IFD Buildings as design and delivery innovation

R. Di Giulio*, M. Coccagna*, G.-J. van den Brand**, L. Quah Kiang***

Abstract— **The building construction industry in Europe is now experiencing new forms of procurement and production systems, reflecting a matured market client/user-dominated, where the demand of new building is both for high-quality and low costs. The current state-of-the-art in building procedures must be improved, according to the dynamism of economic, social and technological factors that greatly affect users' functional needs over time.**
The building industry in major European Countries is facing such a transition. It needs to be more customer-focussed, less fragmented in organising project delivery and increasing current levels of industrialisation. Therefore the existing tools need to be updated, most of all because of the long time and fragmentation of delivery system, of the low levels of industrialisation and because of the difficulties in implementing new shared technical and management process models. Innovative technological and process models have to be developed, addressing market dynamism and client demands in a more efficient and cost effective way.

***Index Terms*— industrial, flexible, demountable, buildings, customer satisfaction, collaborative engineering, comakership, product development**

I. Introduction

A significant change, resulting from investments in R&D, is changing the role usually played by manufacturers producing and supplying building components and systems. Customers have a higher role, asking more and more to partake in design, selecting and combining factory-produced components from product catalogues available on and off-line.
These developments change the traditional role of architects, contractors and builders and the building design and construction itself.
The natural progression towards economic grouping, permanent partnerships/joint ventures between architects, contractors and manufacturers do not appear to have materialised despite operational benefits to do so. Continual improvement and changes are needed in response to the structural decline in demand and changing market place.
The three-year research program called IFD focused on developing a process model to design and deliver Industrialised, Flexible and Demountable Buildings.
The research group comprises nine independent organisations from five countries, representing and simulating the interest of the main participants in a building project. The main aim of this program was to develop a pan-European technological and organisational framework and supporting systems to deliver buildings that could offer to the client more freedom of choice through the use of factory-made and interchangeable building components. Therefore the IFD Buildings strategy needs the establishment of an IFD co-maker consortium where partners agree to a long-term view of the venture and combine and build upon individual knowledge and skills. The IFD consortium sought to provide the required technological, organisational and commercial framework to deliver the client-oriented Industrialised, Flexible and Durable constructions. These IFD buildings have been considered as consumer products, therefore the consortium in interested in setting out to identify and/or to create the needed building market and branding of the IFD system, defining a longer-term feedback with clients and users.
The IFD system comprises four main clusters of activities viz. Market Research, Product Development, Production and Sales. Processes intra and inter cluster mutually support the realisation of the IFD process and end product, through specific ICT and collaborative engineering strategies.
The management of the IFD buildings as consumer products offers to the clients more freedom of choice. On the other hand the building industry needs to be more client-focussed and knowledge-based, changing its modus operandi to better gear itself to meet market demands as dynamic economic, social and technological impetus can change a client's functional requirements of a building over its physical life. Above all, the industry needs to operate in a less fragmented manner in project delivery and increase its current level of industrialisation both on and off-site. This will require new roles and new management procedures, and above all a new market approach, giving factory-made and interchangeable building components and more flexible layouts to better forecast the changing of user requirements.

The building industry in major European countries is facing such a transition. This impetus should drive the industry to develop innovative technological and process models which can address market dynamism and evolving client needs in a more efficient and cost effective way.

This paper shows the final results of the UE research project entitled 'Social-Technological-Commercial Process Model and Supporting Communication/Information System for Design and Delivery of Industrialised, Flexible and Durable Buildings' or 'IFD Buildings' in short; this program was officially completed in March 2004. The IFD system proposes a more effective and unified approach to building procedures, standing from the Client need for quality, shorter delivery time, flexibility in use and economy, the Community needs for sustainability, safety and healthy work environment and the Industry organisational requirements for partnerships and alliances.

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II. THE IFD APPROACH

The IFD design system tries to develop technical solutions to meet the high-tech performance requirements of flexibility and demountability, using a 'soft' architectural design. Trends and expectations of potential clients have been assessed and technical solutions defined to satisfy their needs.
Technical performances of IFD Buildings include:

- possibility for the client to choose components, materials and finishing from an IFD catalogue;
- flexibility of layouts for changing user requirements;
- possibility to recycle components;
- reduction of maintenance and refurbishment costs due to ease of disassembly for repair and replacement.

The IFD strategy includes two different typologies: house and office building (Figg.1-2), each one decomposed into three technical 'macro-modules' viz. Core, Functional Modules/Working Spaces and Shell (the external envelope which acts as roof and façade of functional modules).
The technical system of each macro-module is made-up of different sub-systems, comprising a set of compatible and interchangeable components. Macro modules can be combined in several predefined configurations, resulting in a customised dwelling.
The Technical Core includes services, circulation areas, equipment and the major technical solutions needed to make the IFD Building systems flexible and demountable; it's then possible to design and achieve a 'softer' look to the other parts of the building. The Core can be provided with different services, equipment and finishes to the internal and external components. It can be delivered ready assembled and equipped or completed on site, in any case it's used as a 'guide element' to coordinate the joining of the other components.
Design and construction of the other macro-modules is based on the 'Industrialised Open System' approach. The building production and assembly tries to emulate the manufacturing models and collaborative engineering processes used in the industries (i.e. the automotive one) where the high reliance on co-makers fosters long-term strategic partnerships, marketing/distribution arrangements and joint ventures.
The suitability of existing building components for their incorporation into IFD system depends on a set of 'assembly rules', which define the basic component requirements to be included in the catalogue. Assembly procedures and flexibility of layouts are based on the modularity of unit spaces enabling

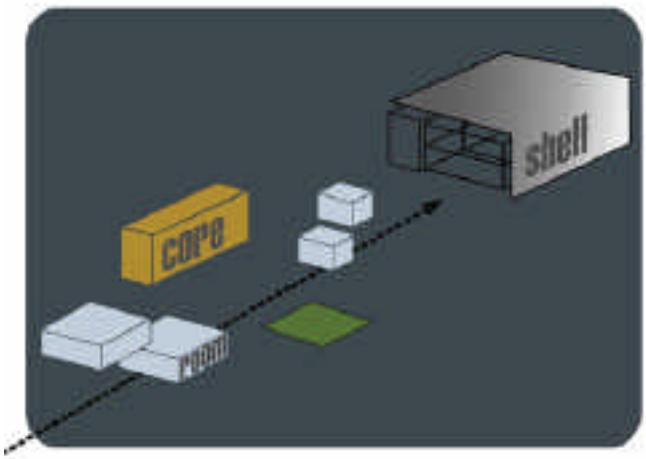

Fig. 1. Scheme of the IFD house building typological approach.

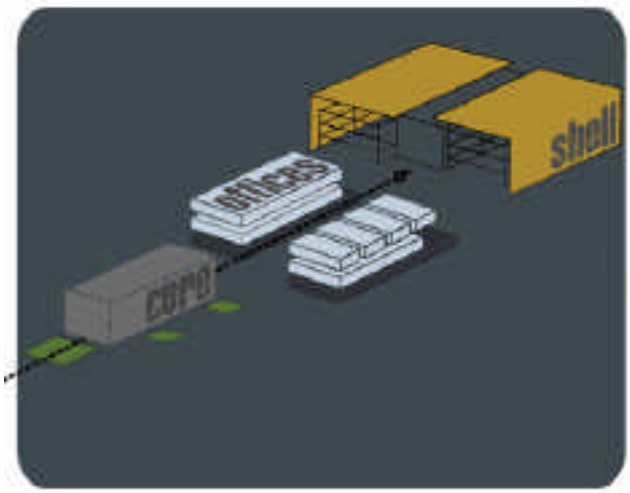

Fig. 2. Scheme of the IFD office building typological approach.

the building to be shaped according to different solutions. The IFD House and Office prototypes have been designed using technologies, components and materials available in Europe.
The inner criteria to chose the suitable building elements included in the final IFD catalogue are:

- defining a building system than can be clearly understood and labelled as a "real" IFD project;
- including the highest number of existing element still on the market;
- reducing the number of joints;
- giving the chance to integrate traditional building works.

The IFD design concept envisages a separation of the building production process into three distinct sub-processes viz. production of primary building components (load-bearing parts of the structure), secondary components (facades and roof), and tertiary components (infill and services). The final choice of components can be resumed in three different "families": prefabricated, semi-finished and materials, each of them still existing on the market, modified for the IFD project or ready made.
The analysis of performance requirements of joints between components has been focused on:

- testing elements, to check the basic requirements for an IFD building system (in particular structural framework, external walls and service subsystems);
- studying the component compatibility collecting more information about the joint systems which optimise flexibility and adaptability of the IFD building;
- shortening the number and complexity of interfaces.

Client involvement is high in the design stage and design solutions can be developed in consultation. A first list of typological opportunities arise from the basic choices of the IFD design pool (according to the preliminary market analysis), any other specific request dues to the environment analysis, to the client needs or to local norms have to be previously verified and assessed by the consortium (Fig. 3).
There aren't absolute parameters that can be applied to the architectural value of the final proposed layouts but, naturally, some design choices have been automatically proposed as preferred ones. The IFD system can be easily adapted to specific target groups, without carrying out any change to the methodological approach or to the inner structure of the system.

III. THE USE OF INTERACTIVE TOOLS

The flexibility of the IFD building has been pursued also in the communication system made to manage both the process itself and the data publishing, in and outside the IFD consortium. The information protocol covers indeed the transformation of data input and output into the proposal of a building design and in the dissemination of IFD methodological matters.

The continuous feedback between the producers/suppliers themselves and the clients/users, in particular according to the international perspective of the business, can be arranged just supporting and implementing a global communication/information plan, able to show the implications of the decision making system. The real challenge was to develop a new designing strategy starting from an international building market more and more marked by its variedness, incostancy and opposition to changes. The main purpose has been therefore to bypass the traditional inelasticity of the building demand/supply system, trying to catch and to address the expectations of the target groups interested in a more flexible set of building performances. The change of the building market toward a more demand-driven supply chain search for this kind of managing system, focused both on the client expectations and on the capacities of producers and suppliers to work all together, surfing the market waves.

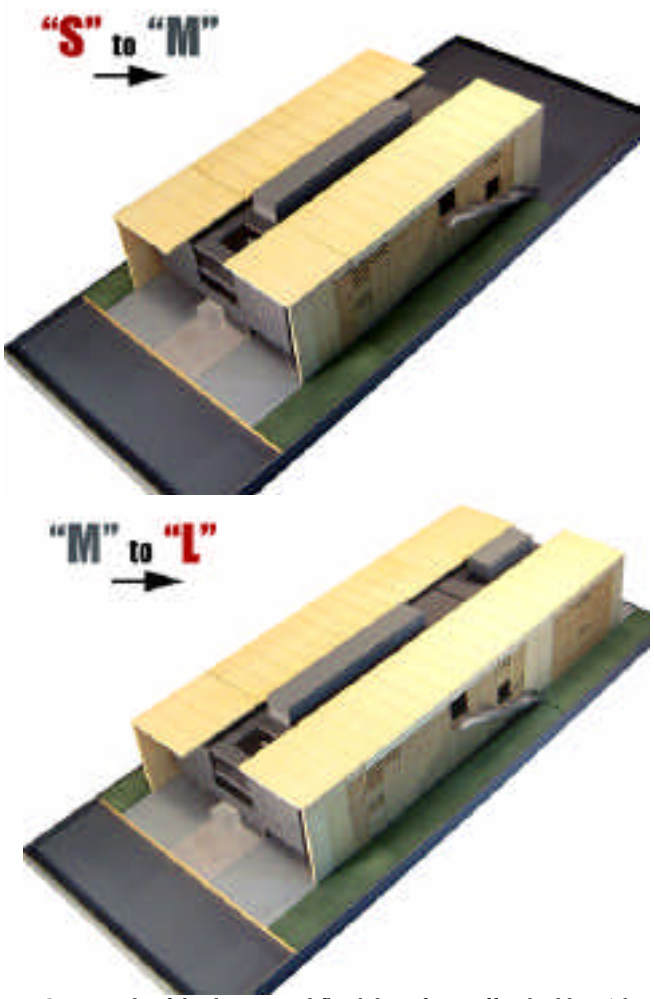

Fig. 3. Example of the dimensional flexibility of IFD office building (photos of the demountable maquette made to show the project to clients).

Fig. 4. Example of the dimensional flexibility of IFD house layout (the VR and scale model pictures have been directly compared with client target groups, layout, drawings, technical specifications, etc).

The proposed model is based on a continuous spreading of information controlled and addressed through a network between partners, that is a set of "parallel sessions" discussing the specific aspects related to the building design, sending questions and results to all other subject involved in each phase. The IFD Buildings organisational and process model comprises four main clusters of activities viz. Market Research (M), Product Development (D), Production (P) and Sales (S). Processes intra and inter cluster mutually support the realisation of the IFD process and end product.

The IFD protocol can be divided into its eight main steps:

1. Building Market and Market Segments
2. Definition of Client Needs
3. Building System Design
4. Catalogue of Building Products
5. Building Production
6. Promotion and Sale
7. Delivery and Assembly
8. Post Occupancy Evaluation

The "public" version of this system has been made to show the on-going results of each design step and it can be read both as a gradual shifting from requirements to the building production or as a rough of independent technical features (i.e. the assessment of social and economical trends, the design approach, the product supply scheme).

The distinction between different kind of data and tools allows to target the information to the specific capacities and expectancies of each single subject (client, suppliers, builders, etc). According to this the IFD consortium designed a set of tools, all available through the web[1], than can help to focus the client expectations and to translate the data from a common to a technical language using images, videos, questionnaires, games but also diagrams, 2D and 3D drawings, technical grids, schemes and specifications (Fig. 4).

The IFD approach is made of different kind of interrelated tools to manage the proposed building solutions, in particular:

- the Table A defines a matrix of all possible Architectural design solutions, associated to their dimensional

[1] There is a free demo of the IFD system and tools on the official web site [www.ifd-building.com].

Fig. 5. Pictures of the office building taken from the VR video.

Fig. 6. Example of finishing: pictures associated to the client optional choices for building materials and related to the catalogue of IFD products.

specifications (is filled with a collection of views taken from the virtual models, describing the available solutions).

- the Table L shows the Layouts related with the target groups needs (represents both a resume and a comparison between target data and layout architectural opportunities).
- the Table T collects all the technologies (materials, components, installations) that can be used in the IFD building system.

This step-by-step strategy is carried out using a set of interactive media and procedures, coordinated by the technical responsible research partners but carefully assessed by the consortium as a whole.

One of the most important tools of the IFD system has been developed by the Building Department of the Dutch Government (one of the official member of the IFD Consortium), trying to focus the client requirements using an Excel or a web based application. Analysing the answers to some very simple queries the system is able to generate and put in a brief the performance and technical specification of the building that better than others gives shape to the client needs. This designing procedure shifts through several steps, from "larger" to "smaller" features: building form, inner functions, image, layout, comfort and technical specifications. The results of this tool, completed by the target and commercial market analysis, give the required information to the design pool that translate them into IFD building options.

The same result can be joined by the client using the IFD web gallery, that describes the available examples of buildings designed by the consortium using images and videos (Fig. 5); in a second time the user can analyse the performances and functions associated to the preferred solutions. This catalogue of feasible designs, coordinated by the Italian partner[2], enables the client to configure the house shape and size through the choice of preferred dimensions and layouts.

Possible combinations of basic layouts are shown in a matrix form; thereafter, materials and finishes can be chosen in as much the same way. Each stage of the process moves on electronically (Fig. 6), the preferences can be viewed through a virtual model enabling navigation of the building interiors and turnaround. When the final choice is made it can be automatically produced an instruction manual, showing all possible variations, transformations and extension of spaces and services.

The development of these tools requires a close consultation between the Product Development, Production and Assembly clusters. These construction phases have been simulated during the research project looking through the relationships

[2] The research group includes, besides the project coordinator (the Dutch consultant association Damen Bouwcentrum), the international partners: Climaconsult Finland OY (FIN), Costain Ltd (UK), Halton Group Ltd (FIN), Ipostudio Architetti Associati (I), Périgée (F), Rijksgebouwendienst (NL), Tampere University of Technology (FIN), TNO Bouw (NL).

Fig. 7. Pictures of the house building taken from the VR video.

between the involved partners: engineers, architects, builders, etc. These tests covered a lot of specific technical stages as the architectural design, the 3D rendering (Fig. 7), the deepening of technical drawings and specifications, the detailed analysis of building services (Fig. 8).

The end results have been finally resumed in some basic IFD building design configurations, shared between specific targeted client groups and sub-groups. In this way users can make a selection directly from the library of basic designs, components, finishes according to their preferences, or choosing further options from an IFD building product catalogue and viewing the effect of their decisions through virtual reality models. Using a database strategy, driven by a search engine, clients can select from and view the effect of their choice in real time, analysing the IFD basic design that they have opted for.

The IFD inner catalogue of building products gives also the chance to arrange a group of suppliers, working together because able to adapt their elements to the design needs and to manage the design itself according to the co-marker consortium trends. This list of building producers can be updated regularly to enlarge the building offer and to short the delivery times enlarging the geographical fields. Analysing sales trends and patterns, it may be then possible to arrange for a 'just-in-time' production model, ascertaining minimum inventory types and level to produce and hold.

IV. Conclusion

Foreseeable benefits accruing from IFD Buildings are economies from standardisation of designs and components, facilitating a range of client/user needs and choice, higher productivity and reduction of site labour and construction waste and better management and control of building time and quality.

Current ICT and collaborative engineering tools can be harnessed as an enabling tool to support concurrent engineering, group decision making and data sharing and transfer to meet IFD building organisational and process needs. The IFD Buildings research project amplifies the collaborative R&D efforts required to develop and forge the innovative change needed in building process design, organisation and delivery. It hopes to spur the economic grouping and permanent strategic alliances/partnerships that have so far eluded the building industry and prevented its elevation to a first world service industry and production process.

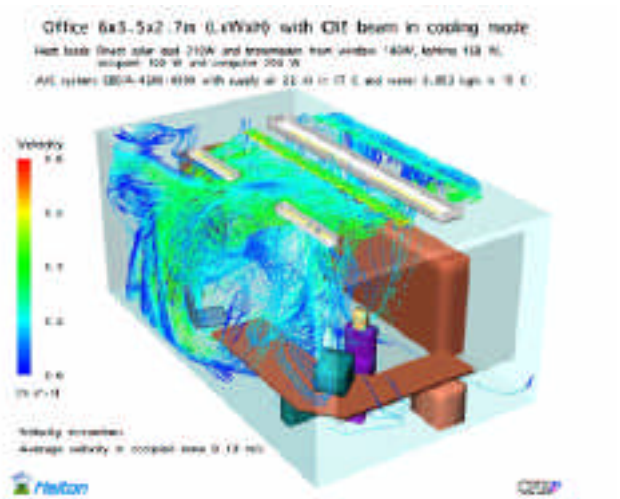

Fig. 8. Example of interactive simulation of the service behaviour to analyse the internal comfort of designed spaces (coordinated by the Finnish partners: Halton and Climaconsult).

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