One of the main goals of I3CON from an industrial point of view is the use and further development of new components as well as new production methods for these and other components. From the outset it became clear that we would be dealing with different innovative components and concepts in different stages of development and with overlapping functions. The complexity of including such components in a concerted and coherent design process quickly becomes obvious: integrating new, complex, and innovative systems is exceedingly difficult if the overall planning process adheres to “traditional” design procedures.

In a traditional construction process each project phase, from planning to construction, can be practically seen as independent, taking place more or less back to back. This is often coupled with unsynchronised planning, as each phase of planning often depends on results from a previous phase. It is therefore difficult to introduce technical innovation which relies on integration and high levels of coordination, as this would have to begin at a very early project phase and traverse many project phases. With the overall timeline of a construction project in mind and laying emphasis on the design of integrated BSS pathways, a common platform and the need for tools to facilitate the overall process became increasingly clear.

The different aspects of the individual structural and BSS elements were taken into account, as the levels of interdependence and reciprocal influence vary greatly. The 3D model was used to clarify pathway concepts and geometry clashes and provided the necessary data for further expert calculations by other expert systems (areas, volume, geometry, geographical alignment etc). In an iterative process the 3D model was refined with the results returning from the expert analysis.

The final VIP is a fully detailed virtual 3D model of a fictitious project (pictured in the top left of figure 1) showing the

The VIP is a good showcase for the necessity not only to develop new components and innovations but increasingly to address the aspect of a comprehensive new design approach in order to ensure that these systems find appropriate acceptance and application to the full benefit of all involved parties. Incorporating the space concepts developed in WP3 as library elements in the T6.4 building configurator will further expand the VIP. This will allow for faster and more integrated planning from a very early project stage on, with the focus on clash-free production optimisation.
By: Miguel J. Segarra Martin, Carlos Bárcena Martín, Fco. Javier García Costas, Raúl Sánchez Labrador, Dragados

In view of the difficulties with implementing the innovative components and controlling systems conceived in the I3CON project on a dwelled building (because of the early stage of development of some of them), one of the main demonstration activities has been building a Mock-up to test the feasibility (in terms of physical integration and logical interoperability) of these components and systems, and measure their performance whilst working altogether.

The design of all the systems involved in the Mock-up has the aim to develop new and efficient solutions for the common issues in housing and, at the same time, to allow the evaluation of these systems, which are the following: envelope system; electro-chromic glazing; water saving system; domestic fire extinguishing system; under-floor radiant heating; and multi-service trunking system.

The values to be measured and monitored are: water (hot and cold), electricity and energy consumptions; temperature (ambient and surface) and relative humidity degree, both indoor and outdoor; presence; water temperature and flow; CO2 concentration; and light level. This is done by means of a network of sensors, meters and actuators deployed throughout the Mock-up. All these systems are controlled by the Building Operating Systems (BOS), and the information handled by this system can be accessed through Mobile Productivity Tools (MPT) for operation and maintenance issues.

Regarding the architectural design of the Mock-up, the innovative effort is made on the development of new façade solutions adapting current manufacturing processes, such as the Sandwich Framex typology, and the improvement in the thermal and acoustic behaviour of the Mock-up envelope with passive strategies, e.g. by using Phase Change Materials (PCMs).

Three main structural configurations, most of them based on the usage of Glass Reinforced Concrete (GRC), are employed to design the façade panels of the Mock-up:

- **GRC Stud-frame**: GRC shell attached to a tubular steel-frame, mullioned with vertical trusses. Two panels are configured with this solution, with the special feature of gypsum plasterboard sheathing enhanced with PCM micro-capsules.

- **GRC Sandwich**: panel anchored to the main structure by means of cast-in channels and sliding bolt connections (for tolerance re-adjustment). As a result of the manufacturing process, the side over the mould is better finished and hence is typically installed facing the exterior, while the other side of the sandwich, that is finished with a trowel, is sheathed with plasterboard. In this case, the mould face features a special pattern to improve the acoustical behaviour by diminishing the reverberation time and faces the indoor space. Since now the outmost surface (the trowelled face) is not acceptable from the aesthetic standpoint, it is covered with different kinds of composite panels.

- **Sandwich Framex**: it is an evolution of different kinds of composite panels. Sandwich Framex is the flexibility of the external cladding, which may consist of a great variety of elements configured in a modular way over a common sub-structure (the steel frame) and installed so that they can be easily changed for maintenance, renovation or substitution. Examples of external elements have been selected in response to bioclimatic concepts and market trends, and include: photovoltaic modules, vegetated cells and wooden panels. Other possibilities are composites, metal sheets and ventilated ceramics. Two of the Mock-up panels which are configured with this solution include, PCM packed in plastic boxes within the sandwich core, in order to improve thermal behaviour.

In support of improving thermal efficiency, visual comfort and privacy, an Electro-Chromic Glazing Unit (ECGU) is provided in one of the rooms and adapted to a regular window frame, allowing power and control cabling. The ECGU features a number of degrees of shading that are controlled by the BOS in response to solar irradiance, presence, glare and indoor temperature, and operated in conjunction with the HVAC system thanks to the integration of all the systems within the BOS.

The Water Saving System consists of a hot water recirculation system which works only when it is needed. This system is connected to the sensor network in the building, which activates the system when a person is within a predetermined area (bathroom or kitchen) or if the water temperature inside the pipes is lower than a set value. Some advantages of this solution are less water wasting and less waiting time for hot water.

The Domestic Fire Extinguisher System stands out for its simplicity: the cold water supply pipe passes through the sprinklers, ending at the toilet. Thus, every time the toilet is flushed, confirmation is provided that there is no impediment (e.g. incrustations due to hard water) for the water to flow and therefore the system would work if a fire started.

The Under-Floor Heating (UFH) system has been installed over the floor concrete slab. Its main virtue is its reduced installation height which makes it especially suitable for renovation works. The use of PEX pipes for this and the water-saving and fire-extinguishing systems, installed using the "pipe-in-pipe" method, facilitates the renovation of the pipes given the case.

The Multi-Services Trunking System (MSTS) is a very innovative concept that comprises a set of runs for different kinds of media. The MSTS has been manufactured using rapid prototyping tools, and is installed in the Mock-up for proving the concept: hot and cold water, air and electricity are delivered through the MSTS.

Concerning the monitoring and control of the Mock-up, the following inputs are studied:

- Consumptions measured with metering devices: hot and cold water, electricity and energy.

- Parameters measured by the Wireless Sensor Network (WSN):
CO2 concentration, presence by means of a Passive Infra-Red (PIR) technology, Relative Humidity (RH) degree, light level and indoor ambient temperature. There is a gateway that converts the radio messages transmitted by the sensors into TCP/IP messages which are then accessible from the BOS.

- Sensors deployed at different layers of the façade panels: ambient and surface temperature, and RH degree, in order to assess the overall performance, with a focus on the effect of PCMs and vegetation.
- Parameters measured with wired sensors: presence, light level, water temperature and flow in the pipes, ambient and surface temperature (indoor and outdoor).

The BOS allows the controlling of the Mock-up based on the information gathered by the sensor network installed. The BOS handles the following signals: readings from the metering devices, inputs from the sensors located in the kitchen, the bathroom and each one of the test rooms, data from the HVAC and UFH systems (controlled individually for each room), the heat pump, water pumps, domestic hot and cold water consumption simulation, and signals from façade panels.

Remote access to the Mock-up monitoring and control systems is very important for the measurement plans. Internet connection plays an important role for accessing the data and carrying out usage simulations. Furthermore, the application of Mobile Productivity Tools (MPTs), e.g. a Personal Digital Assistant (PDA) carried out by the maintenance staff, means that any relevant information about the equipment installed in the building (i.e. the Mock-up), such as the drawings, location in the building, and any data accessible from the BOS, will be accessible for the operator working on site in real time.

To sum up, the concept of I3CON open building services architecture is present in the Mock-up in so far as are demonstrated the feasibility of constructive components such as the façade panels, the correct operation of all the systems involved, and the efficiency of the Mobile Productivity Tools.

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**WP7 Second I3CON Handbook published**

**By Ian Wallis, BSRIA**

Within the fourth year of the project, the second volume of the I3CON Handbook has been published and together with the Handbook 1 can be now downloaded from [http://www.i3con.org](http://www.i3con.org).

The 2nd handbook "Industrialised, Integrated, Intelligent sustainable Construction" has allowed the leading Institutes and Universities to present varied methods, techniques, services, technologies and new ways of collaboration for the construction industry to promote innovation and to attain sustainability in the industry. Procedural and technological innovations introduced within the book have been supported by a set of practical methods fostering further development and acceptance of new approaches, theories and ideas.

While the 1st handbook has been created from contributions from the Project partners, the second volume gave an opportunity to external collaborators, such as University of South Australia, the British University in Egypt, Delft University of Technology, Georgia Institute of Technology, Danish Technological Institute, Institute for Industrial Production, National Institute of Solar Energy and many others, to share their views on the I3CON project related topics.

**Target audience**

The prime audience of the book is industry practitioners, construction stakeholders (architects, consultants, building owners and users, organisations with legislative power and others), researchers and academia with an interest in the development and application of new effective techniques, methods, components and materials. Nevertheless, everyone who is interested in helping the construction industry become more sustainable will enjoy the reading.

The third and final volume of the I3CON Handbook will be available to download in September 2010.

The book will be released shortly before the end of the project showing the main I3CON achievements and results. It will also bring together available innovations and their benefits to the construction industry sector.
**WP2 Evaluation criteria, metrics and measurement methods of building lifecycle performance**

By Jo Harris, BSRIA

Issue 06 provided an outline of the work undertaken in WP2. This WP was to develop concepts and tools for intelligent performance measurement models to increase the performance of buildings. With identification and development of evaluation criteria, metrics and measurement methods of building lifecycle performance.

You cannot improve performance without first measuring it, but what is it we need to measure? When building performance is measured, we need to consider both physical metrics that can be measured with devices along with surveys through which users’ satisfaction can be evaluated, since the ultimate requirement from a building is its value to the occupier.

At an operational level it is acknowledged to ensure standards are maintained then performance has to be measured. There are no clear set of performance metrics that have been adopted by the industry to measure operation and maintenance. Individuals select those that are most appropriate for their circumstances.

The question that has been researched is: what measures indicate building performance and what does an organisation need to know to allow them to make informed property decisions? There are many metrics that need to be available about a facility before reliable strategic property decisions can be made:

- life cycle costs
- functionality
- building operations costs
- business and strategic needs
- requirements (risk, redundancy)
- lease obligations
- disposal and dilapidation costs
- statutory compliance.

There is a need in building operation and maintenance to provide a clear and compelling case for resources and show a positive impact on an organisation’s objectives. Organisations need to be convinced that proactive maintenance efforts are in their best interest and the metrics measured need to verify that maintenance makes sense from a business perspective.

Measurable metrics have been developed in consultation with industry stakeholders through a focus group meeting held in March 2009. The focus group considered the interrelationship between measuring performance of a building as an asset and measuring the value or impact on the organisation. The aim was to identify metrics that provide important indicators for organisations. It was also intended to consider an initial indication of how building performance measures differed according to the use of a building.

The results were developed into an initial set of operating and management metrics. They are grouped into 7 headline indicators:

1. Building running costs
2. Reliability of the building and resilience to failure
3. Flexibility of the internal space
4. Complexity of the building and its systems
5. Productivity of occupants
6. Contribution to corporate image
7. Environmental impact

<table>
<thead>
<tr>
<th>Headline indicator</th>
<th>Suggested metrics</th>
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<tbody>
<tr>
<td>1. Building running cost</td>
<td>Total facilities management cost per m², workstation or employee</td>
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<td></td>
<td>Building cost / business revenue ratio</td>
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<tr>
<td></td>
<td>Lifecycle cost per m², expressed as equivalent annual cost</td>
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<tr>
<td></td>
<td>Remaining liability, £</td>
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<td></td>
<td>Availability against plan</td>
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<td></td>
<td>Planned/reactive ratios</td>
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<td>2. Reliability of the building and resilience to failure</td>
<td>Business impact of disruption</td>
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<tr>
<td></td>
<td>Ease of maintenance for range of typical maintenance activities</td>
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<td></td>
<td>Time to reinstate</td>
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<td>3. Flexibility of the internal space</td>
<td>Time and cost to move single member of staff/office/room, reconfigure group of desks</td>
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<tr>
<td></td>
<td>Utilisation of space</td>
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<td></td>
<td>Flexibility of support systems</td>
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<td>4. Complexity of the building and its systems</td>
<td>FM perception</td>
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<td></td>
<td>User perception</td>
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<td></td>
<td>Sick days/Full-time equivalent</td>
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<tr>
<td>5. Productivity of occupants</td>
<td>Contribution to personal productivity</td>
</tr>
<tr>
<td>6. Contribution to corporate image</td>
<td>Design Quality Indicator assessment – particularly the Functionality and Impact measures</td>
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<tr>
<td></td>
<td>Desirability of location</td>
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<tr>
<td>7. Environmental impact</td>
<td>Carbon footprint</td>
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<tr>
<td></td>
<td>Water footprint</td>
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<tr>
<td></td>
<td>Energy use per m² or per person</td>
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</table>
To determine how the use of these metrics would differ depending on stakeholder organisations a second survey was conducted. The results demonstrated that in general all stakeholders found all the metrics suggested to be important. Environmental and Reliability measures were highlighted as the most important measures to the stakeholders.

When the respondents were asked which metrics they already use the results were slightly different from those they thought important. There is a tendency to record the metrics that are easiest to measure. Metrics that were difficult to assess, such as impact on productivity, were rarely used.

Comparing the ratings for importance and usage give a ratio. This gives some measure of the unsatisfied demand for the metrics. The results highlight that measurement of occupant productivity is greatly under-used. Lifecycle cost per m² is also considered more important than reflected in its usage.

Remaining liability costs, Business impact following disruption and Flexibility of support systems can also be considered under-used.

It is reasonable to assume that if effort is concentrated on these top 5 most under-utilised metrics and workable methods are developed for their measurement, they will be welcomed by the facilities management community. Of course, facilities managers do not all occupy similar premises or have the same needs.

The stakeholder responses to this research were examined into three main groups Manufacturing, Universities and Offices. This highlighted they have different focus when measuring building performance. The first 3 measures used by all the groups are the Environmental measures. User perception becomes less important for the Offices and Manufacturing groups but remains a priority measure for Universities.

When usage is compared with appropriateness, the measure that is noticeably different is Total FM costs. This is regarded as something that a good percentage of the respondents in each group already use but some Universities and Manufacturing respondents don’t see it as an appropriate measure for their facilities. The number of responses was too small for detailed analysis but the results are a good indication that there is a differing need for performance metrics across industry.

Further development of these measures is being considered in the final deliverable for WP2. The goal is to find a set of metrics that can aid operations and maintenance professionals to demonstrate what impact the performance of a building can have on an organisation.

**WP8 I3CON Water & Electricity information System:**
**An I3CON result in a real commercial development**

**By Ana Iglesias & Almudena Fuster, EMVS**

An I3CON system - developed by several partners as part of the project - has been implemented in two apartments (one 2-bedroom and one studio) at the Margaritas building, a commercial development ran by EMVS, the Madrid City Council Housing Agency.

The Margaritas development is a social, mixed use building located in North Madrid (Spain), and comprises 33 social dwellings for young people under 30 years, with shared facilities such as a laundry, a semiautomatic car park with 32 spaces and facilities for a public urban cleaning service (offices, storage space, parking).

The dwellings were handed over by the Mayor of Madrid in December 2009 and since then the development has been selected by the Spanish Committee for Better Living Conditions Best Practice for the Dubai International Award (February 2010), awarded as Geothermal Energy Emblematic Use in a Building, by Dirección General de Industria, Energía y Minas. Comunidad de Madrid (May 2010), and awarded as Best Technological Initiative at the International Real Estate Awards Asprima-Sima (June 2010). The Margaritas development is a bioclimatic building, with high efficiency heating-cooling systems, and where innovative RES have been implemented, such as geothermal energy, solar thermal panels or remote management and control tools.

The I3CON Water & Electricity Information System is an user interaction system to help the occupant to improve sustainable self-management of the dwelling, based on internal ambient conditions information from sensors (humidity, temperature, presence, luminosity, CO2 level) and electricity and water consumption meters.

Business impact, flexibility, lifecycle costs, remaining liability and productivity are not important at all to the Universities and only of small importance to the Offices and Manufacturing groups.

All the consumption information is displayed on a touch screen - an adapted user interface - installed at the apartment. It is aimed at enabling energy savings through an increased level of self-control and sustainable awareness of the users. To support this, daily, monthly and annual consumption levels are indicated and evaluated according to the average consumption level. The system is able to alert the user when exceeding the average consumption and provides easy and common sense tips to save energy and reach better performance.
By Irena Saniuk, BSRIA.

The 2nd International Conference on Industrialised, Integrated, Intelligent Construction took place on the 9 June at the Cultural Centre Eduardo Úrculo in Madrid, Spain. The event was a great success attracting over 400 delegates from Spain and internationally from all over Europe.

This final I3CON Conference was organized by EMVS (SPAIN) with the main support of DRAGADOS (Project Coordinator, Spain) along with all other 23 I3CON partners.

The tight but interesting programme of covered a variety of aspects, from the keynote speakers to the I3CON project outcomes sessions and other parallel activities fostering a new approach, theory and ideas into the future practice of the European construction industry.

Supported by a practical emphasis, the event brought together leading professionals in the construction sector to advance understanding of and encourage an innovative methods, techniques, services and technologies in attaining sustainability in the construction industry.

The Speakers

The prime theme of the Conference - I3CON results - has been introduced by the Project partners promoting innovative approach in the construction industry. The speakers covered the following achievements and outcomes from the I3CON project:

- "Lifecycle building information integration: From modeling and design to building services & maintenance" Anu Kätkä – Lonix, Finland and Philip Ackermann – Perspectix, Switzerland
- "Industrialised components for improved construction and building performance" Miguel Segarra – DRAGADOS, Spain and Ian Quirke – Züblin, Germany
- "Building operation & maintenance: Adding intelligence" Artur Krukowski – Intracom, Greece
- "End user’s point of view on innovation: Margaritas demonstrator & other examples" Ana Iglesias and Almudena Fúster – EMVS, Spain
- "A mock–up module for demonstration of research results" Juan Barceló – SEIS, Spain and Carlos Bárcena – DRAGADOS, Spain

The stimulating conference programme also featured outstanding speakers from across Europe, giving them an opportunity to present their views on I3CON project related topics, including:

- Dietmar Eberle – Baumschlager Eberle Architects, Austria – "European middle-class houses: Standards & optimization"
- Frank McLeod – Bryden Wood MacLeod, United Kingdom – "Design for manufacture: Some examples"
- Paul de Vroom – DKV architecten, The Netherlands – "Time-based housing: Methods & typologies"
- Gerd Hauser – Fraunhofer Institut für Bauphysik, Germany – "Increasing the energy-efficiency of buildings"
- Luis Vega – Instituto de Ciencias de la Construcción Eduardo Torroja, Spain – "Sustainability in the Spanish Technical Code"
- Enric Ruiz-Geli – Cloud 9 Studio, Spain – "The Medi@Tic building"

Parallel activities

A varied Conference programme encouraged different types of activities, and the day was complemented with a parallel I3CON results poster session, 3D Margaritas demonstrator show room and the Hogar Digital demonstrator – a real scale Digital Home equipped with high technology systems promoted by the ASIMELEC – ITC association, in collaboration with the Madrid City Council and the Science & Innovation Ministry and co-financed by the European Regional Development Fund (ERDF).