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FUTUREHOME - MANUFACTURED HOUSING FOR EUROPE

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Abstract

The provision of housing in Western Europe is characterised by stark contrasts. On the one hand, Sweden considers its housing needs in terms of requiring in the region of 30 000 dwellings per year. Compare this with the UK, where more than two million homes are presently regarded as unfit. Elsewhere, the picture is generally of provision that lags demand and significantly so. The major response needed from government and industry has been significantly boosted by the European Commission's decision to fund the *FutureHome* programme. The essence of the project involves developing know-how to create affordable, high quality,[1] cost effective manufactured housing, taking account of the diversity of styles, designs and materials as well as the preferences of owners and occupiers (the customer).

FutureHome aims for reorganisation of design and production schemes in construction, with a focus on the integration of activities, development of clean, lean and reliable systems that are adaptable to the economic, social and cultural needs of different customers. The project programme will make extensive use of new developments in IT components and subsystems for intelligent, autonomous mechatronic systems, where the emphasis is on flexibility and reconfiguration of production facilities. These leaner design and construction processes will focus on value for money, improved productivity, maintainability and sustainability.

FutureHome is expected to have benefits through savings in construction cost of 30% and 35% in construction time together with a reduction in defects on completion of 60%, enabling industry to be more competitive overall. Other benefits include improving the quality of life, social fabric and health of the European economy through a more efficient and effective construction process.

1. BACKGROUND AND RATIONALE FOR *FutureHome*

1.1 *General*

Most construction methods for housing in Europe are based on methods employing manual labour that are slow and relatively expensive. Predicted demands for both quality and quantity in the housing sector indicate that factory methods will be essential in the future. Other engineering sectors are already enjoying the benefits of lean production and automated assembly techniques. A major change in methods and acceptance of prefabrication technology is essential for the construction industry if it is to handle future demand and avoid the loss of this market to foreign competition.

Across Europe, housing provision is diverse; it is a picture of low quality housing interspersed with affluent living – a combination with the potential for social disorder. Housing Europe's growing and ageing population in the next century will present major challenges, not least in the capacity of the construction sector to deliver adequately against calls for sustainable development and environmentally-aware life-styles. Piece-meal attempts at dealing with the problem of modern housing at the local (national) level are not a solution: a co-ordinated response is needed, one that has the ability to exceed expectations coloured by memories of past mistakes. Europe cannot afford to waste scarce resources in housing its people. It must take steps to ensure that it can guarantee affordable housing of a high quality, that is, homes which are built to last.

In decades past, the usual response to the need for new or replacement housing on a large scale was to adopt

[1] Quality is defined to include aesthetic appeal, functionality, specification, energy-efficiency, durability, adaptability and other factors.

industrialised building systems for the creation of vertical communities on a grand scale. History shows what happened. Even so, not all of those initiatives were unsuccessful. Some have survived and show that innovative manufacturing can provide a solution to the housing needs of significant parts of the community. Drawing on the success of Swedish and Finnish experiences in manufactured housing, combined with technological innovations from Germany, Spain and the UK, this research programme proposes to tackle the long-standing problem of providing affordable, high quality homes for all by applying the technology of intelligent manufacturing both off and on-site.

1.2 Industrial objectives and expected achievements

FutureHome is the European self-standing component of a global IMS (*Intelligent Manufacturing Systems*) [1] project and can be seen in terms of meeting a number of technological challenges that will lead to greater efficiencies within industry across the world. It will concentrate on developing tangible solutions and know-how to create an effective industry response mechanism for overcoming the barriers to the establishment of affordable, high quality housing in Europe.

FutureHome will take account of the diversity of styles, designs and material composition, as well as the preferences of owners and occupiers, that is, customers who are as diverse as Europe itself. Even so, all share the same basic requirement of a home that is affordable, decent, modern in its facilities and capable of adapting to changing needs. In this latter respect, the general maintainability of the products of *FutureHome*, together with components that can be recycled, are amongst its key objectives.

FutureHome has the following objectives, where the highlighted phrases correspond with the respective objectives of the IMS project (IF7).

- developing adaptable and sustainable building system concepts and testing their performance using computer-based simulation and scaleable demonstrations, as part of ***the study of design and assembly processes for*** large-scale ***structures***;

- developing off-site and on-site (field factory) production and assembly processes involving ***the use of intelligent automation systems***, as the basis for a highly mobile response to the need for robust solutions to local housing demands;

- developing an IT infrastructure that is capable of supporting concurrent engineering and efficient supply chain management in the design and construction process, involving ***the use of autonomous cyber-agents as support tools***.

These objectives are developed in more detail in the sections that follow. They also constitute the European element of the linked IMS project (IF7) "*Innovative and Intelligent Field Factory*" [2], which involves further teams of partners in Japan and Canada, and is described in the document, "*IF7: Description of the inter-regional project*".

The results of *FutureHome* will, however, do far more than address a level or target of production. The adoption of advanced manufacturing and modern materials and components will bring other tangible benefits for industry and its customers. A preliminary study of the scope for reducing both time and cost indicates real gains.

- Reducing overall time from placing order to occupation by 50%
- Reducing construction time by 35%
- Reducing cost construction by 30%
- Reducing overall cost of housing by 40%
- Reducing reported defects on completion by 60%

These represent further goals or targets for *FutureHome* in its development of a range of products that must succeed in a highly competitive marketplace.

1.2 Industrial relevance

Europe does not have the capacity or even the capability at present to solve a fast growing need for affordable, high quality housing. Initiatives for dealing with the problem in Europe are fragmented, with little concentration or co-ordination of effort. This means that the size of the problem will get worse before it gets better, unless there is a concerted effort now. Moreover, traditional or conventional building technology and its associated methods of construction could not be reasonably expected to change this situation. Something like the Japanese approach to large-scale manufacturing could, however, make a major difference.

The collective efforts of the partners in *FutureHome* will enable a large-scale response to this large-scale problem, leading to the following benefits for industry.

1. Advances in the ability of the European construction industry to deliver housing at lower cost with a real improvement in quality over the life cycle; for example, benefits from advanced manufacturing coupled with intelligent, autonomous field agents to provide consistency, certainty and durability in the end-product.

2. Improved maintainability of the completed product by a more exacting manufacturing process in which present needs can be balanced with those of the longer term. Opportunities for active recycling of components and materials can occur when whole life implications have been considered from the outset.

Other, specific attractions for European industry include the following.

3. Stimulating investment in IT infrastructure and human resources to raise levels of productivity and effectiveness overall; for example, eliminating inefficient work practices and other forms of waste from the design and construction process by adopting a leaner design and construction process focused on value for money and the principles underlying sustainability, maintainability and recyclability. Customers (owners and occupiers) will also benefit from the provision of 'intelligent' computer-based models to support the operation and enjoyment of their buildings.

4. Greater competitive advantage for the European construction industry overseas through its ability to initiate rapid responses to housing needs; for example, in mobilising resources and facilities for major projects in the aftermath of natural disasters and generally in more effective support to third world countries. In other words, providing the widest possible geographical market for Europe's industrial products and services.

The automated construction and prefabrication technology to be employed will be heavily dependent upon the use of information technology and communications technology, productivity methods as used in other engineering sectors and modern construction management principles. These will draw on the very best of what European industry has to offer presently and will challenge it to raise its competence still higher. This will be accomplished in large part from the application of proven advanced manufacturing technology to an industrial process that has for so long seemed immune to change. Bringing building construction into the next century is one of the implicit goals of *FutureHome.*

An important aspect of *FutureHome*, as reflected in the global IMS-IF7 project, is the development of the *intelligent field factory,* an on-site production facility for the assembly and finishing of prefabricated components. This mobile production facility will use innovative ideas and exploit new technology to bring many of the benefits of fixed production plants to the construction site. These benefits will include weather protection, dimensional certainty in a generally unstructured environment, risk and hazard protection systems and low environmental impact production processes.

1.3 State-of-the-art and degree of innovation

Housebuilding across Europe is a pretty mixed affair in terms of standards, quality and durability. Even where investment in innovative forms of construction has been significant over the years, there is still a distinct lack of modern industry of the kind that one associates with mainstream manufacturing. Put another way, housebuilding in Europe has yet to advance to where the automotive industry was 25 years ago. Some advances have been made in both the engineering and fabrication of the main structural elements of domestic scale construction, yet these too are lacking in many aspects. For example, the intrinsic quality of the end product and customer satisfaction with it leave much to be desired. Additionally, the housebuilding sector in Europe is not as competitive as other sectors of modern industry. The opportunity to apply advanced manufacturing techniques to housing would, we believe, produce demonstrably improved quality, durability, maintainability and customer satisfaction. This confidence is based on success in other industrial sectors where quality improvements and value for money have advanced dramatically in recent years through the application of advanced manufacturing.

Traditional housebuilding uses a variety of basic materials and components. The crafts-based nature of most construction does not lend itself easily to manufacturing and continues to employ methods and practices that hark back centuries. Even so, this adherence to traditional values does not bring with it a necessarily sound product. Owners and occupiers continue to suffer because the product cannot be engineered to a high enough specification and fails repeatedly to eliminate long-standing failures.

FutureHome wishes to bring about a revolution in housebuilding, but one where the stimulus for improvement comes from the successful marrying of customer preferences coupled with advanced manufacturing capabilities. Critics of this approach will say that it has all been done before. In some respects it has, but it has also failed because of the absence of a socially acceptable product. Moreover, ultimate quality was shown to be lacking largely because of the ill-defined control between what can be manufactured off-site under factory controlled conditions and what should be done on site.

Where current initiatives in modern housebuilding fail is in trying to automate a traditional process that adheres obsessively to outmoded industrial practices that are at best uncompetitive and at worst dirty, dangerous and of doubtful quality. Waste in construction is a serious problem today and yet has been known about and debated vigorously for decades. So, the problems are recognised, yet the solutions are not being adopted. There are other factors, but the point is made: housebuilding must adopt modern (if not advanced) manufacturing methods if it is to change once and for all its poor quality image and the reality that too often goes with it. This means a manufacturing approach that puts quality first. If construction were ever to do this, it might be surprised to see how cost and time then fall into line.

The partners in *FutureHome* can, however, demonstrate considerable innovation in structures and components for modern housebuilding that will provide a higher level starting point than would otherwise be possible. In many respects, the industrial partners are able to demonstrate the state-of-the-art. British Steel plc is amongst several of the partners who have undertaken substantial RTD in manufactured housing. *FutureHome* represents the latest phase in a continuous process of innovation and product development for them and others. In the case of British Steel, its *SureBuild* system has benefited from EC support under ECSC funding. *SureBuild*[3] is a light steel framing system that provides the internal framework of the building on to which plasterboard, floor boards, insulation and cladding are attached. The development of this panel system provides a good understanding of the various challenges facing the *FutureHome* project. Similar advances and innovations have been made by the other industrial partners. *FutureHome* can, therefore, expect to build on a wealth of first hand experience and results.

The major innovation that *FutureHome* represents is in applying advanced manufacturing methods to construction, especially housebuilding and light industrial and commercial buildings. The latter can be thought of as particularly important spin-off from *FutureHome*. This project will draw on a components-based production process that is highly engineered and that can benefit from automation systems and robotics tools. For the underlying building technology, components and systems will be designed along the lines of generating an infinite variety of styles and shapes that can be easily reconfigured to suit changing needs. In common with other industries, concepts such as design for production and built-in redundancy will be used to deliver what the customer wants.

The *FutureHome* consortium is well aware of the long life implications of buildings and has placed issues such as durability, maintainability and recycling towards to the top of its agenda. This approach envisages, therefore, that the products of *FutureHome* will be both the parts needed to achieve this goal of differentiation through variability in design and the means for realising it in a far shorter time and at a lower cost than is possible under conventional construction. We can expect, therefore, that the products of *FutureHome* will adapt well to the local market conditions that prevail across Europe.

2. RESEARCH APPROACH AND METHODOLOGY

FutureHome will combine various types of research: investigation, analysis, experimentation and demonstration. It is the latter of these that will enable the research to show very clearly what can be achieved through the application of advanced manufacturing techniques to construction.

The wide-ranging research requirements of the project have been divided into three main research areas, which can be summarised as follows:

- **MODULAR STRUCTURES**

  Design and assembly methods, taking account of the needs of customers and requirements of long term needs, especially those of sustainable development.

- **AUTOMATION SYSTEMS**

  Design of systems for the associated assembly processes, including the intelligent field factory concept, and the deployment of advanced construction plant and equipment.

- **AUTONOMOUS AGENTS**

  Study of the application of autonomous agents for the management of information and the construction process.

Further details of the work content are given in tabular form below.

MODULAR STRUCTURES: Building system concepts and performance.

Development of adaptable and sustainable building system concepts and test of their performance over the life cycle of a project using computer-based simulation, as part of the study of design and assembly processes for large-scale structures.

Study of building system concepts and performance studies. The objective will be to establish how manufactured large-scale housing can be designed to produce a minimum of 30% savings in cost and time over existing methods, with improvements in quality and whole life performance.

Production of a demand matrix for housing in different European regions; building system design case studies; computer simulations demonstrating high performance fixing mechanisms; sealing methods with built-in diagnostics and condition indicators; and the mock-up of an innovation module comprising a small size, domestic scale structure acting as a demonstration of the FutureHome concept.

AUTOMATION SYSTEMS: Off-site and field factory production and assembly

Development of off-site and on-site (field factory) production and assembly processes involving the use of intelligent automation systems, as the basis for a highly mobile response to the need for robust solutions to localised housing demands.

Study of off-site and on-site (field factory) production and assembly. The objective will be to determine the most efficient distribution and production capability and the division between (fixed) factory and field factory. Effort will be concentrated on the management of the supply chain to ensure a seamless, value-added process from component identification to its ultimate incorporation in the end product.

Development of analytical tools for zero start-up factory production; tools for the design and control of integrated, multi-site production capacity; and demonstrations of on-line interaction in the supply chain in relation to key elements.

AUTONOMOUS AGENTS: Cyber-agents, communications and IT infrastructure

Development of an IT infrastructure that is capable of supporting concurrent engineering and efficient supply chain management in the design and production process, involving the use of autonomous cyber-agents as support tools.

Study of the operation of autonomous and semi-autonomous 'search and do' agents (called cyber-agents). The objective will be to determine how an effective IT infrastructure and communication network can be built to create a vertically integrated cyberspace in which information and knowledge circulates and accumulates. This virtual world of the supply chain will mirror the needs identified in the building case studies, and support the physical infrastructure determined above. It is assumed that the data-world of FutureHome will make extensive use of electronic communications such as the Internet. Intelligent cyber-agents will play an active role in managing and co-ordinating the whole specify/design/construct/maintain cycle.

The outcome of this study will include specification of the optimal design of cyberspace data structures; methodology and guidance on the design of cyber-agents; demonstrations of cyber-agent operation for the building case studies and of cyber-agents to assist in the integrated control and management of the distributed off-site factories combined with the field factory.

3. STRATEGIC IMPORTANCE OF FutureHome TO EUROPE

FutureHome is a truly European concept; it recognises that the skills and experience required are scattered across Europe, and the outcome – high quality, affordable manufactured housing – has application across the whole region. Furthermore, the export potential of this project to European constructors, a valuable world market, could be lost to foreign competition.

Benefits to the European partners are expected through the interaction with IF7 project participants from Japan and Canada. In particular, Japanese participants will make available valuable know-how on advanced manufacturing and intelligent field factory production. This is an area in which the Japanese have led and from which Europe now has the chance to learn and benefit.

Enhancing the capabilities of the European construction industry to enable it to produce the number of homes indicated would make an enormous difference to the quality of life, social fabric and health of the European economy: better housing can help in combating crime, as well as creating more settled communities.

FutureHome is also expected to be able to make a positive contribution to the development and updating of codes and standards as it applies innovative methods and systems to the design and construction process.

4. ECONOMIC AND INDUSTRIAL OPPORTUNITIES

There are many areas where the existing housing stock is of low quality by today's standards, due to a

combination of economic, cultural and technical factors. Across Europe this problem can be seen to different extents in every country and it is evident that the real working life of much of our housing exceeds its original design life by a significant margin. This is in direct contrast to Japan, for example, where there is a substantial market in replacement housing as opposed to refurbishment.

European construction companies and component manufacturers will be provided with an opportunity to exert a significant role in the large world markets for high quality housing, using efficient manufacturing techniques to provide them with a competitive advantage.

High reliance upon automation and IT will allow rapid mobilisation for bidding and reduce time to market. FutureHome will support the design tools and evolving standards for data exchange in this sector, including concurrent engineering methods and electronic trading. This will strengthen the competitiveness of European companies working in consortia and will encourage this form of operation. It will succeed in breaking down artificial divisions between specialist companies in the construction industry, as well as bringing in expertise from the mechanical and electrical engineering sectors.

FutureHome thus addresses many of the known problems in the construction industry, notably:

- over reliance on traditional or conventional building technology;
- low labour productivity;
- poor production control; and
- high levels of waste and rework due to poor quality control.

The main thrust of the project is towards greater efficiency of working for which realistic target cost and time savings have been set – see section 1.2. Provisional estimates, based on the potential manufacturing output of *FutureHome*, indicate that at least 2 billion ECU could be saved in each year of full production.

4. SAFETY, SOCIAL AND ENVIRONMENTAL IMPACT

Safety : The project aims to address ongoing safety issues in the sector by:

- Use of advanced automation and prefabrication techniques to avoid manual operations, especially those that need to be carried out at height.
- Development of smart connectors for site assembly, thus minimising arduous labour.
- Development of an on-line, on-site support system for risk diagnosis of site hazards.
- Development of materials handling and assembly machines, thus minimising man-handling and damage to components.
- The use of cyber-agents to minimise human error.

Employment :

- The technology enhancements to the construction process are not expected to reduce employment; rather they are seen as means of improving the health and welfare of the workforce, job satisfaction and expansion in construction activity

Environment : The project will specifically address:

- Minimisation of waste, especially that caused by reworking, by use of automation and improved process control.
- Reduction of the environmental impact of the construction process by virtue of the on-site and off-site factory concept.
- Greater energy-efficiency, maintainability and adaptability to changed requirements during the occupancy phase, with the real prospect of recycling obsolete components and elements.

5. DISSEMINATION

The *FutureHome* and other IMS research groups will publish results at ISARC and similar conferences. The main focus for information will be the project Website[4], which will also be used to establish an 'Economic Interest Group' and show links to associated activities.

6. POSTLUDE

FutureHome is one of the largest housing innovation projects for some time. It proposes major changes to fundamental production processes that many involved in this traditional industry believe to be comfortably far in the distant future. The lean manufacturing approach has, however, swept rapidly through all other fields of engineering; even the motor industry, seemingly resistant to rapid change, has encompassed this approach within little more than a decade.

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