

STAKEHOLDERS' REQUIREMENTS ANALYSIS FOR A DEMAND-DRIVEN CONSTRUCTION INDUSTRY

PUBLISHED: October 2009 at <http://www.itcon.org/2009/41>

EDITORS: Rezgui Y, Zarli A, Hopfe C J

Jilin Ye

*Department of Civil and Building Engineering, Loughborough University, Leicestershire, LE11 3TU, UK
A.J.Ye@lboro.ac.uk, <http://www.lboro.ac.uk>*

Tarek M. Hassan

*Department of Civil and Building Engineering, Loughborough University, Leicestershire, LE11 3TU, UK
T.Hassan@lboro.ac.uk, <http://www.lboro.ac.uk>*

Chris D. Carter

*Department of Civil and Building Engineering, Loughborough University, Leicestershire, LE11 3TU, UK
C.D.Carter@lboro.ac.uk, <http://www.lboro.ac.uk>*

Lidewij Kemp

*Draaijer+Partners, Postbus 436, 9700 AK Groningen, Netherlands
L.Kemp@draaijerparkers.nl, <http://www.draaijerparkers.nl>*

SUMMARY: *Construction – and its significant impact on quality of life – has received considerable attention in recent years, however, there is little agreement on how to create an environment that will allow construction to move from a supply-driven industry to a demand-driven industry focusing on delivering extra values such as sustainability, productivity, comfort, flexibility and energy and resource efficiency. Within this context, the Industrialised, Integrated and Intelligent Construction (I3CON) project aims to enable this transformation by bringing together industrialised production technologies, integrated processes and intelligent building systems. In order to achieve this, a key task is to identify and understand stakeholder requirements – what do clients, designers, contractors, end users and communities require from the buildings of the future? In this paper, a comprehensive requirement development methodology is described, by which the state-of-the-art stakeholder requirements from seven defined stakeholder categories across Europe are collected. Qualitative and quantitative analysis of the identified results have been interpreted and translated into six key requirement themes that the ongoing work within I3CON will address. A case study on high performance buildings highlights the key requirement themes for developing new space concepts. The results outlined in this paper reflect major concerns for the European construction industry and the expected improvements for both the industry and its stakeholders.*

KEYWORDS: *Stakeholder requirement, requirement identification, requirement analysis, high performance buildings, I3CON*

REFERENCE: *Ye J, Hassan T, Carter C, Kemp L (2009) Stakeholders' requirements analysis for a demand-driven construction industry, Special Issue Building Information Modeling Applications, Challenges and Future Directions, Journal of Information Technology in Construction (ITcon), Vol. 14, pg. 629-641, <http://www.itcon.org/2009/41>*

COPYRIGHT: © 2009 The authors. This is an open access article distributed under the terms of the Creative Commons Attribution 3.0 unported (<http://creativecommons.org/licenses/by/3.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.



1. INTRODUCTION

Construction is unquestionably one of the most significant industry contributors to the European economy in terms of gross domestic product and employment (CIE, 2009). However, globalisation, advances in technology, environmental factors and changes in the structure of the European economy are presenting new challenges in today's competitive market conditions. To increase its contribution to European wellbeing and to exploit new opportunities, the industry must respond positively and radically. It has been recognised that developments in the areas of innovative industrialised production technologies, integrated processes and intelligent building systems are critical to the future of the European construction industry (I3CON, 2009). Although construction – and its significant impact on quality of life – has received considerable attention in recent years, there is little agreement on how to create an environment that will allow construction to move from a supply-driven industry to a demand-driven industry focusing on delivering extra values such as sustainability, productivity, comfort, flexibility and energy and resource efficiency. This is particularly true of the construction sector in the European Union (EU), comprising architects, contractors, consultants, material and product suppliers, and operation and maintenance service providers. As a result of this diversity, there are isolated materials, components, services and subsystems within the construction sector (Raja and Fernandes, 2003). Also the construction sector has a tendency to focus on what is available on the market (supply-driven) rather than on what is actually needed (demand-driven) (Kemp and Camphuijsen, 2008). Here the demand-driven concept stands out as an initiative undertaken to improve customer service and better respond to demand variability. Furthermore, there is reluctance by the construction industry to embrace innovative technologies, working practices and effective processes (Egan, 1998). Thus, existing studies (Goodier et al, 2008; Hampson and Brandon, 2004) have emphasised that the construction industry is challenged with not only providing a set of physical buildings, but also offering the most effective long-term support services to its clients and, at the same time, responding to society's growing requirements for sustainability, productivity, comfort, flexibility, energy and resource efficiency and life cycle value.

Recent research has addressed stakeholder management and engagement, but focused mainly on project management skills and performance (Chinyio and Akintoye, 2008; Mathur et al, 2008; Olander and Landin, 2008). Some studies discussed uncertainties emerging from stakeholders in construction (Ward and Chapman, 2008), while others addressed ethical issues in relationship management of stakeholders (Smyth, 2008; Moodley et al, 2008) and risk sharing among stakeholders (Chapman and Ward, 2008). Previous EU-funded projects addressed user requirements analysis as their primary goals (e.g. ELSEWISE and ManuBuild), but their focuses were relatively narrow (e.g. the ELSEWISE project was concerned with the end user requirements focusing on Product Data Technology and Information Technology from the European Large Scale Engineering industry (Hassan et al, 1999; Hassan and McCaffer 2002); the ManuBuild project gathered and analysed stakeholder requirements surrounding an Open Building Manufacturing System concept (ManuBuild, 2005)). There is a paucity of literature revealing the real demands of construction stakeholders to be addressed by the 21st century construction industry.

This paper investigates the state-of-the-art stakeholder requirements from six European countries on an industrialised, integrated and intelligent construction concept. It then interprets and summarises the identified stakeholder requirements into six key themes - using a comprehensive requirement development approach - for delivering flexible and adaptable building space that is highly resource-efficient and enhances human creativity, productivity and quality of life. The paper is organised as follows. Section 2 introduces the identified stakeholders in seven categories. Section 3 presents the requirement development process. Section 4 describes the overall requirements collected from stakeholders including the findings from interviews, importance of factors and importance of trends. Section 5 discusses the requirement verification process. Section 6 presents the requirement consolidation process which leads to the six key requirement themes. Section 7 gives an example of how these six key requirement themes apply to developing new building spaces. Section 8 draws conclusions and outlines future work.

2. IDENTIFICATION OF STAKEHOLDERS

The construction industry involves a wide range of stakeholders, each bringing them with a great variety of interests, concerns, requirements and potential opportunities. In this study, in order to provide structure when covering these stakeholders, they have been grouped in seven main categories, based on common interests and needs. These categories, and examples of the groups included in them, are as follows:

- A.** Clients – This includes individuals or organisations that initiate the building process/generate the need for a building (e.g. businesses, housing associations and private developers).
- B.** Professional teams – This includes individuals or organisations that are involved in the project management, design, planning, insurance, and contractual and financial control of the building process (e.g. architects and design engineers). The key difference between these stakeholders and those in category C is that they do not construct or manufacture building elements.
- C.** Constructors – This includes companies that are involved in building, testing and commissioning of the building (e.g. manufacturers and suppliers).
- D.** Occupants – This includes individuals or organisations that use the building (e.g. residents and office workers).
- E.** Occupant support services – This includes individuals or organisations that are responsible for the ongoing maintenance & operation of the building and the functions that take place within it (e.g. utilities companies and waste management and maintenance).
- F.** Regulatory bodies – This includes organisations that provide and enforce codes and standards (e.g. environment agency and local authorities). These codes and standards constrain other stakeholders.
- G.** Infrastructure – This includes physical and social infrastructures around the building (e.g. transport links and emergency services).

Although in reality these groups will sometimes overlap and the boundaries between them blur, they represent the majority of all stakeholder types.

3. THE REQUIREMENT DEVELOPMENT PROCESS

A comprehensive requirement development process was developed based upon the stakeholder classification discussed in Section 2. This process comprises methodology and procedure, requirement collection, requirement verification, requirement consolidation and requirement actualisation through a case study. This is summarised and illustrated in Figure 1.

A multi-dimensional framework for structuring the stakeholder requirements was created in the methodology and procedure development. This consists of four dimensions including European regions, stakeholder categories, building categories and technology subjects. The dimensions of building categories, stakeholder categories and European regions are used to provide more insight into the various stakeholder requirements, rather than to limit the stakeholder requirements to specific domains. For instance, good coverage of European regions is important to avoid capturing requirements relevant to only certain countries. The technology dimension was added so that identified requirements can be mapped against technological research and solutions delivered by technical work packages within the I3CON project.

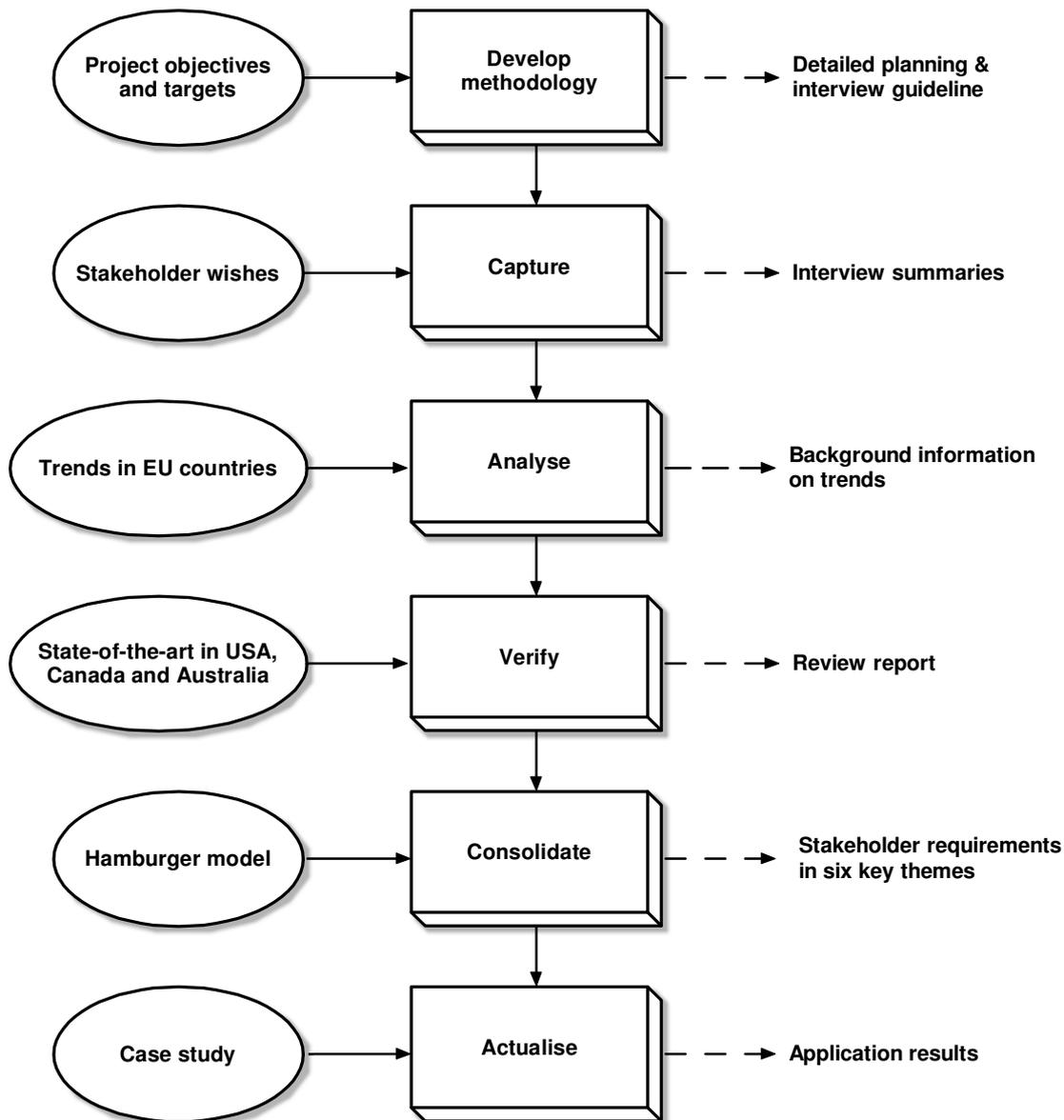


FIG. 1: Requirement development process

Several brain storming sessions were held with all involved I3CON partners to establish common views on the methodology to be adopted. It was decided to collect the stakeholder requirements by undertaking formal interviews rather than sending out questionnaire surveys. This ensured high quality, precise and detailed information on stakeholder requirements – rather than large volumes of vague information – by allowing interviewees to clarify their answers by explaining the context that was underneath a certain answer (see Section 4.1). In order to avoid organising similar focus groups to acquire quantitative data so as to save time and cost, it was agreed that quantitative data was also collected by sending a list of factors and trends summarised by a panel of experts coming from I3CON partners to each interviewee beforehand, and asking them to rate the importance of them (see Sections 4.2 and 4.3).

To place the EU region’s stakeholder requirements in context, a literature survey of the state-of-the-art of stakeholder requirements in other major markets (the USA, Canada and Australia) was undertaken by the authors (Ye and Hassan, 2007). Comparison was made, and this confirmed that the I3CON project was addressing the main and relevant issues in its research and technological development work.

In the requirement consolidation process, the Hamburger Model introduced by Gielingh (1988) was employed. The consolidated requirements were matched against the technical tasks being undertaken within the I3CON project in order to identify directly impacts and benefits to stakeholders. This also provided assessment criteria with which to benchmark the outputs of I3CON technical work packages against stakeholder requirements. As a

result of this process, six key requirement themes have been established, which can be considered as the vision/focus of major stakeholders in the European region for achieving innovation and competitiveness of products and processes in the industry.

Finally, a case study was conducted to demonstrate how these six key requirement themes could be realised in a real application. The results from this benchmarked the effectiveness and efficiency of applying the identified stakeholder requirements to the I3CON research and technological development work.

4. VOICE OF STAKEHOLDERS

In order to obtain stakeholders' visions and foresights regarding the specific features of I3CON, current industry trends and important factors, their main concerns, ideas for possible changes and their real needs and expectations, a total of 72 formal interviews were conducted in six European countries (Spain, Turkey, the Netherlands, Germany, Finland and the UK). The interviewees were from a range of different roles in construction projects, and were classified in categories from **A** to **G**, as discussed in Section 2 (see Fig. 2).

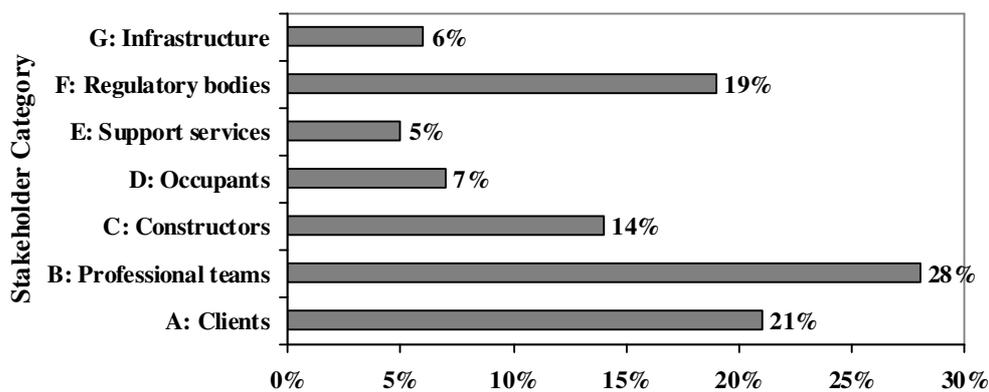


FIG. 2: Interviewee distribution by stakeholder category

The results from interviews include two types of information, namely qualitative data (views and concerns from the interviewed stakeholders) and quantitative data (their rating of given factors and trends). This combination of qualitative and quantitative data increased the value of the information collected, because it allowed open questions to be asked during the interviews, to which the interviewees could provide answers and detailed explanations. This provides valuable information (visioning/thinking), but is more challenging to compare and analyse. Qualitative and quantitative analysis of the results from the interviews established the six key requirement themes which are discussed in detail in Section 6.

4.1 Results from the interviews

A questionnaire based on existing I3CON partners' visions and aspirations for the industry was developed and used in the formal interview. The questionnaire consisted of a standard set of open questions. In this way, more valuable/qualitative data has been captured than possible using just closed questions. Interview summaries – sorted by country – were produced by the I3CON partners involved in this study (Kemp and Camphuijsen, 2007). The main results from these interviews can be summarised as follows:

Industrialisation

- A major trend that will become even more important in the future
- Innovation in this area is important, since the current construction process has been generally similar for over 50 years
- Increased use of prefabricated/standardised building elements needed to reduce time
- Will bring cost and time advantages and will increase quality
- Will increase safety levels in the industry

Integration

- Today's building processes are highly fragmented (from procurement to in-use); there should be more cooperation between organisations involved in construction projects
- A global picture of the whole process is missing: Construction projects became more complex and more specialised, and contain more interfaces (problems arise with coordination and the decision making process)
- Maintenance issues are not sufficiently planned for during design

Intelligent buildings

- High performance = intelligent = good environmental performance
- Top measure of building performance = total energy consumption. However, the most important thing a building can do is to make people in it more productive; in terms of costs, in-use costs far outweigh any other
- Necessary to be energy-efficient
- Automation is essential at a certain level for low-energy technologies
- Users need to learn how to use/manage such technology (training can be offered); higher levels of automation require more skilled labour
- Intelligent buildings can also mean intelligent concepts: Sustainability, flexibility (facades, building technology, adaptable interiors)

Main problems

- Changes are necessary in regulations, mentality, businesses, etc. in order to facilitate innovation
- Lack of flexibility in buildings: Not built for specific users' needs, then tweaked for other users' needs – leading to sub-optimal performance for all users
- Current procurement: Time consuming, complex tendering – wasteful
- While looking to make buildings more sustainable, some organisations might be reluctant to use highly innovative technology as it is seen as too risky – unknown on-going costs, reliability, etc.
- Buildings change less quickly than social trends
- Increasing specialisation: The complete overview is lost so cooperation becomes more difficult between specialists (each with their own very narrow focus)
- Tender, approval and decision making processes take too long and require excessive administration
- The industry, and innovation within the industry, is mostly supply-driven rather than demand-driven
- Requirements are proposed either too late or at the wrong time (ecology, user, flexibility)
- Good management / planning from beginning to end is missing (consider what the important criteria in each construction phase are, and if all important aspects were considered)

Market opportunities

- Regulation is essential for innovation (although many would consider that regulation limits the freedom of innovation)
- It has been demonstrated that if you offer better quality in terms of what the client wants, and you really show the quality, clients will pay for it. Opportunity is to improve the level of service to clients
- A large percentage of construction projects involve the adaptation and re-use of old buildings, therefore finding smart solutions for refurbishment is important
- Buildings conceived from design phase to accommodate different uses, keeping in mind flexibility
- Projects to be assigned to the best overall offer, with the best technical, resources and economical aspects, and not just the lowest price
- Design from 'cradle to grave'
- A high performance building is one that is used for the maximum hours a day and days in a year; efficient to run and comfortable to work/live in

4.2 Importance of factors

To prioritise common issues and concerns in the current construction industry, the interviewees were asked to rank the five most important factors from a list generated by the I3CON industry partners. The authors employed a scale of 1 to 5 to assess the importance of each factor, where 1 represented the lowest level of importance and 5

the highest level of importance. The ‘Relative Importance Index’ (RII) method introduced by Kometa et al. (1994), was adopted for the analysis of the data to determine the ranks of the listed factors. The RII was calculated using the following expression:

$$\text{Relative importance index} = \frac{\sum w}{A \times N}, \quad (0 \leq \text{index} \leq 1)$$

where w = weighting given to each factor by the interviewees and ranges from 1 to 5 where 1 is not important and 5 is extremely important, A = the highest weight (i.e. A = 5 in this case), and N = total number of interviewees (i.e. N = 72 in this case).

TABLE 1. Relative importance of factors

Factors	Relative Importance Index (RII)	Rank
Energy reduction (during operation of the building)	0.717	1
Sustainability (in its broadest context)	0.711	2
Building lifecycle economy & building performance	0.667	3
Work productivity/comfort and wellness (end users)	0.611	4
Flexibility (e.g. adaptability, multi-functionality)	0.583	5
Quality of construction (e.g. material)	0.528	6
Durability	0.483	7
Safety	0.478	8
Social acceptability	0.372	9
Construction methods (i.e. on-site or prefabrication)	0.350	10
Construction time	0.311	11
Cost efficiency/reduction during construction	0.283	12
Capital cost of construction	0.267	13
Other (not stated above)	0.211	14

Table 1 shows the Relative Importance Indices and the ranks of the listed factors. The identified top five factors were: 1. energy reduction, 2. sustainability, 3. building lifecycle economy & building performance, 4. work productivity, comfort and wellbeing, and 5. flexibility. Less important factors indicated by the stakeholders included: i). capital cost of construction, ii). cost efficiency/reduction during construction, and iii). construction time, even though these are often the focus of project management efforts. These findings confirmed that most stakeholders now concentrate more on factors that can deliver extra value (e.g. energy reduction and sustainability) rather than traditional ones (e.g. capital cost of construction and construction time).

4.3 Importance of trends

The interviewees were also asked to rate in terms of importance a given list of trends compiled by the authors from contributions by all I3CON partners. These trends were more detailed than the factors discussed in Section 4.2, and are categorised in six main groups, as listed below:

- Economic/financial
- Technological/building process
- Building functionality
- Ecological/environment
- Social/cultural/demographical
- Regulations/political

Each group contained several trends and, for each, the interviewees were asked to select the top three important ones based upon their knowledge and experience. The RII analysis method was again used, with the results shown in Table 2. These trends are listed in order of importance, starting with the most important per group.

TABLE 2. Top three important trends in six groups

Economic/financial	RII	Ecological/environment	RII
1. Focus on life cycle cost	0.53	1. Low-energy buildings	0.36
2. Focus on energy management/energy costs	0.40	2. Focus on climate changes	0.36
3. Increase flexibility & reduce costs	0.33	3. Increasing focus on energy efficiency	0.19
Technological/building process	RII	Social/cultural/demographical	RII
1. New contract models (PPP)	0.36	1. Social added value	0.69
2. New building processes (procurement)	0.31	2. Increase smaller / single dwellings	0.40
3. Reconstruction, modernisation of old buildings	0.31	3. Improved knowledge infrastructure	0.31
Building functionality	RII	Regulations/political	RII
1. Flexible buildings to adapt to changes of use	0.45	1. Changes in the legislation	0.71
2. New solutions to existing building stock	0.38	2. Quality standards & certificates	0.52
3. Multi-purpose/multi-use	0.36	3. Litigious society - impact on buildings	0.33

It is important to point out that there is no cross-comparison of the RII values in these six groups. The RII values in one group are valid only in their own group and have no correlation to those in other groups. For example, the trend 'social added value' – optimal focus on the demands and desires in society, e.g. sustainability – with an RII value of 0.69 was ranked the most important trend in the social/cultural/demographical group, whereas the trend 'changes in the legislation' – EU essential requirements, e.g. the Energy Performance Building Directive – in the regulation/political group was recognised the most important trend with an RII value of 0.71. The results from the RII analysis on the importance of trends confirmed that most stakeholders now focus more on trends that can bring extra value such as low life cycle cost, flexibility, social added value and energy and resource efficiency.

5. REQUIREMENT VERIFICATION

The requirement verification process checks for redundancy and inconsistencies in the captured stakeholder requirement's data. The goal of this process is to produce stakeholder requirements that are consistent, valid in terms of importance and necessity, and are quantifiable and verifiable.

In addition to the European region, stakeholder requirements from other major markets (the USA, Canada and Australia) were also studied. Additional comparisons between these major markets have been conducted by Ye and Hassan (2007) to ensure that the I3CON project considers the main issues relevant to its three "I"s and incorporates them within its programme of research and technological development work. The three "I"s in stakeholder requirements identified from EU countries, the USA, Canada and Australia have common views as listed below:

- Industrialisation in construction including improvements in building technologies will enhance the daily environment for end users, the maintenance efficiency and the return on investment for owners
- Integration in construction will include integration of partners involved in the building processes (production integration), integration of building systems (physical integration) and integrating maintenance and service aspects into building and design (operation integration)
- Intelligent buildings will improve the quality of life and at the same time focus on sustainability, flexibility, durability and energy and resource efficiency

6. REQUIREMENT CONSOLIDATION

The aim of the requirement consolidation process was to validate the captured stakeholder requirements, and provide a basis for understanding, communicating and appropriately linking the different requirements to the corresponding activities within the I3CON project.

In order to translate the stakeholder visions and expectations, which can be described as 'functional wishes', to technical requirements (that the tasks in I3CON technical work packages will address), the 'Hamburger Model' approach (Gielingh, 1988) was employed to shape these translations. This model distinguishes a 'Functional Concept' on the demand side and 'Solution Concepts' on the supply side (see Fig. 3). In other words, the 'Functional Concept' states in 'user language' WHAT is required and WHY it is required and the 'Solution Concept' states in terms of technical specifications HOW the requirements are supposed to be met. The 'Functional Concept' in the I3CON project represents the stakeholder requirements captured through interviews (both qualitative and quantitative data) in the European countries, and the 'Solution Concept' consists of

solutions to the 'functional needs' to be developed by the I3CON project. Finally the 'Solution Concept' should directly map onto the 'Functional Concept'.

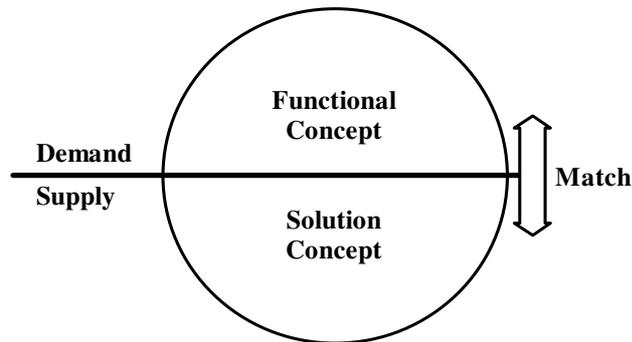


FIG. 3: The Hamburger model (Gielingh, 1988)

In order to have a better understanding of the captured stakeholder requirements at a high level, the consolidated stakeholder requirements are further combined and grouped in six key themes, as explained below. This can be seen as new demands and the vision/focus of the I3CON project according to different stakeholders.

Energy management

The objective of energy management is to ensure maximum efficiency and lowest operational cost. Energy management involves all energy and environmental aspects of a building, such as energy usage and efficiency, focus on climate changes and solutions and usage of materials for low-energy buildings. An example of energy management in relation to a building is having a building information system, which provides information on energy usage. In addition to smart energy-saving solutions during the design and construction phases, educating end users on how to save energy while using the building is considered essential.

Comfort

The comfort feature of a building refers to the internal environment (e.g. temperature and indoor air quality), the design (e.g. comfort level of furniture) and the user-friendliness of a building (e.g. easy to use). It also involves the consequences of the internal environment, such as productivity, which mainly applies to office buildings. Some studies found that improved thermal comfort, reduction in indoor pollutants, and enhanced ventilation rates/effectiveness can increase productivity by 5-10% (Wargoocki et al, 2000). Future intelligent buildings should apply innovative technologies (e.g. increasing automation and enhanced knowledge infrastructure) to improve the building environment and functionality for occupants while controlling costs. Improving end user security, comfort and accessibility all help user productivity and comfort levels.

Life cycle costing

Financial impact in construction is always significant, including capital costs, expenses and revenues. Low initial costs are attractive to developers, while owners/operators and occupants/tenants are more interested in ongoing operational costs. Currently financial implications of a building are mostly upon an investment oriented basis (focusing on initial costs). It is important to consider the total life cycle costs of a building. Some measures (e.g. energy saving) can lead to higher initial costs, but will save costs during the use of the building. For example, having solar panels on buildings might require a higher initial investment, but this will save energy or even produce more energy to meet a building's need during the use of the building, thus leads to lower running costs/overall life cycle costs.

Customer-orientation

As discussed in Section 1, current construction practice is more supply-driven rather than demand-driven. Customer demand should drive the provision of the required capabilities in construction, because when customers insist on their needs, there will be vendors who will provide what is required. Making a better match between buildings and customers (end-users) real needs will influence the users' satisfaction and thus might be satisfied longer with the building, leading to a higher level of durability of the building. An example of customer orientation in relation to buildings is giving the users' insight in what they can choose, for instance having a catalogue with which an "à la carte" building can be created, based on customers' preferences. Furthermore, it is important to educate customers on what they can demand practically. When taking customer orientation into

consideration, not only should choices be offered, but also insight on the financial and technical consequences of those choices, or the level of sustainability should be provided.

Flexibility

The flexibility of a building is important in terms of the potential to easily change the use of a building, or to accommodate the different demands resulting from a change of user. The higher the uncertainty about what the demands will be, the more benefits will be achieved if the building is flexible. The flexibility of a building might have characteristics of adaptability, modularity, expandability, multi-functionality, etc. An example of creating flexibility in buildings is to develop adaptable buildings - a building should be configured initially to a wide range of scenarios and should be able to change, over its lifecycle, facilitating the evolving needs of their end users (Beadle et al, 2008).

Building process

Traditionally, project management in construction mainly focuses on construction time, construction costs, etc. There is now a demand for organising the building process to create extra value such as suitability, productivity, comfort, flexibility and energy and resource efficiency. The building process discussed here is one that considers stakeholder requirements crossing through all of the five key themes described above. For example, reasoning from the total life cycle of a building would suggest that it is useful to involve financial organisations (that own and maintain the building) in the design phase of a project, by inserting their knowledge about the operational phase at the design stage. Also, customer orientation might lead to involving end users in the design of a building through the use of catalogues with which they can 'design' their own buildings.

Finally, a matrix mapping approach was utilised to create the links between the six key requirement themes and individual tasks within the I3CON project. Kemp and Camphuijsen (2008) provide a more detailed description of this approach, the main results of identification of the links and the selection of the six key requirement themes for the technical work packages within the I3CON project. The following section gives an example to exploit this approach.

7. A CASE STUDY: NEW SPACE CONCEPTS DEVELOPMENT

Once the most important stakeholder requirements were consolidated, they were linked to the technical work packages in the I3CON project to which they apply, e.g. the vision/expectation of stakeholders to develop new space concepts applies to the Work Package - "Integrated Building System Architecture" in which new space concepts are researched and developed. Fig. 4 demonstrates the main features of high performance building spaces and their links with the six key requirement themes.

The links between the features and the six key requirement themes cover several aspects including space usages, types, characteristics, dimensions and technical requirements, which are described below:

Usage: The building usage relates mostly to the requirement themes of customer orientation and flexibility. When customer orientation is considered, it is important to focus on end-users (customers) and their real needs, based on what the preferred usage of the building will be. In addition to this, if the future use and changes in the building are not quite clear, it will be preferable to have a higher level of flexibility to adapt to future changes of usage.

Type: The building type (office, residential or public) applies to the preferred level of flexibility if the building should be easily adaptable to other types (e.g. an office building that is later used for residential apartments). Within this context, specific spaces are developed taking into consideration the requirements and/or design specifics of spaces for each building type. Furthermore, the commonalities and discrepancies are researched, so that spaces that are appropriate to any building type can be developed.

Characteristics: The issue of characteristics shown in Fig. 4 applies to several key requirement themes. The adaptability and modularity of spaces relate to the flexibility theme. Ergonomics and quality relate to the comfort level of spaces (Quality in this context means the design quality of the space as well as the inside fixtures (furniture), which provides a certain level of comfort for the user). Ergonomics deals with the user-friendliness of spaces or furniture. Quality and ergonomics also relate to customer orientation: The level of quality should meet the customers' needs and the human-building interface should be user-friendly and easy of use.

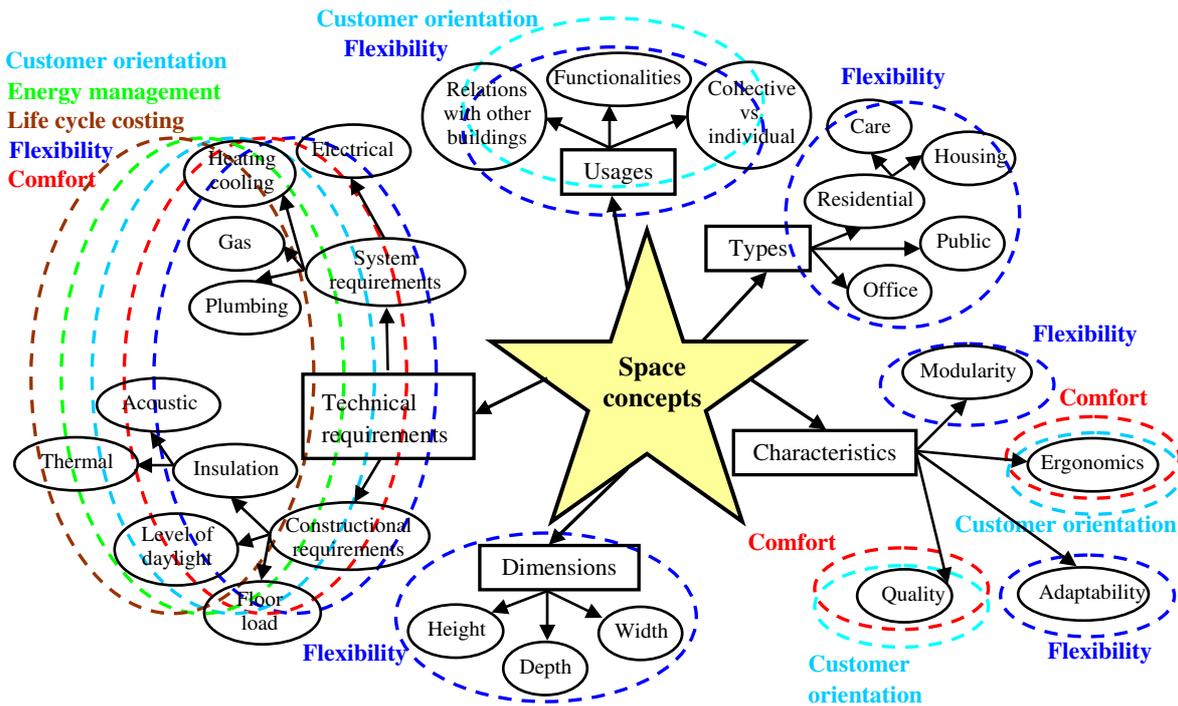


FIG. 4: Features in space concepts and their links to the key requirement themes

Dimensions: The dimensioning of spaces should be considered when the level of flexibility is required and defined. Different building types should have different dimensions for their specific purposes. If a building is developed to be used for different types (e.g. office and residential), functional or non-functional specific spaces in that building need different dimensioning so that the building will have features of adaptability, expandability and multi-functionality.

Technical requirements: The technical requirements cover two groups, system requirements and constructional requirements. These system and constructional requirements apply to almost all requirement themes. For example, the system requirements will change if the expectation of energy use (energy management) is higher. The focus on life cycle costing also relates to the system requirements; the building systems are then implemented on their total lifespan, not on their initial costs. The design of the building systems and their technical requirements influence the level of comfort that is delivered.

8. CONCLUSIONS AND FUTURE WORK

In this paper, a comprehensive requirement development process has been developed, which comprises methodology and procedure, requirement generation, verification, consolidation and actualisation. Using this approach, the state-of-the-art stakeholder requirements from European countries have been collected and analysed within the I3CON project. The research results not only revealed what stakeholders really want from the buildings of the future, but also gained a deeper understanding of their growing demands for extra values such as sustainability, productivity, flexibility and energy and resource efficiency. This also led to a fundamental base to implement the transformation of the construction sector to a demand-driven industry focusing on delivering these extra values. The ongoing I3CON project focuses on developing new technologies, processes, products and solutions to meet the stakeholder requirements categorised in six key themes. Future work will address to what extent the results from research and technological development work in the I3CON project match the identified stakeholder requirements (in six key themes) developed in this research.

9. ACKNOWLEDGEMENTS

This research work has been undertaken within the I3CON Integrated Project, partially funded by the European Commission (EC) under its Sixth Framework Programme (FP6). The authors gratefully acknowledge the support of the EC and the contributions of all the partners.

10. REFERENCES

- Beadle K., Gibb A., Austin S., Fuster A. and Madden P. (2008). *Adaptable Futures: Setting the Agenda*. Proceedings of the 1st International Conference on Industrialised, Integrated, Intelligent Construction (I3CON), Loughborough, UK, pp35-44.
- Chapman C. and Ward S. (2008). *Developing and Implementing a Balanced Incentive and Risk Sharing Contract*. *Construction Management and Economics*, Special issue: Stakeholders Management in Construction, Vol. 26 (6), pp659-669.
- Chinyio E.A. and Akintoye A. (2008). *Practical Approaches for Engaging Stakeholders: Findings From the UK*. *Construction Management and Economics*, Special issue: Stakeholders Management in Construction, Vol. 26 (6), pp591-599.
- CIE (2009). *Construction in Europe*. Available at: <http://www.fiec.org/Content/Default.asp?PageID=5> (accessed 20 January 2009).
- Egan J. (1998). *Rethinking Construction*. Report of the Construction Task Force. Department of the Environment, Transport and the Regions, London, UK.
- Gielingh W.F. (1988). *General AEC Reference Model (GARM)*. Report No. IBBC BI-88-150, TNO, Delft.
- Goodier C., Soetanto R., Dainty A., Austin S., Price A. and Harty C. (2008). *A Competitive Future for UK Construction?*. *Construction Information Quarterly*, Vol. 9 (4), pp169-174.
- Hampson K. and Brandon P. (2004). *Construction 2020: A Vision for Australia's Property and Construction Industry*. Research Report, Cooperative Research Centre for Construction Innovation, Queensland University of Technology, Australia, June.
- Hassan T.M., McCaffer R. and Thorpe A. (1999). *Emerging Client Needs for Large Scale Engineering Projects*. *Engineering Construction and Architectural Management*, Vol. 6 (1), pp 21-29.
- Hassan T.M. and McCaffer R. (2002). *Vision of the Large Scale Engineering Construction Industry in Europe*. *Automation in Construction*, Vol. 11 (4), pp 421-437.
- I3CON (2009). *Industrialised, Integrated, Intelligent Construction*. Available at: <http://www.i3con.org/about.htm> (accessed 20 January 2009).
- Kemp L. and Camphuijsen J. (2007). *Stakeholder Requirements: Captured Requirements*. Final research report, Draaijer + Partners, Netherlands, 17 July.
- Kemp L. and Camphuijsen J. (2008). *Stakeholder Requirements: Consolidated Requirements*. Final research report, Draaijer + Partners, Netherlands, 17 January.
- Kometa S. T., Olomolaiye P. O. and Harris F. C. (1994). *Attributes of UK Construction Clients Influencing Project Consultants' Performance*. *Construction Management and Economics*. Vol.12(5), pp433-443.
- ManuBuild (2005). *ManuBuild Project Newsletter*, Issue No. 1, April.
- Mathur V.N., Price A.D.F. and Austin S. (2008). *Conceptualizing Stakeholder Engagement in the Context of Sustainability and its Assessment*. *Construction Management and Economics*, Special issue: Stakeholders Management in Construction, Vol. 26 (6), pp601-609.
- Moodley K., Smith N. and Preece C.N. (2008). *Stakeholder Matrix for Ethical Relationships in the Construction Industry*. *Construction Management and Economics*, Special issue: Stakeholders Management in Construction, Vol. 26 (6), pp625-632.
- Olander S. and Landin A. (2008). *A Comparative Study of Factors Affecting the External Stakeholder Management Process*. *Construction Management and Economics*, Special issue: Stakeholders Management in Construction, Vol. 26 (6), pp553-561.
- Raja V. and Fernandes K. (2003). *Assessing Application of Virtual Reality in Construction Planning*. A position paper, Warwick Manufacturing Group, the University of Warwick, Coventry, 5 August.
- Smyth H. (2008). *The Credibility Gap in Stakeholder Engagement: Ethics and Evidence of Relationship Management*. *Construction Management and Economics*, Special issue: Stakeholders Management in Construction, Vol. 26 (6), pp633-643.

- Ward S. and Chapman C. (2008). Stakeholders and Uncertainty Management in Projects. *Construction Management and Economics*, Special issue: Stakeholders Management in Construction, Vol. 26 (6), pp563-577.
- Wargocki P., Wyon D.P. and Fanger P.O. (2000). Productivity is Affected by the Air Quality in Offices. *Proceedings of Healthy Buildings 2000*, Vol. 1, pp 635-640.
- Ye J. and Hassan T. M. (2007). Actualisation of the State of the Art Stakeholder Requirements. Internal working paper, Department of Civil & Building Engineering, Loughborough University, UK.