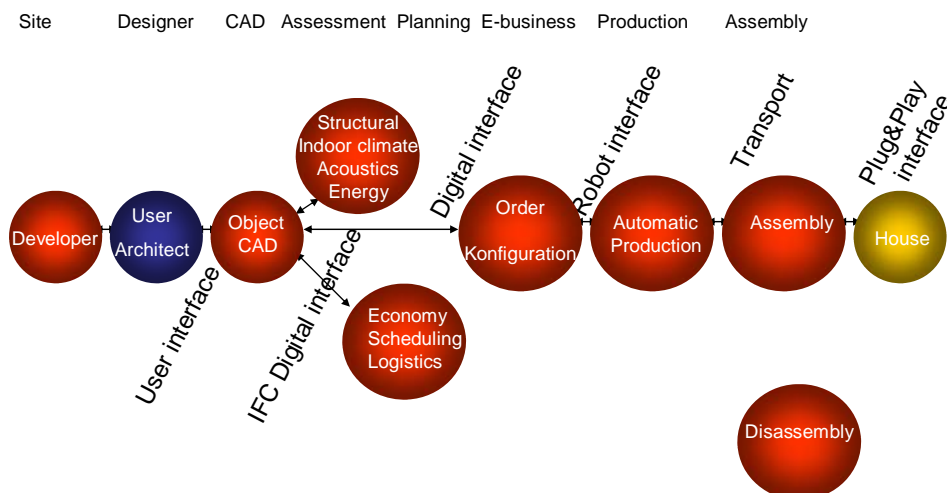
## Information flow



In a knowledge society model we are of course very concerned about the information flow. This flow should be digital, but there are quite a few missing links.

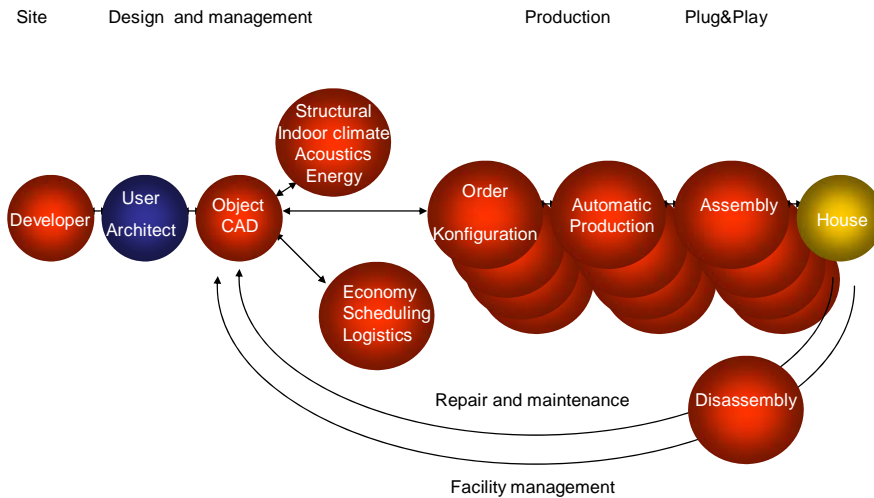
- Developers can handle word processor, spreadsheet, databases and power point but they do not read 3D CAD format. No Sir.
- Very few architects or engineers work with object based 3D CAD. This means that the digital model is a kind of 3D drawing rather than a digital representation of the actual building components. However, the architect works with any of the above mentioned digital tools, but they are proprietary and thus only available for the user and customers on a read only basis. We need some more open source interactive 3D model digital tools like Sketch up.
- 3D CAD models are available in several proprietary models. Inside the system you can do almost anything, but it is very difficult to exchange models between suppliers. Pioneers like Boeing have solved the problem simply by dictating all subcontractors and suppliers to use their software. But in the building construction industry that is not so easy. The new IFC format might solve some of the problems but hardly them all.
- Ideally, the 3D model could be shipped to or transferred to the authorities for approval. The authorities seldom read ICT models and seldom have any tools to check the digital calculation of static issues, energy calculations, acoustics, or compliance with work environment and indoor climate. So every thing is printed out and handed over in a non-digital way.
- Ideally the 3D model could be transferred to the suppliers and subcontractors. But in real life very few suppliers and subcontractors can transfer 3D CAD models into their own very proprietary system. Particularly if the ambition is to transfer the 3D model all the way to the customised production. The necessary translations and manual transfers means introduction of faults, in-accuracies and mistakes
- Next step would be a digital assembly instruction to use on cell phones. This would enable montage crew ans/or self assembly customers to use it at the construction site. I have never heard of anything like this in the construction sector.
- Finally we need information flowing back from the construction side correcting the inaccuracies particularly the early non Plug&Play phases introduce.

## Interfaces



So to connect the value chain you need a lot of interfaces, plug ins and translators.

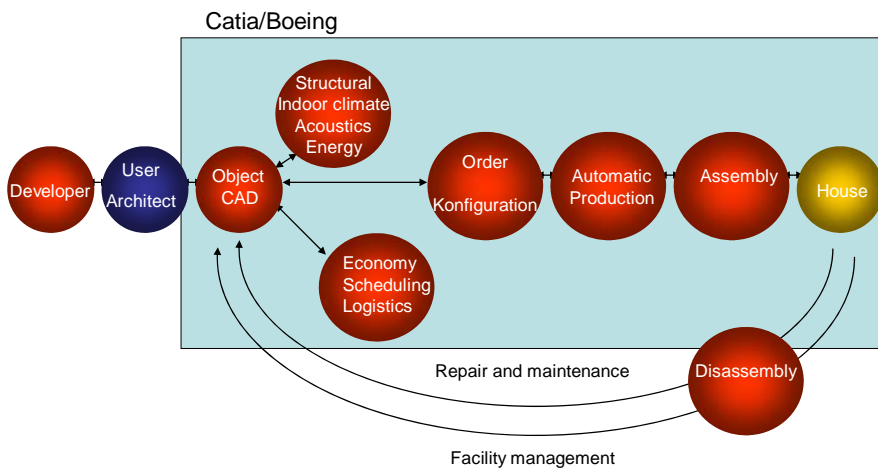
# Value chain



The real value chain contains furthermore a large number of suppliers and subcontractors. That increases the risk that quite a few of them cannot read any digital 3D format.

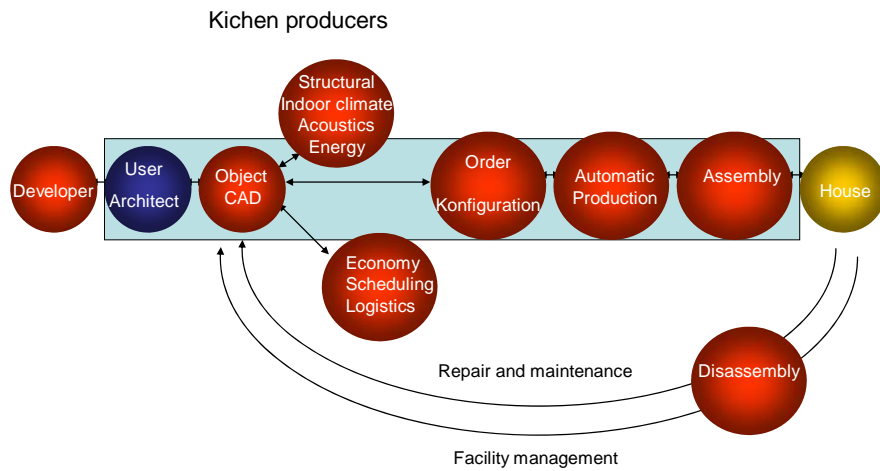
Now, this value chain does not even include the ordinary situation with craftsmen on the construction site. The chance that they can read any 3D digital models are almost zero.

# Who can already



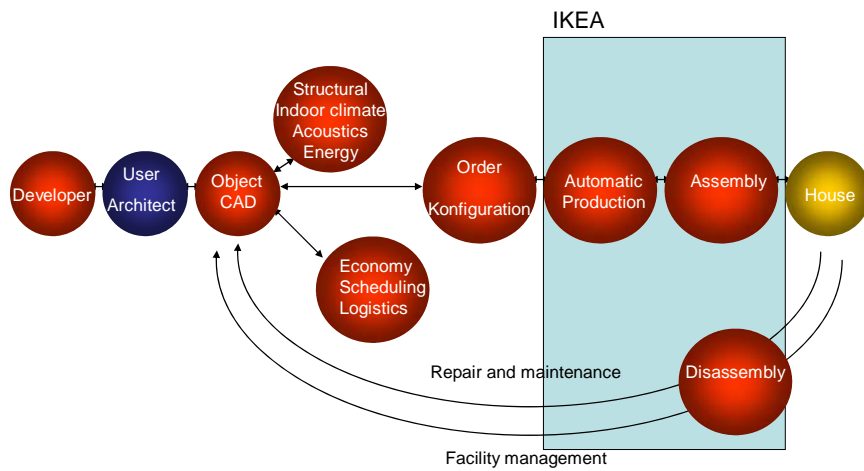
Boeing has demanded all their subcontractors and suppliers to deliver components within a CATIA (IBM) environment. That means that already 15 years ago when they designed the Boeing 777 they could build a 3D model representing all the actual components, and that all subcontractors could actually mill and produce the component accurately in accordance to the 3D model. The final result and performance was within 2% of the predicted performance. Boeings system is however not open all the way to the customers.

# Who can already



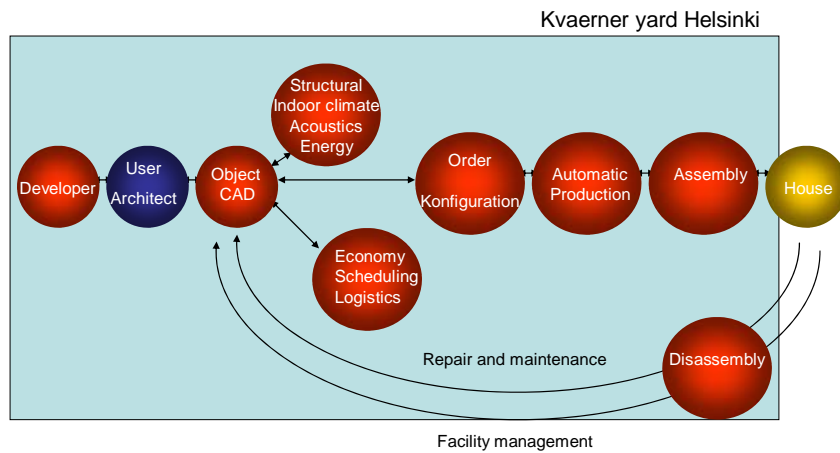
The most advanced players in the kitchen industry can support almost the entire range of digital interaction as long as the entire process is within their system. Their digital system is however not very open to the architects 3D CAD model.

# Who can already



IKEA is world leading on production of self assembly products. They are masters of production system and can deliver kitchens as well.

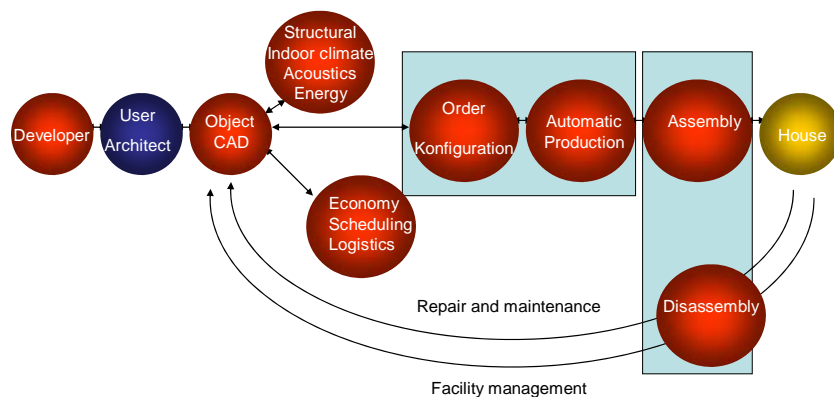
## Who can already



Kvaerner ship yard is world leading in building cruise liners. They started very early on CAD and produce the ship from quite large components. For instance are most cabins produced as complete finished cabin modules with bathrooms, paintings and furniture. The complexity is large with very short series.

They are handling some of the interactions digitally and some manually. It is a very mixed situation far from the consequence in Boeings production.

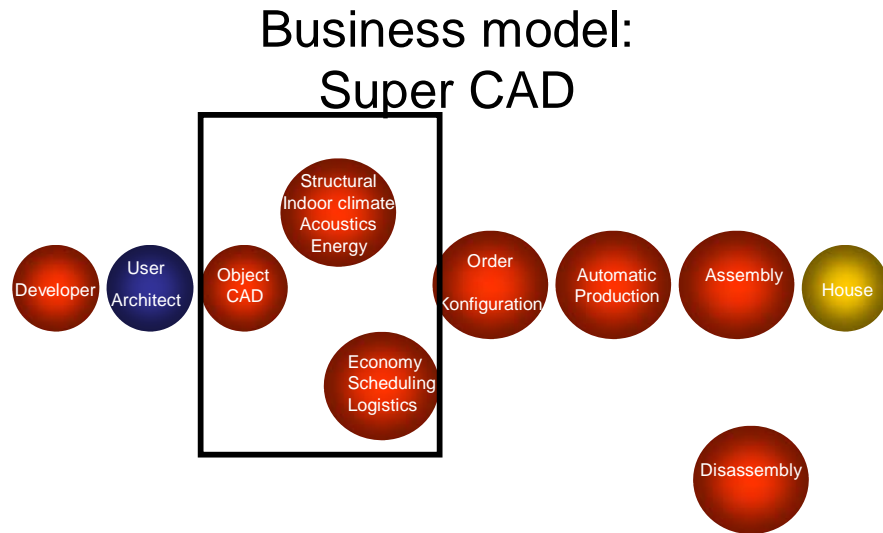
## Missing links i construction industry



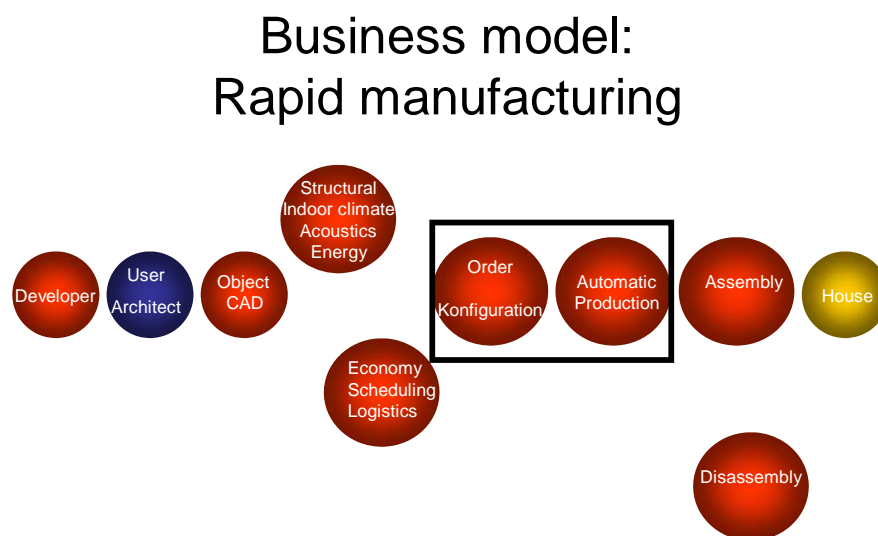
The construction industry is particularly weak when it comes to automatic production and components made for Plug&Play assembly. There is really a long way from the building site to the clean indoor production at Boeings factories. There is a long way in all respects. Boeing assemble 120.000 parts in 5 days. With the same manpower the building construction industry can build a one family house.

## 14. Business models

In this chapter we focus on new business model evolving from the new production paradigm.

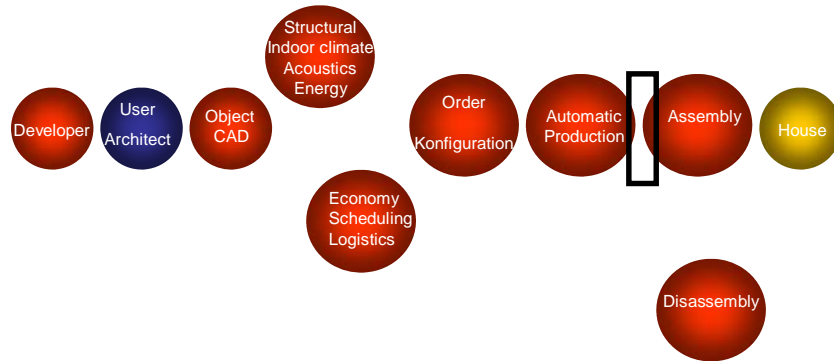


Gehry Technologies is an example of a new business model focusing on running the entire CAD model. They are neither architects, engineers nor contractors. They see to that the design process is kept digital all the way. They have managed a tender where the only material was a CD ROM with a 3D model. Only those who could interpret that model could participate in the tender. Only what was on the CD ROM should be built. All components were objects in the model.



Particularly in the glass and glazing industry there are players who can use 3D models for production and thus avoid mis-interpretations and mistakes.

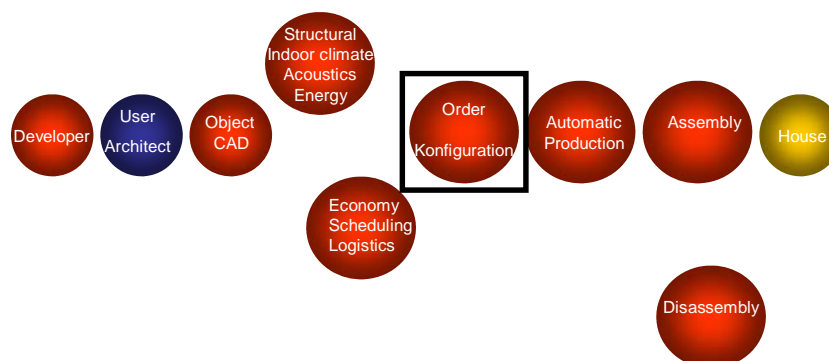
## Business model: Interface frame producer



Like the aluminium frames of the glazing industry the house could be build from frames with the following specification:

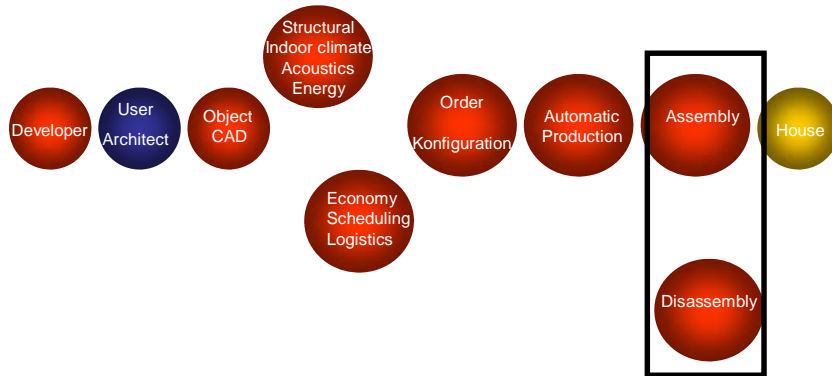
- Extremely accurate
- Montage of exterior cladding on the outside and interior cladding on the inside with insulation between
- Airtight inside and watertight outside
- Path for installation

## Business model: Component broker



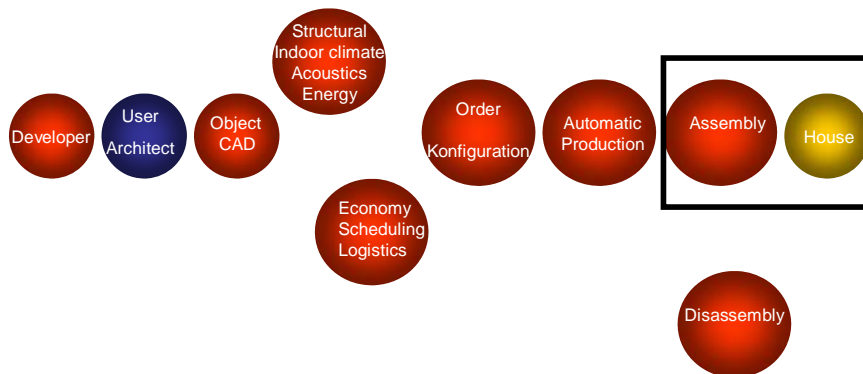
DELL is not producing computers. They are selling computers through a configurator and have them assembled and delivered to you. A DELL kind of role would be possible in the construction sector. A webpage where you could order building components made to measure and where the web owner took care of the translation into the proprietary systems of the producers.

## Business model: Refurbish expert



A new business could evolve taking care of disassemble, process and reinstall components. Such rebuild components could be interesting a decade after the Plug&Play system hits the market.

## Business model: Montage expert



This new business could replace the present craftsmen. The kitchen industry has already such cross disciplinary teams specialised in kitchens. They are able to do all kinds of kitchen related work like mounting tiles, install electricity, attaching water and sewage and of course install kitchen components.

## Appendix 1: Mobile home definition from wikipedia

### Mobile home

From Wikipedia, the free encyclopedia



A modern "double-wide" manufactured home.

**Mobile homes** (or [manufactured homes](#)) are [housing](#) units built in factories, rather than on site, and then taken to the place where they will be occupied. They are usually transported by semi-trucks over public highways. They are less expensive per square foot than site-built homes, and are often associated with rural areas and high-density developments, sometimes referred to as [trailer parks](#). In the [UK](#) and [USA](#) they are referred to as "mobile home parks."

The term "manufactured home" specifically refers to a home built entirely in a protected environment under a federal code set by the [US Department of Housing and Urban Development](#) (HUD). Contrary to popular belief, manufactured homes are not mobile homes. The term "mobile home" describes factory-built homes produced prior to the 1976 HUD Code enactment. <sup>[1]</sup>

These houses are usually placed in one location, often a rented lot, and left there permanently. However, they do retain the ability to be moved, as this is a requirement in many areas. Behind the cosmetic work fitted at installation to hide the base, there are strong trailer frames, axles, wheels and tow-hitches.

Manufactured homes are *not* large recreational vehicles. The latter are more properly called [travel trailers](#), [motor homes](#) or [RVs](#), and they are usually parked at facilities called trailer parks, trailer courts, or RV parks for short terms.

The two major forms of manufactured homes are **single-wides** and **double-wides**. Single-wides are sixteen feet or less in width and can be towed to their site as a single unit. Double-wides are twenty feet or more wide and are towed to their site in two separate units, which are then joined together. **Triple-wides** and even homes with four, five, or more units are also manufactured, although not as commonly.

In the U.S., manufactured homes are regulated by the United States [Department of Housing and Urban Development](#) (HUD), via the Federal National Manufactured Housing Construction and Safety Standards Act of 1974. It is this national regulation that has allowed many manufacturers to distribute nationwide, since they are immune to the jurisdiction of local building authorities. By contrast, producers of [modular homes](#) must abide by state and local building codes. There are, however, windzones adopted by HUD that manufactured home builders must follow. For example, state-wide, Florida is at least windzone 2. South Florida is windzone 3, the strongest windzone. After [Hurricane Andrew](#) in 1992, new standards were adopted for manufactured home construction. The codes for building within

these windzones were significantly amended, which has greatly increased their durability. During the [2004 hurricanes in Florida](#), these standards were put to the test, with great success.

However, older models continue to face the exposed risk to high winds due to the attachments applied such as carports, porch and screen room additions. These areas are exposed to "Wind Capture" which apply extreme force to the underside of the integrated roof panel systems, ripping the fasteners through the roof pan causing a multi series of events which destroys the main roof system and the home. Protecting these vulnerable areas, a Florida company, Hurricane Harness Inc., has devised a over the roof tie-down system with channels designed to prevent the roof panels from separation, distributing the wind loads through tie-downs to anchors in the ground, concrete slabs or masonry walls.

### History



 Manufactured home of the 1960s-70s: twelve by sixty feet

This form of housing goes back to the early years of automobiles and motorized highway travel. It was derived from the [travel trailer](#), a small unit with permanently attached wheels often used for camping. Larger units intended to be used as dwellings for several months or more in one location came to be known as **house trailers**.

The original focus of this form of housing was its mobility. Units were initially marketed primarily to people whose lifestyle required mobility. However, beginning in the [1950s](#), mobile homes began to be marketed primarily as an inexpensive form of housing designed to be set up and left in a location for long periods of time, or even permanently installed with a masonry foundation. Previously, units had been eight feet or less in width, but in 1956, the introduction of the 10-foot wide mobile home was made. This helped solidify the line between mobile homes and house/travel trailers, since the smaller units could be moved simply with an automobile, but the larger, wider units required the services of a professional trucking company. In the 1960s and '70s, mobile homes became even longer and wider, making the mobility of the units more difficult. Today, when a manufactured home is moved to a location, it is usually kept there permanently. Since the 1970s, the term "manufactured home" has largely replaced "mobile home," since the mobility of the units has considerably decreased.

Many people who could not afford a traditional site-built home or did not desire to commit to spending a large sum of money on housing began to see manufactured homes as a viable alternative for long-term housing needs. The units were often marketed as an alternative to the apartment rental. However, the tendency of the units of this era to rapidly depreciate in resale value made using them as collateral for loans far riskier than traditional home loans. Terms were usually limited to less than the thirty year term typical of the general home-loan market, and interest rates were considerably higher. In other words, mobile home loans

resembled motor vehicle loans far more than traditional home [mortgages](#).

Recently, mobile home (trailer / double-wide) sales have hit an all-time high in and around Auburn, Alabama. The student body, alumni and fans have all been aptly branded by other SEC schools as 'Trailer Park U'. This seems to be the preferred housing accommodations of many in the area, and several newspapers have even run articles on what is being tabbed as "Auburn's preferred housing choice".

### Legal complications



A modern "triple wide" manufactured home.

The rise of the manufactured home brought with it complications the [legal system](#) was not prepared to handle. Originally, manufactured homes tended to be taxed as vehicles rather than real estate, which resulted in very low property tax rates for their inhabitants. This led local governments to reclassify them for taxation purposes.

However, even with this change, rapid [depreciation](#) often resulted in manufactured home occupants paying far less in property taxes than had been anticipated and budgeted. The ability to move many manufactured homes rapidly into a relatively small area resulted in strains to the infrastructure and governmental services of the affected areas, such as inadequate water pressure and sewage disposal, and highway congestion. This led jurisdictions to begin placing limitations on the size and density of developments.

As noted above, early manufactured homes, even those that were well-maintained, tended to depreciate in value over time, much like motor vehicles, rather than appreciate in value, as with site-built homes. The arrival of manufactured homes in an area tended to be regarded with alarm, in part because of devaluation of the manufactured housing potentially spreading to preexisting structures.

This combination of factors has led most jurisdictions to place [zoning](#) regulations on the areas in which manufactured homes are placed, and limitations on the number and density of manufactured homes permitted on any given site. Other restrictions, such as minimum size requirements, limitations on exterior colors and finishes, and foundation mandates have also been enacted. There are many jurisdictions that will not allow the placement of any additional manufactured homes. Others have strongly limited or forbidden all single-wide models, which tend to depreciate in value more rapidly than modern double-wide models.

Apart from all the practical issues described above, there is also the constant discussion about legal [fixtures](#) and [chattels](#) - meaning that the legal status of a trailer is, or could be,

affected by its incorporation to the land or not.

### **Manufactured home parks**

In the past, manufactured home parks have, often with legitimate reason, been thought of as substandard. With more modern manufactured home parks however, this is not the case. Most have regulations concerning the size and styles of homes permitted, and many are somewhat similar to more traditional subdivision developments. In some of the more satisfactory parks, all of the homes are owned by the individual occupants. Only the spaces or **pads** are rented, not the units themselves. Developments in which the buyer purchases both the home and the lot are almost indistinguishable from traditional subdivisions. In lower-end parks, some or all of the units are owned by the operators of the park and are rented to occupants. These developments are considered undesirable by property owners because they are known to depreciate the value of surrounding property.

Newer manufactured homes, particularly double-wides, tend to be built to much higher standards than their predecessors and meet the [building codes](#) applicable to most areas. This has led to a reduction in the rate of value depreciation of most used units. <sup>[2]</sup>

Additionally, modern manufactured homes tend to be built from materials similar to those used in site-built homes rather than inferior, lighter-weight materials. They are also more likely to physically resemble site-built homes. Often, the primary differentiation in appearance is that manufactured homes tend to have less of a roof slope so that they can be readily transported underneath bridges and overpasses.

The number of double-wide units sold exceeds the number of single-wides, which is due in part to the aforementioned zoning restrictions. Another reason for higher sales is the spaciousness of double-wide units, which are now comparable to site-built homes. Single-wide units are still popular primarily in rural areas, where there are fewer restrictions. They are frequently used as temporary housing in areas affected by natural disasters, when restrictions are temporarily waived.

### **Modular homes**

Manufactured homes are often confused with but are not identical to [modular homes](#). Modular homes are transported on flatbed trucks rather than being towed, and lack axles and an automotive-type frame typical of manufactured homes. However, like manufactured homes, some modular houses are towed behind a [semi-truck](#) on a frame similar to that of a manufactured home. The house is usually in two pieces and is hauled by two separate trucks. Each frame has five or more axles, depending on the size of the house. Once the house has reached its location, unlike a manufactured home, the axles and the tongue of the frame are then removed, and the house is set on a concrete foundation by a large [crane](#).

Both manufactured homes and modular homes are commonly referred to as [manufactured housing](#), although its technical use is restricted to a class of homes regulated by the Federal National Manufactured Housing Construction and Safety Standards Act of 1974.

Most zoning restrictions on manufactured homes have been found to be inapplicable or only applicable to modular homes. This occurs often after considerable litigation on the topic by affected jurisdictions and by plaintiffs failing to ascertain the difference. Most modern modular homes, once fully assembled, are indistinguishable from site-built homes. Their roofs are usually transported as separate units, eradicating the telltale roofline of the manufactured home. As the legal differentiation between the two becomes more codified, the

market for modular homes is likely to grow.

The traditional manufactured home industry would seem to have a bright future as well. As the demand for housing continues to grow, the price of housing continues to increase rapidly. The quality and features of manufactured homes has led to greater acceptance by a growing segment of the marketplace. Additionally, insurers and lenders are now more likely to treat the higher-end manufactured home as they would a traditional home.

### Manufactured homes and tornados



Mobile home struck by tornado

In the [American Midwest](#), manufactured homes are sometimes facetiously referred to as "Tornado Magnets" or "Tornado Bait" due to the perception that [tornados](#) strike them more frequently than other structures. Tornados do not actually strike manufactured homes any more or less frequently than any other type of structure. However, while an [F1](#) tornado might cause minor damage to a site-built home, it could do significant damage to a manufactured home, especially an older model or one that is not properly secured. Many brands offer optional hurricane straps, which can be used to tie the manufactured home to anchors embedded in the ground. This gives the owner substantial protection against heavy winds.

## Appendix 2: MIT House N project

(The US version of Plug&Play and Manubild)

### Open Source Building Alliance (OSBA)

*House\_n team*

The goal of the Open Source Building Alliance is to develop key components of a more responsive model for creating places of living where: (1) Developers become integrators and alliance builders to offer tailored solutions to individuals, (2) Architects design design-engines to efficiently create thousands of unique environments, (3) Manufacturers agree on interface standards and become tier-one suppliers of components, (4) Builders become installers and assemblers, and (5) Customers (home buyers) become "designers" at the center of the process by receiving personalized information about design, products, and services at the point of decision. [\[PDF\]](#)

### OSBA: Chassis

*Kent Larson and Jarmo Suominen*

Borrowing from recent innovations in the automobile, electronics, aviation, and ship building industries, researchers are developing concepts for creating buildings from an integrated "chassis" that can be rapidly and precisely installed with minimal field labor. One integrated assembly provides structure, ductwork, power, signal, plumbing connections, mechanical attachments for infill, HVAC systems, floor finishes, and ceiling finishes. At the point of sale, demising walls are added to create the size unit required, and the buyer then engages in a design process to define the interior design, systems, and services. The chassis provides the necessary physical, power, and signal connections for mass customized infill components to be quickly installed, replaced and upgraded without disruption.

### OSBA: Integrated Interior Infill (I3)

*Kent Larson, Jarmo Suominen, Pilar Botana, Soraia S. de Souza, and Stephen Intille*

Integrated Interior Infill (i3) components take advantage of computational design and fabrication tools to produce cost-effective, high-performance places of living. I3 components replace interior walls and rapidly connect to an OSBA chassis with highly varied and customizable cabinetry-like components, systems, and technologies - including work-at-home solutions, integrated room acoustics and entertainment systems, transformable elements, networked appliances and devices,

etc. Criteria will be established that may inform industry standards for connections of both physical and digital components for new design and construction methodologies. This work is funded by a grant from the PATH/National Science Foundation.

## **OSBA: Design and Configuration Tools for Non-expert Designers**

*Kent Larson, Stephen Intille, Jarmo Suominen, and TJ McLeish (alumnus)*

In contrast to the generic housing development process, this new model places the individual in the center of participative process via a design platform for non-experts. A tangible interface allows consumers to access sophisticated design tools without requiring them to think like an expert designer. Three design representations are presented: an initial conceptual design to understand relationships and adjacencies, optically tagged physical components permit an exploration of alternative adjacencies and configurations, and real time perceptual representations communicate the resulting form, materials, and light. If adopted by industry, such a strategy could create powerful incentives for innovation.

## **The PlaceLab**

*A House\_n and TIAX, LLC Initiative*

PlaceLab is a highly instrumented apartment-scale shared research facility where new technologies and design concepts can be tested and evaluated in the context of everyday living. This 1000-square-foot facility is located on the ground floor of a new full service condominium building between Harvard and MIT. Not a prototype, and not a demonstration environment, the PlaceLab is a new type of scientific "instrument" that allows researchers to collect fine-grained human behavior and environmental data, and to systematically test and evaluate strategies and technologies for the home in a natural setting with volunteer occupants. The PlaceLab is capable of accommodating multiple and simultaneous experiments proposed by academic researchers, industrial researchers, or collaborative groups. The PlaceLab interior consists of instrumented laboratory versions of the Integrated Interior Infill (I3) methodology. [[web](#), [PDF](#)]

## **OPEN Prototype House Initiative**

*Kent Larson, Tedd Benson (Bensonwood Homes)*

The OPEN Prototype Initiative has been formed to develop a series of prototypical homes that test a new model for the design and fabrication of highly responsive places of living. It brings together advanced academic research and prototyping with

sophisticated commercial design and production processes. This initiative, led by the MIT House\_n Open Source Building Alliance and Bensonwood Homes, will allow industrial partners to collaborate in the prototyping and deployment of new home-related materials, systems, and devices. [\[PDF\]](#)

## **Strategies for Building and Operating Living Laboratories**

*Jennifer Beaudin, Jason Nawyn, Pallavi Kaushik, Emmanuel Munguia Tapia, Stephen Intille, Kent Larson*

The PlaceLab is a Living Laboratory for studying people and their interaction with technologies and design strategies in a natural setting. We are documenting the lessons learned with the PlaceLab and creating design guidelines for other organizations interested in creating and operating such facilities.