Lean Wood Engineering goes Japan

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The Competence Platform

Lean Wood Engineering

...goes Japan

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Foreword: Eva Esping, VINNOVA

VINNOVA promotes sustainable growth by funding needs-driven research and developing effective innovation systems. In VINNOVAs first business plan, Wood Manufacture was identified as one out of 18 sectors with potential for added value growth. Based on an innovation study for sector, the VINNOVA programme for Wood Manufacture was established. Two major calls where launched and one of these aimed to develop a new competence platform focused on industrialized wood building and interiors including lean production concept. Lean Wood Engineering, LWE, a consortium of three universities and several industrial partners in the wood manufacturing and building sectors was formed.

LWE started in late 2006. The research is carried out in close cooperation with about 15 different companies and involves about 15 senior researchers and 15 doctoral students from the universities in Luleå, Linköping and Lund. International dimensions and networks are very important, and in May 2007, representatives of VINNOVA and LWE were invited to organize a joint workshop at the House of Sweden, Embassy of Sweden in Washington. As one result of this arrangement and other networking activities, a joint Sw-US doctoral course in Parametric Design was carried out at Stanford University in 2009.

As the concept of lean production plays a central role in the LWE platform, it felt very natural to look around for other activities based on the lean ideas. During the annual LWE meeting with senior researchers, doctoral students and industrial representatives in spring 2010 a visit to Scania in Södertälje was arranged.

Some years ago, an idea came up about visiting the ”home of Lean” - Japan. Today, lean philosophy is not only connected to modern vehicle factories but is also adopted in other applications, as for instance, house constructions (Toyota homes). Fundamental questions or circumstances for LEAN in Toyota would be very relevant today in many other businesses. Energy conservation, accessibility to land etc., are very hot issues today concerning urban development. How far has the Japanese society come in this development?

Planning the study trip required lots of effort from a working group consisting of Ms Sofia Lidelöw, coordinator of LWE, Mr Tomas Alsmarker, Tyréns AB, and Ms Eva Esping, VINNOVA, and close cooperation with the Swedish Agency of Growth Analyses offices in Tokyo and Stockholm. After more than one and a half year of planning, a list of topics to explore and sites to visit was presented and the Swedish Lean Construction Delegation finally went to Japan in October 2010. The visiting programme consisted of meetings with representatives from four pre-fab house companies, one construction company (including construction site tour), one excellence centre at Tokyo University, and one urban development project area. A joint Japanese-Swedish seminar was also arranged at the Embassy of Sweden in Tokyo.

The Swedish Lean Construction Delegation would like to thank all our hosts at the visited factories, sites and institutions for your great hospitality and for sharing your experiences in the construction field with us during our visit. We also send our warmest thanks to the Tokyo office of Growth Analysis and especially to Ms Izumi Tanaka for her assistance in the planning and organizing phases of the Delegation tour and to Ms Miki Arai, who took care of practical issues during Ms Tanaka’s absence.

Stockholm, November 2010
Eva Esping, Project Manager
VINNOVA
Summary, observations & results

On the 24th of October 2010, eleven delegates from VINNOVA, the three LWE universities and the LWE companies, arrived in Japan for a 7 day study trip in ‘the home of Lean’. Today, the lean philosophy is not only related to modern vehicle factories but is also adopted in other applications, as for instance in construction. Fundamental questions, or circumstances, for the development of Lean in Toyota are highly relevant in many other businesses today.

Energy conservation, limited accessibility to land, etc., are important challenges for modern urban development. How far has the Japanese society come in this development? The visiting programme consisted of meetings with representatives from four prefab house companies (Sekisui House, Sekisui Heim, Toyota Homes and the R&D division at Daiwa House), one urban development and construction company (Mori Building, including a construction site tour), one excellence centre at Tokyo University (the Centre for Sustainable Urban Development), and one urban development project area (Urban Design Centre Kachiwanoha). A joint Japanese–Swedish seminar with about 60 participants was also arranged at the Embassy of Sweden in Tokyo. A few general observations and results are listed below:

- Lean in Japan basically grew out of a lack of resources at the time. Elimination of waste was required because there was not much raw material to start with and taking care of, developing & empowering people happened because there were not enough people to do the work; therefore it was important to keep the good ones!
- Industrial housing in Japan is catered to the exclusive house segment, i.e. a Japanese manufacturer of prefabricated housing does not market their housing as low cost housing; instead, aspects such as earthquake safety, life-cycle support are put forward.
- Japanese housing manufacturers utilise a high degree of automation, made cost-effective by a large production volume. Automation allows for low tolerances which avoids many downstream problems.
- In Japan there are almost no garbage bins available; nevertheless it is mostly clean; lack of space means that every millimetre counts! Japanese people strive for 100% quality, e.g. clean, in all they do; it’s not about making good business, rather it’s a culture thing.
- There is a reason why Japanese trains, for example, are almost never late. Japanese people and companies know that any deviation from plan leads to even more deviations downstream, which in turn lead to a process being out of control. Consequently, there are many Japanese behind the scene that make the system work!
- In Japan, the customer is the centre of attention for house manufacturers. These companies produce homes, not houses. With this mindset, the customer is allowed to, for example, follow the whole production process and even to see when their own individual home is manufactured.
- Japanese companies create visions that pull the whole organisation in the same direction. For example, Japanese house manufacturers are not satisfied with energy efficient building envelopes, instead their vision of zero carbon emissions drives R&D of new energy sources, new insulation materials, new building services, etc.
- Based on the successful seminar at the Embassy of Sweden, and other contacts established at the study visits, a joint graduate course – “Design of sustainable building systems” – is being planned between LWE and the University of Tokyo.
- Some Japanese universities and industry representatives will be invited to participate in the upcoming LWE seminar in the autumn of 2011.
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1 Introduction
1.1 Swedish delegates

The Swedish delegates together with Japanese colleagues from the Centre of Sustainable Urban Generation outside Tokyo University.

**Front row**
1. Hideshi Oika, Arkos KK
2. Staffan Brege, Linköping University
3. Lennart Stenberg, VINNOVA Japan

**Middle row**
4. Eva Esping, VINNOVA Sweden
5. Thomas Olofsson, Luleå University of Technology
6. Matilda Höök, Masonite Beams AB
7. Erik Söderholm, Luleå University of Technology
8. Martin Lennartsson, Luleå University of Technology
9. Jerker Lessing, Tyréns
10. Patrik Jensen, Tyréns

**Back row**
11. Fredrik Wikberg, Lund University
12. Anders Björnfot, Luleå University of Technology
13. Thomas Alsmarker, Tyréns
1.2 Travel plan

1. 26/10 2010  Sekisui Heim
2. 26/10 2010  Sekisui House
3. 27/10 2010  CSUR (Centre for Sustainable Urban Regeneration)
4. 27/10 2010  Urban Design Centre Kachiwanoха (UDCK)
5. 28/10 2010  Mori Building
6. 28/10 2010  Sweden-Japan joint seminar (at the Embassy of Sweden, Tokyo)
7. 29/10 2010  Toyota Home
8. 29/10 2010  Daiwa House R&D Institute
9. 30/10 2010  Todaiji Temple
2 Sekisui Heim (26 October 2010)

Summary by Erik Söderholm, Luleå University of Technology.

Happy Swedish delegates ready for their first site visit; (from left) Staffan Brege, Jerker Lessing, Izumi Tanaka, Patrik Jensen, and Anders Björnfot.

2.1 Introduction

The first site visit the Swedish Lean Construction delegation made was at Sekisui Heim, Saitama. First an introduction of Sekisui Heim and its products was made by watching a video presentation. From the presentation we learnt that Sekisui Heim, which is part of the Sekisui Chemical Co group, is one of the leading companies in the module housing segment in Japan. They have built a great reputation of making comfortable homes that can withstand earthquakes and rough weather conditions. The company’s mission is to produce environmental-friendly homes that last for 60 years. Sekisui Heim launched their first house model, the “Heim M1” in 1970, and has currently eight factories in Japan and one in Thailand which cumulatively have sold over 400 000 houses. The factory plant in Saitama is the world’s largest house factory with a total area of 94 000 m².
The company have four primary focus areas;

1. High quality
2. Production control
3. Cost performance
4. Work environment

The company produces approximately 12,000 houses annually and one house consists of 13 units on average which adds up to an average floor space of 136 m². Every day, 130 units are built in the factory, meaning that every fifth minute one unit pass through the assembly process. The units are steel-framed box structures with the typical dimensions of; length 4,500 mm, height 2,500 mm and width 2,400 mm.

2.2 Site visit

After the introduction we were invited into the factory, where we were guided through the production lines. All together the production lines were approximately 500 metres long. More than 80% of the work is performed in the factory by the company’s 450 workers.

It takes about three hours to build a house in the factory, wherefore customers are invited to come and visit the factory to see for themselves when their new home is being built. Every process in the production lines has a cycle time of three minutes, and is manned by five workers, where one person is considered “overcapacity” in case of correcting quality issues or other faults that may occur during production.

Illustration of the Sekisui home (left) and automated welding of the steel frame (right).

After the walk through the production lines, we got the opportunity to enter one of the display homes that Sekisui Heim have, where we could experience how the finished result could look like. The site visit was ended by a Q&A-session. Examples of questions asked by the Swedish Lean Construction Delegation were:

- How do Sekisui Heim plan to handle the challenge with a decreasing Japanese population? Do the company also produce multifamily houses?
- What is the average lifetime for a unit? Is any part of the production outsourced?
- What performance measurements are most crucial for the company to monitor the overall performance?
- What demands are placed on suppliers? What does the selling process looks like?
3  Sekisui House (26 October 2010)

Summary by Patrik Jensen, Tyréns.

Focused (Erik Söderholm, left) and happy (Anders Björmfot, right) ready to be inspired.

3.1  Introduction

Sekisui House started their production in 1960. Since then, they have produced more than two million houses. Sekisui house is the biggest house manufacturer in Japan, and probably in the world (according to the assistant manager Sadao Motoe). They have five factories producing houses in different regions of Japan; Tohoku, Kanto, Shizuoka, Hyogo, and Yamaguchi. They also have a factory that is manufacturing structural wood components in Azai. The Company started with steel frames but have also systems built on timber frames. About 80% of the houses delivered today are made of steel frames, but it seems like the wood market is rising since customers wish to end their lives in houses made of wood.

The production consists of a steel framing process, panelling process, woodworking process, and manufacturing of SHAWOOD structural components. These different components are shipped to site where the houses are completed.

Illustration of SHAWOOD structural components.

3.2  Site visits

The factory that we visited is named “Kanto” and is the biggest factory of Sekisui house. The factory consists of 310 000 m² and there are approximately 1000 employees working here. This factory produces 1558 units per month with a tact time of about six minutes, providing about
512 houses produced per year. The visit began with an introduction of the company and the Kanto factory, followed by the introduction of what Sekisui house have named the “Zero Emission Centre” that consists of two different buildings:

1. Zero Emission Centre
2. Waste deposit centre

After the introduction, the guided tour started with looking at how SHAWOOD products were produced. The product is based on glue laminated timber that is quality checked. The reason for using gluelam is mostly to reduce cracks. The laminated wood beams are cut to customer unique lengths and then the interfaces are prepared. This is all done automatically with CNC machinery. When the wood-beam is finished, the interfaces are quality checked using a high definition camera to make sure that the predrilled holes are done according to standard (the tolerances are very tight).
After the visit at the factory shop floor, we went to the “Zero Emission Centre”, a centre for environmental conservation starting in 1999. The Zero Emission House is 200 m², and is a demonstration house for new technologies to reduce environmental impact. The building was originally constructed for the Toyako summit in 2008, but it was relocated to Kanto the same year. Some of the systems that are implemented in the house are a 14.5 kW photovoltaic system, roof vegetation (on the south side) and vacuum insulating glass.

Grass growing on the south side of the Zero Emission House (left) and advanced control system for warm water, temperature, fresh air, etc. (right).

The waste deposit centre has 56 employees with a utilized area of 5 000 m². The centre divides waste in 80 categories and separates in average 1 350 tons per month.

Sorting waste exemplified by separation of materials in a composite element (left). Electric cables were also separated in its constituent parts; plastic, copper, etc (right).
4 Centre for Sustainable Urban Regeneration (27 October 2010)

Summary by **Erik Söderholm**, Luleå tekniska universitet.

*Parts of the Swedish delegation (from left to right: Lennart Stenberg, Martin Lennartsson, Tomas Alsmarker, Anders Björnfot, Matilda Höök and Eva Esping) listening intently with Japanese friends.*

### 4.1 Introduction

The visit at the Centre for Sustainable Urban Regeneration (cSUR) was designed as a meeting between researchers from Tokyo University and the Swedish Lean Construction Delegation. The meeting was arranged so that the hosts first presented their research projects, then four of the Swedish delegates presented their work, followed by an open discussion.

The Centre for Sustainable Urban Regeneration (cSUR) is based on collaboration between three different departments of the School of Engineering, Tokyo University; Civil Engineering; Urban Engineering and Architecture. The background to why the centre was created is the expanding of mega cities all over the world and the unsustainable phenomena this results in. In year 2050 the world population will be near 7 billion and 70 % of all people will live in urban areas. The centre focuses on four important areas; Urban Environment Management; Urban Stock Management; Urban Informatics and Urban Design & Planning. The centre has published more than ten books on various aspects of this subject.

### 4.2 Presentations

Professor S. Matsumura gave an overview of the Japanese housing sector, where currently 20 % of new-built houses are prefabricated (this includes wooden panel, steel modular and concrete panel houses). This market share in Japan is covered by 10-13 companies, which can be compared to the conventional wooden design & built houses holding 6 % of the total market, but is carried out of over 10 000 small construction companies. In Japan, prefabricated houses are relatively expensive wherefore the market segment it targets is wealthy people. One explanation is the extensive costs for sales - “…Mass production needs mass sales…”

Dr R. Kitagaki presented his ongoing research about recyclable concrete and fire resistant materials. In Japan 10 % of the CO₂ emissions come from the construction industry and 40 % of the natural resources are used by the construction industry. Since a lot of concrete is demolished, recycling it is crucial. Dr. Kitagaki research is focusing on creating a high-quality aggregate from demolished concrete.
Dr. K. Hiyama presented his ongoing research about a dynamic insulation system applied to window frames in residential buildings in order to reduce the heating/cooling load. A new system has been proposed and now testing and simulation of its feasibility is performed. In the future, the option of using wood fibres for insulation material was to be tested.

Eva Esping, VINNOVA gave a presentation about VINNOVA and about one of the prioritized growth areas, “Wood Manufacture” and presented the results from the innovation studies that have been done.

Professor S. Brege, Linköping University presented the facts, purpose and aims for the Lean Wood Engineering research centre and opened up for a discussion with the Japanese colleagues how research is founded and carried out in Japan and Sweden.

Thomas Alsmarker, Tyréns AB presented strategies for sustainable urban development and the challenges that the Swedish construction industry is facing with a focus on reduction of emissions.

Jerker Lessing and Patrik Jensen, Tyréns AB gave a presentation about industrialised development of building systems, where Jerker Lessing shared his experiences from both working in industry and in academia at the same time. Patrik Jensen presented a building system and showed pictures from a project called “Kvarter Skonaren”.

Left: Professor S. Matsumura holds his presentation. Right: Staffan Brege hands out a gift of appreciation to one of the Japanese presenters.

Eva Esping, VINNOVA gives a presentation about VINNOVA and one of the prioritized growth areas, “Wood Manufacture” and presents the results from the innovation studies that have been done.

Left: Presentation by Tomas Alsmarker; Staffan Brege, Thomas Olofsson and Erik Söderholm listens interestingly. Right: Eva Esping presents VINNOVA.
5 Urban Design Centre Kachiwanoha (27 October 2010)

Summary by Jerker Lessing, Tyréns.

Left: the entrance to the UDCK information building. Right: an illustration of the area to be developed. In the background, university students are performing school work.

5.1 A New Ecological city

Kachiwanoha Campus is a new development area located 30 minutes from Tokyo on the Tsukuba Express Railway system. The land area was formerly used by the US Air Force, a golf course and an area for industrial purposes. When the plans for a new railway line were decided the idea of this new urban development project was initiated.

A new ecological city is planned here in a joint venture called Knowledge Based Cluster, where three categories are represented, Companies, Universities and Authorities;

- Companies (e.g. real estate company Mitsui Fudosan and Tsukuba Express Railway)
- Universities (e.g. Chiba University, Tokyo University, Institute for the physics and mathematics of the universe, Tokatsu Techno Plaza, National Cancer Centre, Hospital East)
- Authorities (e.g. National Police agency, Ministry of Finance Customs, Ministry of Finance)

During the development of the area, a centre for information and education was established, called UDCK – Urban Design Centre Kachiwanoha. The centre is used for education of students within various fields, meetings for the public and exhibitions about sustainable habitat issues. The centre itself is built with a timber frame and has an advanced system for balancing daylight and artificial light in order to minimize the use of electricity.

5.2 The new housing area

In the area, different actions are planned in order to minimize the use of energy and the emissions of CO₂, increase environmental awareness, and make this into an urban design lifestyle. Examples of actions taken and planned are the following:

- Rooftop farms; to get citizens to interact and enhance environmental awareness by seeing nature at work.
- Wind and solar power generators to help satisfy the electricity needs.
• Monitoring CO₂-emissions from apartment buildings; with sophisticated IT-solutions, the use of gas, electricity, water is monitored for 100 apartments in the Park City Kachiwanoha. Energy consumption rates and CO₂-emission status and rankings for each unit are displayed.

• People powered public transportation; Velotaxi which is a pedal-powered vehicle will create jobs and zero emissions. A mobility operation will be tested.

• Urban design school; offers free courses and encourages citizen participation, interaction and feedback in town planning

• Eco-design tours; promote hands-on experience and participants learn techniques and knowledge applicable in the home which leads to greater eco-awareness.

• Bicycle sharing; possibility to rent a bike to ride from the train to work and back. A system where payment is done with the cell phone is tested.

• Electricity purchase; test of a system where electricity can be bought for charging an electronic device for a short period of time. A system where payment is done with the cell phone is tested.

The development area contains a large portion of new housing. The area will be populated by 45 000 people when the development project is completed. For this, 15 000 new houses will be built by the housing company Mitsui Fudosan. The houses will be built at site and will not be prefabricated. The houses will be built with timber frame structure.
6 Mori Building (28 October 2010)

Summary by Fredrik Wikberg, Lund University.

The Swedish delegation awed at the sight of the extensive, yet so detailed, city models.

6.1 Introduction - Brief

The Swedish Lean Construction Delegation of 11 persons, assisted by three local Embassy professionals visited Mori Building headquarters in Roppongi Hills on the 28th of October. The purpose of our visit was to get acquainted with the incentives of a big player in urban development and facility management. Our own field of lean construction and industrialised building was therefore not primarily on the agenda. In focus were rather visions on urban design, safety and environment. After the Mori company and project presentations, we visited their impressing model gallery with scale models in 1:1000 of central Tokyo, and parts of Shanghai and New York. The session then focused on the construction company Obayashi. Our host was Ryoji Mizuno, site manager. This visit gave light to Japanese construction. The company Obayashi presented themselves and their ongoing Mori redevelopment project of Toranomon, followed by a walk on site. The following summary is based on the presentations we were given, beside handed out material.

General figures Mori building:

Mori Building had a turn-over of 177 billion yen with a profit of 20% in 2009. The number of employees is 1,361. The company consists of 21 consolidated companies specializing in all areas effective for project development and facility management. The company owns 106 buildings with approximately 1.19 million m² for lease.

General figures Obayashi:

Obayashi group had a turn-over of 1,060 billion yen in 2009 and is one of Japan's five largest construction companies. The number of employees is 9,222 in the main contracting business, but including its 24 affiliated companies the group has over 14,000 employees. The company is active all over Asia and is represented also in Europe and North America.

6.2 Presentation Mori Building

Mori building was founded in 1959 and made its fame after the war in providing international class office space for lease. Today, it has turned into a big commercial player in real estate leasing and management, covering as they say themselves every aspect of the urban landscape. The focus has then more and more shifted towards whole urban redevelopments, as they brand “hills”. The realizations of such “hills” are the result of long planning processes often involving hundreds of former site owners. The process took 17 years for the visited Roppongi Hills.
The company is mainly active in the greater Tokyo area, but expresses interests also in other urban areas in Japan as well as abroad. In China the company has recently completed the prestigious 101-story Shanghai World Financial Tower. In each project the company is active in project development, procurement and facility management. All design and construction works are carried out by esteemed firms and must comply with demands set-out in detail by the Urban planning and development division of the company. This division is supplemented by divisions of daily leasing operations, building management etc. Mori prefers to call the daily operation town management, as they say that a main strategy is to provide both “hardware and software” within their concepts. Within an urban redevelopment both the right mix of tenants and offered services is important. Three major “mission” areas are extensively focused on, namely (1) Environment, (2) Safety and security, and (3) Culture and art. These mission areas are focused on both in the urban design phase and in the future town management.

Illustration of the Roppongi Hills (www.mori.co.jp)

6.3 Environment

Based on visions partly reminiscent of Le Corbusiers’ “plan Voisin”, Mori Building expresses an urban design vision for the future city in its “vertical garden city” approach. Such ambitions call for big redevelopment lots within a township in order to realize a “greenery” effect. The redevelopments normally feature high density exploitation only in minor parts, in Roppongi Hills expressed in a majestic office tower and some apartment tower blocks. These are flanked by primarily lower retail and mixed-use buildings as part of a unifying design approach. Most of the ground space of a typical ‘hill’ development could thus be left open for improved traffic circulation, public arenas and primarily public green space. This “greenery” was expressed not only in parks, but included also a rice paddy and a revived old Japanese garden. In figures the “green” ratio was now 25% compared to the 20% it used to be. In the past, Roppongi Hills was in risk of neglect and decay as it was packed with houses in small blocks, criss-crossed by narrow congested streets. Roppongi changed into an exclusive “green island”; a welcomed diversification from modern townscapes; exemplifying coming Mori redevelopments.

A major issue of Mori is to reduce the CO₂ footprint per person active within their communities. Much could then be accounted for only through involving people in their ‘life style concept” where the possibility of working, living and relaxing in the same
neighbourhood drastically could reduce the impact of pollution from daily commuting. Active measures taken by Mori in lowering the CO₂-emissions are also the use of ‘green’ technology for generating power, heat and cooling in their communities. The primary energy source is natural gas, supplemented by the reuse of waste heat and advanced use of thermal storage systems. Side-effects in the Mori “hill” projects were the mitigation of the “heat island” phenomenon as well as the contribution to local biodiversity.

Illustrations of the vertical garden city (www.mori.co.jp)

6.4 Safety and Security

An important issue in Japan is earthquake safety. Mori building wants their “hill” communities to go one step further and have a function as relief centres also on an urban scale level. Starting with the redevelopment itself, the transformation from congested areas with houses not able to withstand earthquakes, the new communities offer sheltered areas and also improved escape-routes through improved street network. The buildings are made earth-quake-resistant using features like dumping walls, green mass dampers and emergency power generators. A green mass damper is visible only as a green roof terrace, but in case of an earthquake the heavy weight of the whole terrace could swing back in order to reduce the horizontal force. Locally produced heat and power system have its roll through offering double power systems as part of the taken precautionary measures. Safety from natural disasters also includes resistance against fire, tsunamis, typhoons etc. The focus on local energy production as well as all the applied earth-quake proofing technology is strikingly different from normal Swedish concerns.

6.5 Culture and art

Culture and art is considered important for the ‘hill’ concepts as it contributes to an innovative climate and makes the whole community more open and attractive for working, living and visiting. The featured Roppongi Hills therefore offered meeting places in a number of different arenas beside only business, including an amphitheatre, a concert hall, an art museum, a library, beside education facilities etc. For residents of Roppongi Hills a neighbourhood association is also responsible for supporting a sense of pride and identification with the community, embodying traditional ceremonies and arranging festivities, cleaning-up days etc. The ”hill”-concepts have been a success, much due to the growing number of wealthy elderly and aware young in their careers interested in alternative living concepts in central locations. For those aware safety and sustainability may be the most important parts of the concept, but the devotion to culture and art give the concept also a philanthropic touch. The community is therefore quite different to that of traditional business parks and gated living communities. To a foreign visitor it’s however still striking that the traditional Japanese, in terms of style, has almost no impact on the urban design and architecture in general.
6.6  Presentation Mori City models

In a big open space on the visited 42nd floor three city models were displayed, one gigantic of central Tokyo and to minor of Pudong area Shanghai and Manhattan New York. The model of central Tokyo covered 17x15 meters and gave us an almost perfect bird-watch. The richness of details was striking at a scale of 1:1000, showing also roof profiles and façade layouts. The motive of Mori Building for such scale models was to get a better understanding for the effects of their urban designs from clients, tenants and society, but for themselves also improved abilities to compare urban structures. The analysis in scale models of new developments were nevertheless supplemented by studies of 3D-models using advanced virtual reality (VR) techniques.

A detailed model depicting central Tokyo (only part of the model is illustrated on the photo).

6.7  Presentation Obayashi Building Company and field visit Mori construction site

After the presentation at Mori building the Swedish Lean Construction delegation was invited to visit the Toranomon construction site in the Roppongi area. The site was featuring an ongoing Mori redevelopment commissioned to Obayashi Building Company. The company acts for a sustainable society in 2050 through its Green Vision Plan and is active in research concerning both eco-friendly construction including CO2 reduction and resource circulation, besides being a leader in earthquake resistant technologies. “Lean” was however not heard of, even if our central process issues in much seemed implemented in their practice.

The manifested Eco-friendly construction was focusing on reducing emissions and waste, but expressed also high-end skills in production off-site in its use of pre-cast concrete. The construction we visited was well under way and had reached its 35th floor out of 50. An impressive orderliness on site with paved access ways and seemingly just-in-time deliveries, covered scaffoldings etc added to the impression of construction excellence. Also, looking down into an over 20 metres deep foundation pit through a wide opening in the tall structure above was breath-taking. This portion of presented hard stuff made the day for some of us! In the Toranomon project all the Mori devised “missions” were envisioned to be incorporated, forming a new attractive hill development.
7 Sweden-Japan joint seminar (28 October 2010)

Summary by Anders Björnfot, Luleå University of Technology.

The embassy of Sweden in Tokyo is prepared for the Sweden-Japan joint seminar.

7.1 Background

As a consequence of the LWE visit to USA in 2009, a joint Swedish-American seminar was held that proved to be very successful; the seminar resulted in for example a joint Swedish-American course for doctoral students held in Stanford. Consequently, LWE is hoping for a similar Japan-Swedish collaboration. To start off the Japanese-Swedish collaboration, a seminar was held at the Embassy of Sweden in Tokyo.

7.2 Presentations (Part I)

The topic of the seminar was: “Sustainable Society - How can the construction industry and university R&D contribute?” An opening to the seminar was held by Anders Karlsson (Office of Science and Innovation/Growth Analysis) while Staffan Brege introduced the seminar by stating that Swedes prefer to engage in long-term relations and Swedes also have a high degree of business and technical maturity. Consequently, there are many similarities, i.e. Swedes can be considered the “Nordic Japanese”. The seminar was divided in two parts, where all Swedish LWE representatives held a presentation, focusing on research and development respectively:

The seminar was introduced (left) by Anders Karlsson and Staffan Brege (on the podium) while Thomas Olofsson and the audience listen attentively (right).
PART I – PRESENTATIONS

1. **Swedish housing from a Japanese perspective**  
   *Hideshi Oika*  
   *Arkos KK*

   Hideshi Oika discussed the possibilities of exporting Swedish housing to Japan and concluded that there are many differences in regulations, especially concerning energy saving.

2. **From black box to prioritized R&D**  
   *Eva Esping*  
   *VINNOVA*

   Eva Esping explained the role of VINNOVA in Swedish R&D, exemplified by the development of the wood manufacturing platform followed by the Lean Wood Manufacturing program.

3. **Lean Wood Engineering research centre**  
   *Staffan Bregé*  
   *Linköping University*

   Staffan Brege gave a presentation of LWE and explained that LWEs vision is part of a strategic 10-15 year vision for the development of the whole Swedish wood manufacturing sector. LWE is financed in equal measures by VINNOVA, the three involved universities as well as the involved companies. Staffan also stated that the influence of working methods from the Toyota Production System is the reason that Lean is in the program name.

4. **Industrial development supported by industry and university R&D**  
   *Jerker Lessing*  
   *Patrik Jensen*  
   *Tyréns AB*

   Jerker Lessing began by explaining that his licentiate work was performed jointly between Lund University and Tyréns and that he is now continuing his research towards his doctor degree in the same fashion. Patrik Jensen then presented an ongoing research project between Luleå University of Technology and Tyréns, i.e. joint R&D on both project and business levels.

5. **Toyota way – A case study of kaikaku/kaizen at Misawa Homes**  
   *Takayuki Wakamatsu*  
   *Culman co., LTD*

   Misawa Homes produces about 7 500 houses per year using an element building system. Today they have 30 factories and one ceramic plant. However, before the crisis production was performed in fewer factories and it was concluded that they had outgrown efficient human resource management.

   Takayuki Wakamatsu stated that Misawa’s Lean journey already began in 1987 where the
specialised plants led to inefficiency due to too much logistics leading to high costs. JIT was the solution but back then it did not work due to the batch oriented production system leading to inefficiencies in the form of increased downtimes and increased inventories (increasing the time to find components during production).

Misawa Homes solution was to state a clear vision of an ideal factory, arrange production so that only assembly is performed on site (meaning increased pre-assembly and a reorganisation of the factories), production per need (pull, i.e. downstream processes are regarded as customers), piece-by-piece flow, and parallel production lines.

The Lean transformation has lead to 95% reduced inventory and reduced number of components which means that anyone can understand assembly. The lead time after contract to delivered house is 30 days; production time on site is 26 days with a factory tact time of 60 s. According to Takayuki Wakamatsu, Lean is a selling product theory while making product theory is the traditional thinking.

6. **Lean Construction: From theory to practice**

   Anders Björnfot  
   Luleå University of Technology

   The understanding of Lean ultimately originates from the Toyota Production System (TPS). Anders Björnfot explained how a theory of Lean Construction has been developed from the TPS to in construction involve an integrated consideration of the products produced, the process utilized to produce these products, and the supply chain, i.e. the resources required for production. Anders Björnfot argued that; if an organization wants to be truly Lean, then all aspects of Lean must be considered. Examples were then provided of ongoing research in LWE related to the product, and parallel production lines.

Finally, Anders Björnfot informed about an ongoing collaboration project with small- to medium-sized timber companies in north Sweden who is interested in, or already, exports highly appealed wooden products for the Japanese market.

7. **Strategies and performance measurements**

   Erik Söderholm  
   Martin Lennartsson  
   Fredrik Wikberg  
   Luleå University of Technology & Lund University

   Erik Söderholm, Martin Lennartsson and Fredrik Wikberg provided insights into three PhD projects in LWE. Erik Söderholm provided information about the company Moelven ByggModul and their ongoing process of process standardisation. Martin Lennartsson presented an ongoing collaboration effort of industrialised housing manufacturers to modularise service systems. Finally Fredrik Wikberg explained ongoing research striving to better include architecture in the design process using configuration of architectural objects.
**PART I – DISCUSSION**

Staffan Brege emphasised that Lean is a western concept where we have only, really, picked up fragments from Japan. In the 1980’s, the lack of profitability of the Swedish car manufacturers was blamed on high worker wages (that of course were too high as we did not properly understand Lean).

Staffan Brege further argued that of course the customer wants everything. However, value adding is not always profitable; it all depends on how you get paid! Consequently, companies that make their business directly with customers are not necessarily profitable.

It was asked whether Misawa Homes always have been industrial producers. Takayuki Wakamatsu clarified that Misawa at the beginning produced components but that they today are organized for panel production.

Hideshi Oika clarified that termites is not a problem for wooden houses in Sweden. However, there are other insects that degenerate wood. In Japan, termites can be an issue though. Hideshi Oika also stressed the importance of protecting wood from long-term contact with water, for example in the foundation.

According to Takayuki Wakamatsu, domestic timber is hardly used at all in construction. Misawa homes, for example, import timber from Finland.

Staffan Brege concluded the first discussion session by stating that theory indicates that construction is the worst industry; there is a lack of international competition, there are many specialists involved, there are strong regulations and products with long life time. Staffan Brege further pointed out that LWE, promoting industrialisation, is one strategy (among others) to improve productivity.

**7.3 Presentations (Part II)**

**PART II – PRESENTATIONS**

8. Strategies for sustainable urban development

*Tomas Alsmarker*  
*Tyréns AB*

Tomas Alsmarker provided a presentation about Tyréns, a R&D company (not a consultant) with a long-term sustainability perspective – “We want to make a difference”. According to Tomas Alsmarker, the construction sector stands before an exciting and challenging future! The society can be illustrated as a circular system that must be taken care of, and consumed resources must be reused. A circular system can be compared to a journey to Mars where the space shuttle must take care of itself for a long time.

The ecological footprint of construction is critical – today it takes about 1000 years for nature to recover from one built house. It is imperative that the footprint is reduced. By building for example passive housing then the footprint can be reduced to maybe 500–600 years. However, Tomas Alsmarker stated that clear goals are essential; visions drive innovation! Tomas Alsmarker further presented an ongoing study of trends for successful future sustainable cities.

9. Trends in standards and design method for energy conversation in Japan

*Takao Sawachi*  
*Building Research Institute*

Takao Sawachi explained that the Building Research Institute is an organisation that aids the Japanese International Business and organizes cooperation with the construction industry and other research institutes. Takao Sawachi further described some of the Japanese efforts in Energy saving. For example, in 2009 new regulations were developed for the performance of building services (heating, cooling, ventilation, hot water and lightening). Regulations for the building envelope were already developed in 1980. Influence for the building envelope
regulations was Swedish and North American building design.

10. Process and energy efficient building through Lean and collaboration  

Matilda Höök  
Masonite Beams AB

Matilda Höök presented Masonite Beams AB – a manufacturer of timber beams and boards that have developed a complete building system composed of timber panels, the Masonite Flexible Building System. By seeing the end product as a goal, and through the cooperation with experts, Masonite has developed a technical manual and a process manual to support design of buildings composed of the new building system. The technical manual provides standard technical solutions while the process manual facilitates common goals, standard work and continuous improvements.

11. Virtual construction and cooperation: Experiences from a Swedish-US Workshop  

Thomas Olofsson  
Luleå University of Technology

Thomas Olofsson shared some experiences from the joint Swedish-US seminar that served as the background to this seminar. The seminar led to a joint Swedish-US graduate course in virtual design and construction. Thomas Olofsson proposed that this seminar would lead to a joint Japanese-Swedish graduate course in “Design of sustainable building systems” where the Swedish and European technical knowledge of building system design is combined with the Japanese expertise in sustainability.

Are the local and the global conditions the same? For example, kitchens and cities do not have the same conditions for successful design. Tomas Alsmarker explained that there are no conflicts between local and global conditions. Instead, there are many similarities. In both cases it is important to learn how people think. It is thus important to have the global perspective in mind but to focus on the local perspective.

Are there any side-effects from the Japanese regulations? Takao Sawachi explained that it is difficult to understand heat insulation. In Japan there is a need to study more how to provide efficient heat insulation as it is not possible to apply thicker walls.

In Japan, high quality wood is used in engineering products. Consequently, there is a need of more high quality wood. In Sweden wood is used for buildings and there is a large industry that is depending on timber, e.g. paper, energy, etc. Japan has abundant forests and need to learn how to better use their timber. However, it is difficult to use much timber in Japanese housing due to fire regulations. Eva Esping stated that when we cut forests in Sweden then we
need to cultivate the cut trees. We also keep forests close to cities for places of recreation. This is possible because Sweden of course is less crowded than Japan.

Staffan Brege stated that about 90% of detached housing in Sweden is constructed in wood and that prefabricated homes are catered towards the low- and premium segment. While in Japan standard manufactured homes are catered towards the premium segment. According to Staffan Brege, Swedes are used to working in standardised ways. However, as clarified by Tomas Alsmarker, we do not use the words standard design, processes, platforms, etc. in Sweden.

To summarise the seminar, Tomas Alsmarker stated that it is a question about partial vs. total optimization, i.e. energy savings is only part of the solution. Thomas Olofsson emphasised the opportunity to learn from each other; how can we approach energy conservation? Staffan Brege concluded that we have a challenging future ahead of us that requires a split vision between Lean – Sustainability, between local and global optimization, as well as between setting visions and taking the first step.
8 Toyota Home (29 October 2010)

Summary by Martin Lennartsson, Luleå University of Technology.

Left: Martin Lennartsson with the Toyota Mascot. Right: Another Toyota Home on the road.

8.1 Introduction

Toyota home was founded in 1975. The automatic production line was introduced in 1987. The building system is based on steel frames which are welded together. The projected tact time is 4.6 minutes per unit. Toyota home is working continuously with Kaizen, Lean and their production system. They have an annual record of 2200 customers. A way to maintain the quality and endurance of the steel beams is the application of anti-rust technology adapted from the automotive division of Toyota. Noise reduction is an issue when dealing with these kinds of structures, which has been addressed using damper technology aiming to significantly reducing noise within the building and between floors. In Japan another problem to handle is humidity and heat which is addressed using insulation technology.

Illustration of the Toyota home housing models and a detailed model used for sales.

Toyota home relies on their company slogan “sincerely for you” and aims to fulfil this by construction of houses that won’t burn, implicating robust and durable houses. Another important issue due to Japanese conditions is solutions for handling possible earthquakes. In this aspect tests and experiments have been conducted to verify the resistance for such forces. The system provides the customer with a variety of choices in design. The building system also presents possibilities for participation in urban development projects.
8.2 Site visit

The factory was covering an area with size of 1/3 of the Nagoya dome. The unit had a designated area for training of new employees, both practically and theoretically in order to understand and maintain the prevailing culture in the company. Outside the factory, Toyota home had built experiment houses to investigate durability and heat insulation. The houses were able to rotate in 360 degrees in order to analyse the environmental effects and comfort in the houses. There was also a test building which had been exposed to earthquake tests of 7.0 on the Richter scale. The results could be presented to visitors and customers.

Left: welcome to Toyota Home. Right: an earthquake damper at the In-house testing facility.

The production line was divided in a sequence with seven steps.

1. Machine Cutting
2. Cords
3. Unit assembly
4. Outer walls
5. Inner walls
6. Equipment
7. Inspection and delivery

The company aimed for a prefabrication level of 85% in order to ensure quality. The steel frames were assembled using CNC welding robots. If problems or irregularities were discovered there was a repair area to make corrections, which was re-checked afterwards. The steel frame measures were 125x125 mm. The whole frame is immersed in anti-rust coating. Experiments have been conducted for a sixty year period with no trace of rust. In the automatic welding robot area there were also displays of personnel authorised to do manual work in case of failure in the automatic process.

The noise reduction technology was based on automotive systems. To verify quality measurements there was an optical robot which was scanning the surface. Irreparable components were scraped. Wires and pipes were delivered in preassembled packages in preset lengths and was also an adaptation from the automotive division. On the assembly line the company applied jidoka and Andon strings to handle deviations. There were a red and a yellow string, where the yellow meant that local efforts were implemented to solve the problems, while the red meant immediate stop in the process. There was also a Board connected to the Andon displaying the stop times.
Illustration of the Toyota home housing manufacturing line and the yellow and red Andon strings.

Illustration of the “Andon Board” indicating a Andon string being pulled and the total stoppage time from deviations in hours and minutes (in this case 6 minutes).
The process contained of 75 different activities. A house consisted of average 10 units and 104 units per day were produced with a work force of 350 employees. The time for a house was 6 hours in factory and 6 hours on-site and completion in a month and a half.

The overall impression of the visit was good and it gave inspiration to the delegation regarding how Toyota home has decided to design their manufacturing process. The process is dependent on the choice of building system and the steel frame system. A main driver for this choice is the prevailing conditions in Japan and the potential risk for earthquakes.
9 Daiwa House R&D institute (29 October 2010)

Summary by Jerker Lessing, Tyréns.

Left: Jerker Lessing posing with the Daiwa House Mascot. Right: The Swedish delegation anxiously awaiting the start of the Daiwa House tour.

9.1 Introduction

Daiwa House has 13,700 employees, 10 housing factories and 83 established sales offices around Japan. The company’s missions are to:

1. Provide individual homes
2. To build and operate commercial facilities
3. Providing support of daily life

The Daiwa House R&D Institute supports the whole company and was established in 1994. The institute has 154 researchers employed to conduct research, testing and support for the whole company. Testing and research is carried out in the following fields:

- Climate, rain, snow, wind etc
- Earthquakes
- Acoustics
- Material
- Energy
- Environmental issues
- Health
- Information and Communication Technology
- Structural resistance

Not only new technology is examined but also traditional building techniques and solutions from around the world, are examined and analysed at the institute. By understanding traditional ways of building houses, new and modern technology is developed, with a strong connection to the fundamental and basic solutions from the traditional building culture. Examples of areas in this context are heat insulation, ventilation, light, air tightness etc.
9.2 Examples of R&D efforts

Daiwa House has a high standard for their products in terms of earthquake resistance. An example mentioned was that in the Kobe earthquake in 1995, 6500 people died and over 100,000 houses were ruined, but none of them were built by Daiwa House. The reason mentioned was that a Daiwa house is built to resist earthquakes and technological solutions are built in to prevent damages from earthquakes. The Daiwa House Research Institute has an advanced earthquake simulator in which new technical solutions for minimizing vibrations from earthquakes can be tested.

Thomas Olofsson, Fredrik Wikberg, Patrik Jensen, Jerker Lessing and Anders Karlsson take the Daiwa House earthquake simulator for a test drive.

During the visit at the Daiwa House Research Institute, several innovations and testing facilities were shown to us. The following is a summary of what we experienced:

- Heat insulation; a new insulation material, which should be assembled on the outside of a building's structure in order to decrease heat loss from the structure.
- Ventilation; a smart sensor activated by temperature is used to control hot air supply.
- Acoustics; solutions for windows to prevent noise from leaking into the house. Advanced technical solutions to bring down vibrations in the structural frame including a hanging ceiling, rubber as damper, mineral wool. This was used both in single family houses and apartment houses.
- Toilet; ICT solutions for measuring a person's health in terms of blood pressure, blood sugar and weight. This was explained as a good way of sending frequent reports to the
doctor or hospital, without a need for travel and hospital visits. This was considered a growing area of interest since the aging population is growing.

Left: Test rig for acoustics evaluation. Right: Illustration of the “ICT toilet”.
10 Todaiji temple (30 October 2010)

Todaiji is a Buddhist temple complex located in the city of Nara, Japan. Its Great Buddha Hall, the largest wooden building in the world, houses the world's largest bronze statue of the Buddha Vairocana, known in Japanese simply as Daibutsu. The making of the statue was started in 745 and finally completed in 751. The original complex also contained two 100 m pagodas, perhaps second only to the pyramids of Egypt in height at the time. These were destroyed by earthquake. The current building was finished in 1709, and although immense, 57 m long and 50 m wide, it is actually 30 % smaller than its predecessor.
A giant Buddha is the centre of attention in the temple interior.

A hole through a pillar in the temple interior, who’s meaning is unknown.
11 Individual reflections

11.1 Eva Esping, VINNOVA

It has been a challenging task and a real experience for me to be appointed as "project leader" for the delegation tour to Japan; it would have been difficult to accomplish my task without the support from our own working group in Sweden. When VINNOVA asked us to be a kind of test pilots for future similar tours, this greatly assisted our preparations as the delegation tour became included in VINNOVA - Growth Analysis annual cooperation for 2010. We were asked to note good practices and advice from the preparation phase; you will find some important points in the end of the text.

Most of my personal reflections and impressions from the delegation tour, site visits and seminar have already been noticed by other members in the delegation and can be read on previous pages. But I do remember some very interesting things, which no one else have mentioned or noticed.

1. Due to a decreasing national demand, a strategy for Japanese house producers is export where China is viewed as a valuable market. This is interesting, as China also has been discussed in Sweden as a market with great export potential for Swedish producers.

2. Wooden based prefabricated houses are merely a small part of the annual volume of prefabricated houses in Japan. On reason, that is often referred to, is fire regulations which in some aspects limits the use of wooden constructions or wooden based interiors and façades. This is probably true. However, in previous Swedish reports about potential export markets for wood, Japan is referred to be a "huge" market.

3. I am a big fan of TV-series such as Mega Constructions on Discovery and it was really exciting to visit one of these sites in real life. Not so mega as for instance Osaka airport or Twin Tower in Kuala Lumpur, but rather close. What was interesting to hear, which was new to me, is that in Southeast Asia with major risk for big earthquakes, constructions must be secured not only for earthquake damages but also for energy disturbance. The latter is extremely important in business areas, where just a millisecond of power failure may cause huge financial damage as billions of yen, dollar etc. are continuously transferred.

4. From the long planning period and with very good support from the Growth Analysis’ office in Tokyo, it was a fantastic experience. We were also very lucky that Mr. Hideshi Oika, Arkos KK joined our delegation; who could explain technical issues for us. If I ever get the opportunity to be involved in a similar task again, and especially to Japan, I would prefer fewer visits. To choose just a few, you must have the knowledge how to choose and from what, which means you must have been there before. I would also prefer to stay longer at every visit and also be able to discuss some important topics, which mean you need a skilled translator, not only in Japanese but also a translator with knowledge about construction, pre-fabricated house market, etc.

Finally, I will give some short notes from our PM about planning a delegation tour abroad, which is made after request from the international Department of VINNOVA.

- Begin the planning phase a very long time prior to the tentative tour. Use your own experiences and ask for others. From just an idea to a real planning phase for us it was almost a period of two years.
• Be focused and make it very clear from the beginning what you want to achieve from the tour and what kind of sites you want to visit. Do your own research and make notes of companies, researchers, authorities, etc. that you would like to visit.

• We were lucky to be supervised by professionals from the Growth Analysis’ office in Tokyo. You need assistance from resources in the country of visit that are familiar with local habits and traditions. This is very important, especially in Japan.

• It is important that you secure a continuation, not only in the preparation phase but also in the implementation and reflection phases. If your preparation relies on certain persons, divide the responsibility on others who may carry on the work without any interruptions. In our case, we appointed a vice project leader as well as a vice delegation leader, which seemed important as the ordinary delegation leader was unable to participate.

• We were exceptionally supervised by the Growth Analysis’ office in Tokyo in the preparations, including hotel reservations, train tickets, taxi bills, pre-booked lunches, etc. In our case, these preparations were critical as there were always a shortage of time between different sites. In order to make it really clear from the beginning which person has to pay for what, we provided Growth Analysis with a document detailing invoices for every individual participant.

• Before we left Sweden, it was already clear who would be in charge and responsible for preparation of the final report and also which participant would be responsible for each site visit. The Programme Director of LWE also prepared a smaller doctoral course for participating PhD students, to provide new and different views of the site visits and other experiences from the tour.

Left: Schedule for the site visit. Right: Erik Söderholm, Martin Lennartsson, Fredrik Wikberg, Anders Karlsson, Thomas Olofsson and Patrik Jensen preparing for the embassy seminar.
11.2 Matilda Höök, Masonite Beams AB

Compared to Swedish housing production, industrialised factory production in Japan is

- Much more automated, which is not strange as the Japanese house factories produces approximately 50 times as many detached houses as the largest producers in Sweden. However, there are certainly aspects that the Swedish producers may learn from the Japanese housing industry.
- Not as Lean as you would like to believe. Actually, it seems as Toyota Home is the only company, which presents a clear strategy and approach to Lean. By contrast, the Japanese culture means that other companies naturally are working on a strategic, “orderly” and standardized way. It is a natural part of everyday life in Japan.

The goal of high energy demands and zero emissions are well pronounced in Japan. They seem to have higher targets overall than what we have in Sweden, but how Japan vs. Sweden reach the target differs significantly:

- In Sweden we are almost entirely focused on getting the building envelope as tight and well insulated as possible. Whereas in Japan, the focus is more on facilities, energy recovery and the implementation of energy from the sun. Sweden is in this regard not unique at all. In Austria, for example, the approach is more like that in Japan, with great emphasis on developing effective installations.
- One area where the targets appear to be similar in Sweden and Japan is how to get to a building system that works well from an acoustical perspective. The system being demonstrated in Japan shows somewhat innovative techniques that in many respects are similar to our Swedish systems, with different types of vibration dampers. It seems however, that our Swedish building systems has reached a stage further in this area.

What can we learn from each other?

- Even if our market in Sweden is much lower than in Japan, there are certainly things to learn from Japanese production in terms of automation.
- To approach low energy housing, it is fairly obvious (in many cases) that a combination of improved building envelopes or more efficient installations is best. It seems that both Japan and Sweden have much to learn from each other in this regard.

To learn Lean in Japan, the house manufacturers are perhaps not the optimal actors to begin with. In my opinion, learning Lean is best experienced

- At suppliers to Toyota. Toyota however, is too big and automated in order to ensure a fair Lean experience.
- With a Japanese/English-speaking guide who knows about, and is familiar with, Lean and has the opportunity to translate signs and other signals, which better would explain why they work how they work, etc.

Thereafter you can go to house manufacturers and there see with your own eyes how they are working with Lean. However, it is important that the purpose of the factory visits are well explained, i.e. that you want to see how Lean is implemented (if it is implemented) and how they are working with Lean on a daily basis.
Lean Wood Engineering – Travel Report Japan October 2010

Industrial Partners
EFG European Furniture Group AB
Flexator AB
Lindbäcks Bygg AB
Moelven ByggModul AB
NCC Construction Sweden AB
SCA Timber AB
Setra Group AB
Stora Enso Timber AB
Tyréns AB

Project Partners
AB Fristad Bygg, AB Karl Hedin,
BAC Såg & Hyvleri AB, Fristadbostäder AB,
HSB Göteborg Ek fören, Moelven Töreboda AB
Skanska Sverige AB

Akademic Partners

Luleå University of Technology

Linköping University

Lund University