

Hadid's Nordbahn Station in Innsbruck is made entirely from Plug&Play components



ERABUILD:

PLUG & PLAY

A personal executive summary, September 2009 Ivar Moltke, Danish Technological Institute

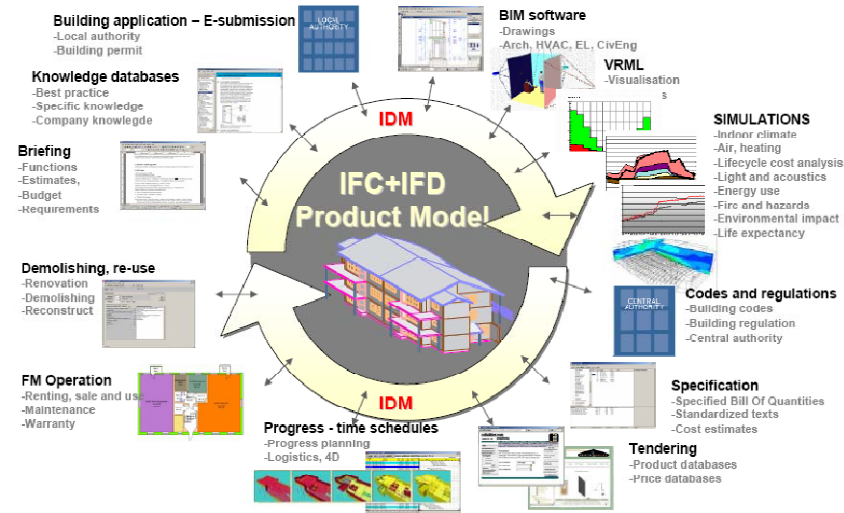
Architecture and construction are actually both taking place in the virtual world and the physical world. The x,y,z dimensions might be comparable but the time is all different. Within the past 50 years since computers and industrialization of the construction sector took off, the growth of productivity in the construction sector has been almost zero, while computers have increased productivity a billion times. Construction materials like concrete are 2000 years old, bricks and mortar are 5000 years old, and wooden buildings are even older. The internet took off 15 years ago. Within the next 15 years the capacity of computers and robots are expected to grow another thousand times, while few people expect the productivity of the construction sector to grow. But it will grow alright along a surprisingly different path.

Ray Kurzweil, the father of the Singularity movement, predicts that we will be the second most intelligent species on earth within 15 years. He has a simple instruction: Any industry, profession, organization and corporation must switch from the slow linear footpath of the physical world to the dynamic exponential warp speed of the virtual world. The challenge is to stay digital all the way from customer co-design to delivery and maintenance. Toyota in Japan have successfully pasted and copied their digital automobile factory into a digital housing factory. They have succeeded because they started from scratch rather than trying to reform the construction industry. And because the entire process is held within the same organization which reduces interfaces (not only for ICT systems but for the participating people). Profactors report has described the advantages and challenges of such digital factories with simulations fully integrating products development, logistics and production, in Product & Process Lifecycle Management

This Plug & Play project has both a digital and a physical dimension. AAA, Profactor and CSTB demonstrates in their reports that the digital world has a potential only limited by all the barriers between products, corporations, institutions, professions and nations we know all too well from the physical world. CSTB has mapped the challenges of software developed for different purposes like simulation of structures, daylight, acoustics, production, robots etc. Each of them work well, but they don't yet communicate and interact well without translation and interfaces. CSTB has investigated the concept of semantic web, IFC and similar tools enabling different software tools to communicate across these boundaries. And don't despair. ICT will soon communicate as they are developing at warp speed. What is presently possible in a main frame IBM Catia environment, will within a decade be possible on a portable PC. AAA has not only illustrated but also demonstrated hands on the great potential of configuration of everything in the architectural process. They have even demonstrated hands on how the design can adapt itself to landscape and orientation. They have developed interactive tools way ahead of just drawing.

Lund has mapped and analyzed the progress of actual industrialization in Sweden, which probably has the world's most industrialized construction sector with 45% industrialization. Sweden has had some examples of moving most of the construction into factories and even turning the construction sites into factories. Open House and NCC komplett implemented closed systems selling their product to their own developer. They are both closed now. Such small national markets are too limited to support industrialization, particularly in times of crisis. The other reasons are extra cost related to the factory, transportation, double walls and floor/ceilings, loss of space and lack of industrial competences on site. Today the most competitive way of building is to use the mindset of industrialization in the entire value chain, finish the design before building, ordering all the components already when the building is contracted, buy large quantities, handle logistics just in time and solve all details with well known, trained and proven solutions in order to make it easy for the staff and to avoid mistakes and risk. Just like the industrial platforms known from the automobile industry.

buildingSMART is about exchange and sharing of information



Pictures from: Selvaagbygg, DDS, Byggesøk, NBLN University of California, CIFE Stanford, Pythagoras and Olaf Granlund Yø.

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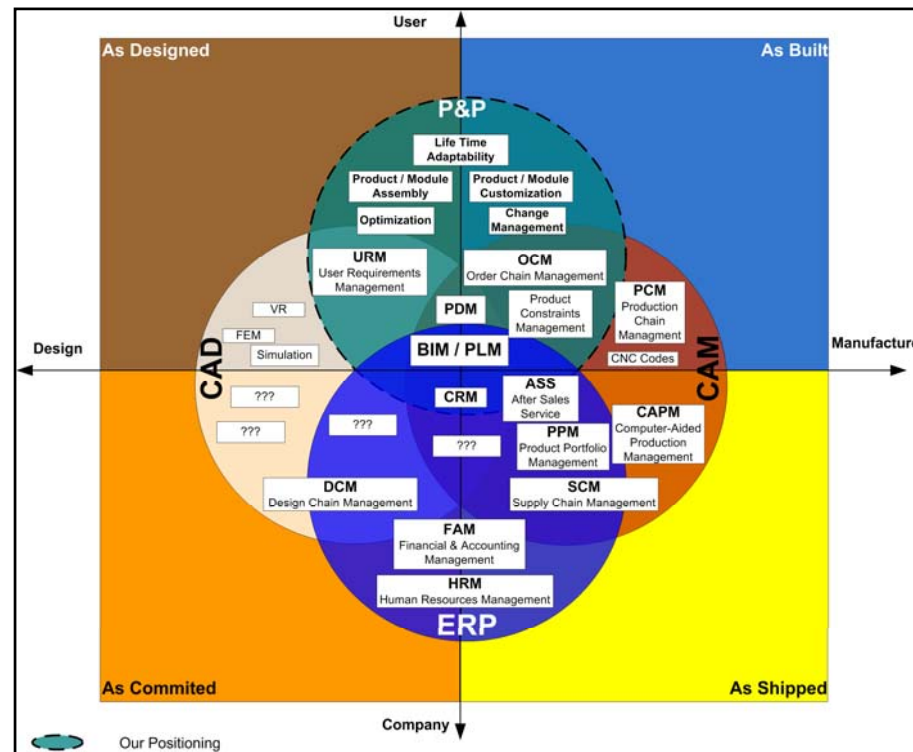


Figure:
Lund & CSTB

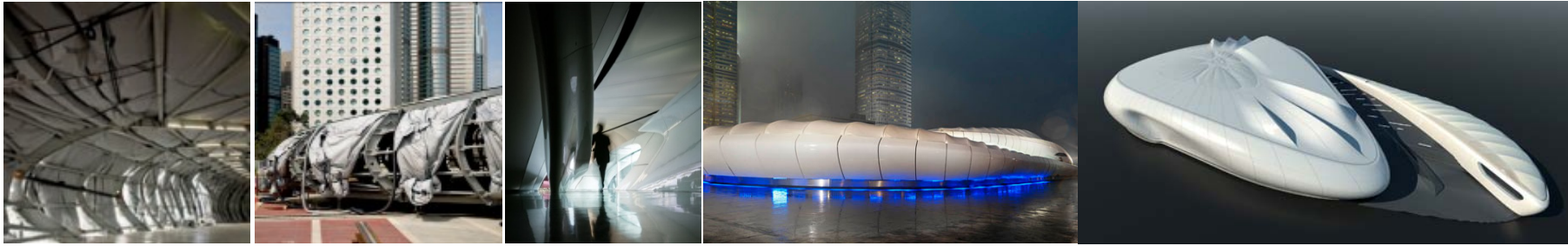
DTI found indeed architects, engineers and production companies handling the entire value chain successfully within the digital world. Not because they experimented with ICT, but because that was the only way engineers like Arup and Buro Happold could build the sculptural spaces designed by architects like Gehry, Hadid and Herzog. The Chanel pavilion was even entirely Plug&Play being assembled and disassembled for exhibitions in, Hong Kong, Tokyo and New York before it ended in Paris.

Building Information Model (BIM) is the digital mirror image of Plug&Play. The full BIM potential was introduced by Boeing two decades ago when they designed the 777 and BIM is the normal procedure in large extremely complex construction works like hospitals, complex factories, certified medical factories, oil refineries etc. As this segment of the construction sector explains it: It would be impossible to organize the construction process without BIM. Some industrial component industry can now interact with customers and architects within an entirely digital world enabling the clients to get the design they want. Necessity is the mother of invention. Size, complexity, user co-design and sculptural architecture are the key drivers because you can't handle them without BIM.

VTT also found Plug&Play where the entire process is within one organization. Lindab and Gyproc has a full menu of self assembly precut parts to build a house. And they can build anything from a simple storage building to Turning Torso in Malmø, as long as you build it from their metal spare parts. In USA and Canada a number of companies offer a self assembly kit for building timber frame houses.

No chain is stronger than its weakest part. Some parts of the value chain find themselves already in an advanced digital environment whereas others are still in stone age. BIM is not yet interactive in a dialog with the users but special game software combined with 3D glasses and "Caves" open the virtual 3D world for user interaction. BIM can show its real value in the production process when integrated with concepts from the digital factory described by Profactor and used along the whole life cycle of a building and its manufacturing infrastructure. A few industries can do that. And BIM is first of full value on the construction site when displayed in some kind of augmented reality like VTT and Nokia are experimenting to do. In most cases only architects, large engineering consultants and large contractors use the full functionality of BIM and often only after conversions of digital formats. Even the authorities demanding BIM, use paper in the approval process. So we still have a long way to go until BIM is fully implemented.

BIM communicating wireless with robots and automated factories and 3D printers will of course close this gap for good within decades. 3D printers are in service for production of prototype boats, airplanes, windmill wings etc. But it is still too expensive for production of houses.



Hadid's Chanel pavilion made entirely from Plug&Play components and assembled and disassembled in Tokyo, Hong Kong, New York

Interfaces were in focus from day one in this Erabuild Plug&Play project. Something like LEGO. Something everybody could assemble and disassemble anytime anywhere. Slowly the challenges became clearer. Even the very mature industries have not yet solved this challenge with an open standard. Not even the electricity plugs are standard. Not even HVAC is standard. Not even wheels for a car of the same make is standard. Not even Bluetooth standards are standard. And who have not had trouble with the many document standards and their incompatibilities in information technology.

The only places they succeed with standards are LEGO as long as you use only LEGO bricks. They sue people who use their standards. And in the kitchen industry where the only interface standard is very simple 10 cm modularity is size

So standards are about control and monopoly. Even de facto standards like Microsoft are challenged. So how can we expect Plug&Play standards in the construction sector, the most anarchistic of them all?

In the book “Home delivery” ,MoMA in New York focus on industrialization throughout the last 90 years. Yes it was 90 years ago Thomas Alva Edison invented industrialized construction. The most popular system became the balloon wood frame system, the second most popular system was concrete elements and the most industrialized until Toyota was Levitt’s Levittown concept, a kind of reversed factory where he moved the entire staff down the line of houses instead of moving the houses down a line in the factory He produced 17,447 homes within a decade. Since then little has happened until DTI in a previous report proposed building houses with a 3D printer.

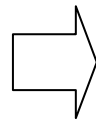
The legal system is part of the problem. The building code is different in most countries, the standards for electricity are different, the municipality planning conditions are different and the public tendering systems make industrialized standards un-conditional. Local planning also ban industrialized products unless they look like the traditional houses. One part of the public administration asks for industrialization while the others prohibit it. Other barriers are transportation and local ad hoc teams.

This doesn’t mean that we should forget about Plug&Play. We have adaptors for electrical plugs and we can have adaptors elsewhere in the building. We have fittings for HVAC and we can have fittings elsewhere in the building. We have “plug in” for translation of software and we can have “Plug in” in the digital structure of the building. The strategy is to produce significantly large structure (within road transport format or floated to the site) within a system delivery environment, and minimize interfaces to the adjoining system. The few remaining interfaces can be handled with adaptors, fittings and “plug in”. We realized the challenges of interfaces between all the different kinds of software necessary to digitalize the entire process. They are also working within specific domains and controlled by proprietary vendors.

Working intensively with interfaces it became obvious that the most important interface is between the building and it’s users. That is not a standard interface. So far the users do not prefer industrialized products. They know that somebody else get the profit and the users are left with the difficulties changing, rebuilding and maintaining buildings designed to be produced, but not to be developed over time. However, in automotive industry disassembly and maintenance studies are already state of the art.. User interfaces are almost non-existing in the most industrialized houses. The sole customer is the company’s own development branch.

	Where we started the project	Where we are heading now
WHO are driving development?	<ul style="list-style-type: none"> • Developers and industry • Designed for first customer 	<ul style="list-style-type: none"> • Users • Designed for learning through 100 years
WHAT kind of industrialization do we want	<ul style="list-style-type: none"> • Standard component • Off site industrialization 	<ul style="list-style-type: none"> • Mass customized component • On site androids
WHY Plug&Play	<ul style="list-style-type: none"> • Profit • Interface between components • Speed and productivity • Higher productivity= unemployment 	<ul style="list-style-type: none"> • <u>Quality of life</u> • Interface component-user • Adaptability , longer life and recycling • Higher productivity =better houses
HOW Plug&Play	<ul style="list-style-type: none"> • Standard interface • Modularity • Total systems • Normal business model 	<ul style="list-style-type: none"> • Mass customized interface and adapters • Breaking geometry down in “puzzle pieces” • Open systems (open innovation) • Home android business model

We have all learned a lot through this project. Above this development is illustrated in words, below it is expressed in Stratcon schemes



Esa from VTT kept asking these “Why” and the “Why not” questions throughout the project. We tried to transform that into equations like:

$$Impact_{(user)} = Love_{(product)} - Hate_{(product)} = Intelligence_{(product)} - Cost_{(product)}$$

And upscaled it to

$$Impact_{(society)} = Impact_{(individual)} \times Individuals\ impacted$$

$$Impact_{(industry)} = Income - Expenses = Profit$$

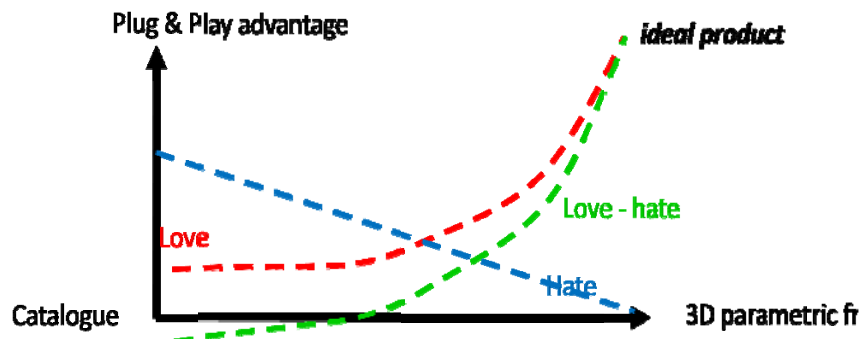
These equations tell about drivers and barriers.

Particularly the first equation tells a very interesting story. The building is not only a physical object. It becomes something more than an object in the relation to the users.

- Something more social and emotional.
- Shifting from house to home.
- Sentimental value to the user.

Part of the value of the house is the physical thing like shelter and safety in the bottom of Maslow pyramid, while part of the value is virtual value in the top of this pyramid. The effect of this knowledge is, that we might not need to transform everything from the slow physical world to the warp speed digital world and back to slow speed on the construction site. Some of value can stay in the virtual world and keep developing over the life cycle of the building.

- More software and less hardware, so to speak.
- More change and adaptability and less cast in concrete.
- More shaped by dreams than by necessity.



Love

- “Better every morning”
- Home is a state of mind
- Beautiful
- Cozy
- Personal/individual/integrity
- Personal history/learning from the user
- Joy and happiness
- Privacy
- Safety and shelter
- Daylight
- Comfort
- Belonging
- Supporting family & friendship
- Adaptability from single to family to senior citizen
- Connection with outdoor
- Personal growth
- For all senses and intelligences

Hate

- Troublesome maintenance
- Energy cost
- Too hot and too cold
- Difficult to change and modify
- Noise and poor sound insulation
- Difficult to clean
- Leaks
- Draft
- Humidity
- Sick
- Not ergonomically enough (not suitable for elderly people; dangerous for young children etc.)

Advantages of P&P adaptability increase with

- Increasing labor cost
- Shorter technical life time
- Shorter functional life time
- Components being barrier for personal development
- Components being barrier for change of lifestyle
- Do it yourself montage
- Value of dry montage
- Availability of Plug&Play components

Advantages of industrialization increases with

- Automation
- Mass customization
- Competition on the global market
- Difference between labor cost on site and in factory
- Units/year
- Load factor on factory
- Economy of scale on supplies and logistics
- Proximity to market
- Limited need for investment in production

Advantages of configuration increase with

- User co-design
- Choices
- Full digital support throughout value chain: configuration, via ordering, production, montage, maintenance, reconfiguration and refurbishment

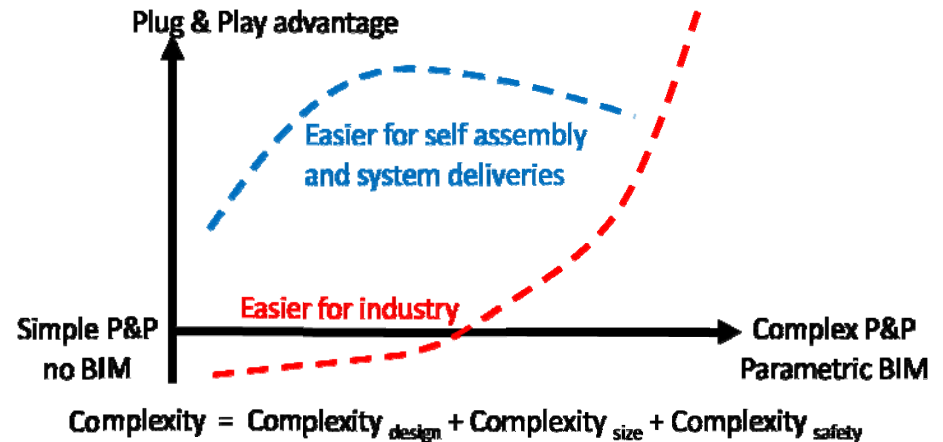
Advantages of ICT factory increase with:

- Saved labor cost
- Totality in solution
- Complexity in architecture
- Importance of accuracy
- Transportation to global market

Advantage of BIM increases with:

- Information flow though value chain with no missing links
- All stakeholders using BIM
- The virtual model is build from virtual and standardized components
- The components can be configured parametrically on line on the factory's production software
- Augmented reality BIM on site
- Refurbishment without the need for on-site measuring

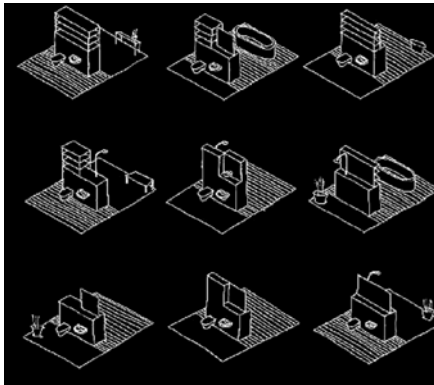
VTT and DTI developed this figure about the benefits of BIM based on complexity. For the private builder the scale of complexity and the barriers of skills are different. The private builder can benefit from any kind of Plug&Play. For the professional skilled competence Plug&Play and BIM is often more trouble than benefit until complexity rises above what they can easily handle.



AAA has exemplified Configuration and Customization with a bathroom in their report. Bathrooms have the highest cost pr. square meter, most installations, and largest risk of all rooms in the building. And most bathrooms are small enough to be transported by road. Bathrooms are the obvious room to industrialize and in fact a large share of the market is produced on factories and some are even transported to Scandinavia from Eastern Europe and China.

All the advantages of industrialization, Plug&Play and BIM described above are particularly relevant for the bathroom. Bathrooms are furthermore very expensive and time consuming to rebuild. If the industrial bathroom unit is attached to the building it could be exchanged with a new bathroom without disturbing the life in the building.

AAA developed a bathroom configurator to configure your bathroom just like you can already configure a Dell computer or a kitchen. The room geometry and installation layout is limited to a few variants, but there is a wide choice of colors, tiles, materials, WC, cabinets, bathtub etc. The concepts were furthermore based on attaching elements to each other, keeping them in a box, keeping them attached to one single wall or having all installations in one unit.



AAA also developed a configurator changing the geometry of the house related to the topology of the landscape and the size of windows related to the orientation of the house.

AAA also demonstrated how to configure a house from room size modules

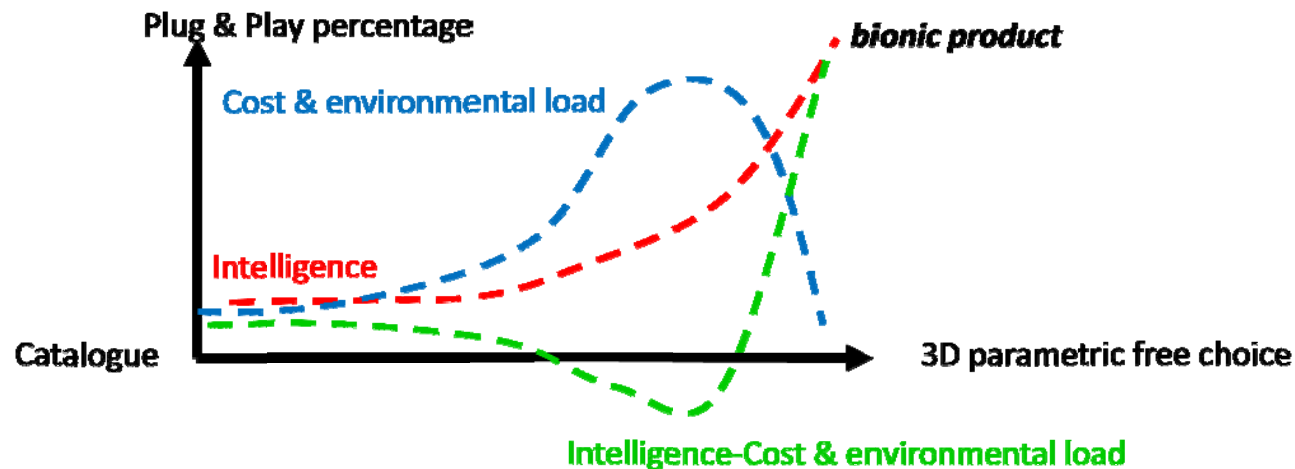
Both the global climate and the political climate are changing. Even the mindset is changing. We are shifting from a linear growth mindset to a cyclic development mindset.

Throughout the age of industrialization we have lived on our inherited natural fortune: Oil, natural resources, fresh water, fish, forest etc. Everything was abundant and for free. An almost 10 times increase in population and even larger growth in consumption pr. capita will soon put an end to that. We have to change our mindset from cradle to grave, nature to garbage dump, and start thinking in cycles and recycles. Both the Plug&Play concept and the more software oriented way of thinking are important steps in a recycling mindset focused on performance rather than consumption. Consumption is becoming more and more out of line with the limited realities of the future.

The society and corporations measure growth. Growth in economy, growth in GNP, growth in power, growth in populations, growth in worshippers in the religion etc. It is as if getting fatter was an advantage. That mindset is disastrously leading us to emptying all the free resources and overpopulating the world. A shift from growth to development would be a giant leap for mankind. From the tangible consumption to the more knowledge based development. Not more of the same but better. Not quantity but quality.

So far sculptural architecture and new technology has made things even worse. The buildings pictured a few pages earlier are both very expensive and waste full in their production. They are pioneering experiments on the road to a new understanding of shape, strength and adventures.

The next big thing will be a Bionic or Biomimic mindset. A mindset, where we combine our intelligence, with the evolutionary intelligence of global species and the artificial intelligence of computer and robots, producing truly smart products, maybe even living and changing products. A mindset where the impact on the users quality of live develop while at the same time consumption of resources decrease

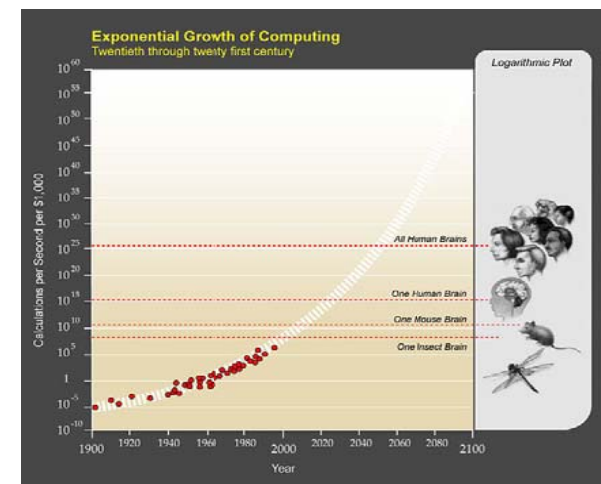
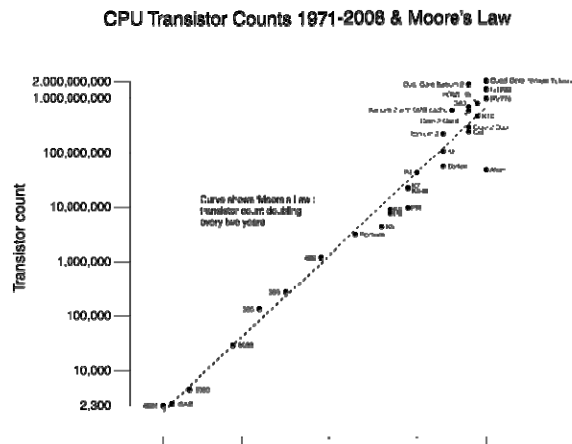


So where are we most likely heading?. Well Ray Kurtzweil call it Singularity. The day when mankind becomes the second most intelligent species on earth. The day when robots and artificial intelligence overtake us. Well in real life that will not be one specific day. I could win any “Who wants to be a millionaire” contest if I have four windows open to Wikipedia. Google has already more memory than any human being. When it comes to all round intelligence, the individual computer is dumb with an IQ of 0.1 . Approximately a thousand times dumber than humans. But when it comes to very specific task they are better, more accurate and faster than us.

Contemporary factory robots are described in Profactor’s report. They are still difficult and time consuming to program, and thus not very flexible. Most of them do one repetitive operation and that is it. Sufficient for an automobile factory, but insufficient on a construction site where there is a large number of different and usually not fully determined operations. Research projects have already married industrial robots with industrial vision systems in order to let robots see what they need to do in a particular situation. So we are not there yet, but we will soon be there. The Urban Challenge of DARPA in 2007 proved that technology is already ready to navigate and drive cars entirely on their own with no human driver and no remote control in a typical traffic situation.

Singularity is only 15 years ahead. It is very likely that we will never experience industrialization of the construction site because robots develops much faster than industrialization in the construction sector. And frankly speaking. Who will ever miss industrialization of the construction sector. Have any users ever asked for industrialization?

This robotic development might follow an entirely different path. USA has already more than 12.000 robots in service at the battlefield. South Korea and Japan has a plan to have android human like service robots in all homes within 10 years. They already have polite service robot prototypes walking around. Old, ill or disabled people need special care and they get the robots first with public subsidy. Next comes the busy people who need cleaning and minor services. And suddenly is all kind of service construction jobs only a download away from your android. One day it becomes a carpenter, next day it services your car and the day after it services your neighbor’s robot like his robot services yours. So you will never need to call for construction service any more. Maintenance and additions to your house is almost for free. And when you first have a robot in your home, it will be easier to sand and reuse the old wood than to buy new. Remember the difference from when you rented a car on special occasions till now when you have one available all the time. Just as you drive more, having your own car, you will also maintain your house better with your own android.



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This report is based on:

CSTB report:

ALLIANCE PLUG & PLAY , Un concept de construction et de relations entre acteurs pour un usage durable tout au long du cycle de vie d'un bâtiment.

AAA report:

IDÉ KATALOG, Udvikling af et badeværelsessortiment

Profactor report:

A SURVEY OF METHODS FROM THE DIGITAL FACTORY APPLICABLE TO AN INDUSTRISED CONSTRUCTION INDUSTRY

Lund University report

ERFARENHETER OCH EFFEKTER AV INDUSTRIELLT FLERBOSTADSBYGGANDE I SVERIGE

DTI reports

TOWNSCAPE@SEA

BUILDING IN THE KNOWLEDGE SOCIETY

VTT report

DRIVERS AND BARRIERS

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