

# VR- Roadmap: a Vision for 2030 in the Built Environment

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## Abstract

VR is an emerging technology that will greatly benefit the construction industry and its supply chain in terms of capacity to experiment, greatly improved communication, data visualisation and capturing ideas.

This paper presents the outcome of a research project that was aimed at developing a 'VR roadmap: vision for 2030 in built environment'. The methodology used was to thoroughly review previous and current application of VR in the construction and manufacturing based industries and conduct brain storming sessions with Experts in IT/VR regarding future functionalities and R&D needed to develop VR tools and processes capable of supporting future built environment.

Twenty three Experts from industry and academia from UK, EU and USA working in diverse roles in academia, industry and software development were invited to participate in a brain storming sessions over two-day workshops.

The roadmap is focussed on three main themes: current state-of-the-art of VR in built environment; technology and process specifications towards 2030 and R&D plans to deliver such specifications. Discussions were focussed on identifying enablers, barriers, opportunities and challenges that prevail in the industry and those likely to be encountered towards 2030 with advancement of the technology and process changes.

The paper introduces and discusses the roadmap and its related methodology.

## Keyword

VR application, Design, Construction, Roadmap

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## 1. INTRODUCTION

For any industry to survive and be a world class player, it needs to innovate. Construction is no exception. The construction industry needs to innovate by searching and experimenting for and with better products and processes that ensure its survival. This need has been highlighted and emphasised by the Egan report and other government and industry sponsored initiatives.

The developments in VR and its use within construction have proved to be of great benefit to users who have embraced the technology. VR technologies can be applied to promote innovation by allowing the construction industry to better explore possible future products and services. This has been the subject of discussion and debate for over 8 years. During this period a number of projects and reports have been commissioned by the EPSRC and the DTI (UK Business potential for Virtual Reality, 2000). Further developments in the

field and innovative means of utilisation are likely to continue.

One of the major conclusions of these studies was that VR is an emerging technology that will greatly benefit the construction industry and its supply chain in terms of capacity to experiment, greatly improved communication, data visualisation and capturing ideas. The last Foresight Report recommended greater VR use in construction. From an industrial point of view, the introduction of VR will add value in the form of:

- Greater site safety – by ability to view pinch-points of projects in terms of restricted access (spatial planning).
- Ability to test alternative construction methods and note the time implication on each.
- Allow more accurate sequencing of operations via the ability to view element interfaces.
- Present a new channel of communication between designers/suppliers/and contractors.

Watts et al (1998) stated that VR can help the innovative organisation in the following respect:

- Low marginal cost --> Capacity to experiment
- Realism/accessibility --> Involving all
- Interactivity --> Capturing ideas

It is clear from the above that VR can play a major part in achieving innovation in the industry. There are ample VR tools that are developed from research or/and commercial activities around the world that support this concept. It is intended to learn from other industrial experiences - the results of the application of VR to various sectors of engineering have so far been tremendous (Boyd 1998; Wilson 1996). VM has been shown to avoid costly mistakes, and enable planners and managers to envision the whole manufacturing process from design and assembly to product shipping. Factory simulation has helped to make substantial savings on tooling, design, construction and installation. Compared to the use of conventional methods, VM has also been shown to dramatically reduce the amount of time it takes to analyse new design concepts and incorporate them into the production process. It has enabled decision-makers to make last minute changes and eliminated the need to build prototypes (Quayle, et al 2005). The application of VR has made it much easier for factory workers to accomplish complex and error-prone tasks, and has also offered a safer environment for testing various manufacturing techniques.

Increasing globalisation is driving the construction industry towards increased competitiveness and in improving efficiency. The current key business drivers were seen to be the need for; efficiency improvements, cost reduction, increased collaboration, ease of communications,

involvement of the client and end users in the whole construction process, accurate progress measurement and modelling of the as-built environment. There are significant benefits that VR could offer to the industry, the construction industry is not adopting VR to its full capacity when compared to the aerospace, automotive and other manufacturing industries. Current applications of VR are used mainly for client walkthroughs, design reviews and the visualisation of construction sequences. The technology is being pushed by the academia or developers and the fragmented and adversarial culture in the industry has to be changed in order to develop the industry and make it more technology based and agile. However, there is a need of simple and easy use cases of applications in the built environment.

To date there is no future vision for R&D development that is focused on VR application to construction products and processes. In this context the objective of the paper is present the output of research project with the aim of developing a visionary VR roadmap for 2030 to support future Built Environment. It is hypothesised that future built environment will be more intelligent (self diagnostic, real time communication for facilities management etc.), flexible, secure, sustainable and with high value to stake-holders

The remainder of the paper discuss the methodology used and deliverables of the 'VR Roadmap: vision for 2030' initiative.

## 2. DEVELOPMENT METHODOLOGY OF THE ROADMAP

A thorough literature review of both academic and industry was conducted to identify state-of-the-art of VR R&D. This included current roadmap initiatives like FIATECH, RoadCON and nD initiative.

The following shows briefly the current state-of-the-art of R&D against construction business processes:

- Initiation and outline design: R&D is mainly in the area of walkthrough of 3D visualisation models, augmented reality application and communication systems of outline design information, urban visual planning (Miles et al 2004)
- Design development: R&D in the area of visual design, 3D/nD modelling and sketching, product models and integrate with VR and search based engines for finding optimal design solutions (Tizani et

- al 2005, Khatab et al 2005, Wu, A, et al 2004 )
- Contract and pre-construction: mostly VR used in marketing and information visualisation like cost, quantities, 4D models, etc (Dawood et al, 2005, Dawood et al 206, Rischmoller L, et al, 2001)
- Construction: R&D is focused on visual construction, 4D modelling, construction sequencing, image analysis, simulation modelling etc.

- Maintenance: Very little work in the area and most of the work is focused on assets information visualisation and simple augmented reality application.

Table 1 gives a list of the state-of-the-art of developments of visualisation and integrated technologies in the built environment with respect to their intended functions.

**Table 1: Current Applications of VR in Built Environment**

Functions	Details
Collaboration/ interdisciplinary work	<ul style="list-style-type: none"> <li>• Compilation of VR models to build prototypes to represent interdisciplinary work.</li> <li>• Developing user interfaces for designers</li> </ul>
Standards	<ul style="list-style-type: none"> <li>• IFC development for CAD</li> <li>• CAD and VR data exchange</li> <li>• Linking with GIS IAI, IFC mapping</li> </ul>
Whole life costing analysis	<ul style="list-style-type: none"> <li>• Visual Costing</li> <li>• What-if analysis</li> <li>• Operation analysis</li> </ul>
Modelling and design	<ul style="list-style-type: none"> <li>• Digital Architecture – design spatial analysis.</li> <li>• Early stage of design – integration of VR model, with structural model, collusion checking</li> </ul>
Planning	<ul style="list-style-type: none"> <li>• 4D modelling process information linked to VR objects</li> <li>• Urban planning/GIS/VR integration</li> </ul>
Progress measurement and modelling As-built Information	<ul style="list-style-type: none"> <li>• Image Capture</li> <li>• Laser scanning technology for the built environment, integration with presentation technologies, object recognition.</li> </ul>
Communication	<ul style="list-style-type: none"> <li>• Visualisation/Walkthrough</li> <li>• 3D/4D/nD visualisations</li> <li>• Mobile and grid technology to communicate visual data.</li> </ul>

This review was followed by brain storming sessions over two-day workshops and presentations by VR experts. The objective was to establish and develop ‘VR Roadmap: vision for 2030’. In order to achieve this, twenty three experts were attended and participated in a two-day workshops at Manchester Thistle airport in the UK. The participants of the workshop had diverse experience in the use of VR technology. The experience of the participants include development of hardware and software technologies, VR modelling, socio-economic analysis on the use of VR, teaching and training , application of VR in industrial projects.

The workshop included presentations from experts which highlighted current practices and three main workshops were used to brainstorm and develop the vision for 2030 of the application of VR and a vision for research and development for the coming

2030. Discussions were focussed on identifying enablers, barriers, opportunities and challenges that prevail in the industry and those likely to be encountered towards 2030 with advancement of the technology and process changes. The following section discuss the pre-workshop data collection and analysis of such data.

### **3. PRE-WORKSHOP DATA COLLECTION AND ANALYSIS**

Experts were asked to complete a semi-structured questionnaire prior to the workshop event. The objective was to elicit their knowledge and expectations of future VR roadmap. This was important to ascertain a successful outcome of the workshop.

The following lists a summary points of the participants expectations of the workshop ( this

need to be tie in with the major deliverables of the net-wok)

- Identify novel ideas, processes, trends and developments of VR.
- Networking, know what others are doing and identify opportunities for research collaborations
- Clear strategy to promote real benefits of VR as cost effective real application, not just an expensive toy
- Appreciation of current research projects and opportunities for liaison with international practice
- Obtain feedback and vision to improve VR software
- Raise the topic of VR standards
- Future vision and an agreed policy on the requirements and functionality of VR.
- VR applications in workflow of construction and Civil Engineering projects.

The main key functionalities that were identified by experts prior to the workshop are:

- Key tool for project delivery
- Aid collaborative design, concurrent engineering, digital architecture and fabrication
- Simple for use in communicating design and construction process-new generation tool
- Object classification.
- Focus on how to deliver simple, cost effective solutions and easily accessible to Architect/ Designer/contractors/sub-contractors
- Increase in stereoscopic and immersive 3D usage; 3D displays (distinct from pseudo 3D displays)
- A paradigm shift of how we do things from CAD to much more 3D visualisation
- Stronger link to the industry and research and development to deliver what industry requires

The experts were of the view that VR is just being used as a visualisation tool and 2D application of CAD is prevailing in the industry. There is a need

for industry and academia to work very closely and deploy the technology to its full capacity. The cultural, technical and other socio-economic barriers must be tackled for to bring efficiency and enhance the performance of the industry and development focus should consider education, training of the industry and stake holders as well as development of natural interfaces. A paradigm shift is necessary.

The next section discuss the operations of the workshop and main outputs.

#### **4. OPERATION OF THE WORKSH: SETTING THE SCENE**

To inform the formation of a new VR roadmap, the research team at Teesside reviewed various reports such as Construction 2020, FIATECH, nD workshops, EU IT Roadmap and Intelligent infrastructure documents. Issues regarding the Role of VR as Enabling Technology Towards 2030, barriers, challenges and requirements were identified and presented to the participants. The aim was to introduce and familiarise the participants with current IT roadmaps initiatives and direct them towards achievement of the aims and objectives of the workshops. This is followed by three brain storming sessions to tackle the development of the vision and the development of the roadmap. Experienced facilitators for each session was appointed and all sessions were video taped for further analysis. The following sections discuss the sessions of the workshops.

#### **5. BRAIN STORMING SESSION 1: DEVELOPMENT OF THE VR VISION FOR 2030**

The objective of this session is to collaboratively develop a VR vision for 2030 which will form the foundation for the proposed roadmap. This session was divided into two groups. First group looked into the development of technical specification for the Roadmap and identified challenges and opportunities (see Table 2). The second group discussed the development of process specification for the Roadmap and identifying challenges and opportunities (see Table 3).

**Table 2: Process Specifications**

Process Specifications	Challenges	Opportunities
<ul style="list-style-type: none"> <li>• Globalisation / Localisation</li> <li>• Energy conservation/ Sustainability</li> <li>• De-fragmentation- Integration</li> <li>• Computerisation - Optimisation of technology</li> <li>• Common Standard</li> <li>• Diversity/ Flexibility</li> <li>• Automated (Semi) building manufacture</li> <li>• Specialisation/ Complexity</li> <li>• Whole life cycle model of building</li> <li>• Information management (representation and use) to match technology and process changes</li> <li>• Product model should support process model</li> </ul>	<ul style="list-style-type: none"> <li>• Data interoperability</li> <li>• Cultural issues</li> <li>• Scale of construction projects (height etc)</li> <li>• Sustainability</li> <li>• Smart materials</li> <li>• Design structure integrity</li> <li>• User perception/ clients requirement capture</li> <li>• Health and safety</li> <li>• Security</li> <li>• Shifting professional roles and responsibilities</li> <li>• Retain creativity</li> <li>• Maintain energy efficiency</li> <li>• Include maintenance of facilities</li> <li>• Education of construction workforce</li> <li>• Legal concerns</li> </ul>	<ul style="list-style-type: none"> <li>• Mass customisation</li> <li>• Reality/ VR integration</li> <li>• Efficiency drivers- Time, Cost Performance</li> <li>• Increased safety</li> <li>• Increased buildability</li> <li>• Alternative materials</li> <li>• Professional integration</li> <li>• Shortened life cycle</li> </ul>

**Table 3: Technology Specifications**

Technology Specifications	Opportunities	Challenges
<ul style="list-style-type: none"> <li>• Tools to be used in whole life cycle of the projects</li> <li>• Full control/interactive</li> <li>• Object Modelling a “new way of thinking”</li> <li>• Communicate 3D/ objects to project team</li> <li>• Use 3D from the beginning</li> <li>• Link and provide design process functions such as sustainability, energy, maintenance etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Cost dropping</li> <li>• Generic objects/ components/library- office metaphor</li> <li>• Parametric modelling/Object modelling</li> <li>• Feed data in different ways.</li> <li>• Realism v artistic (game) depends upon task/views</li> <li>• Embedded intelligence</li> <li>• 3D plane</li> <li>• Free channel of communication (motion, sound etc)</li> <li>• User interface “Selling the dream”</li> <li>• Structure data</li> <li>• Language/ technology</li> <li>• Visual scale</li> </ul>	<ul style="list-style-type: none"> <li>• Change <ul style="list-style-type: none"> <li>○ Legislation</li> <li>○ Globalisation</li> <li>○ Competition</li> <li>○ Generation shift</li> <li>○ Energy/sustainability, production + efficiency</li> <li>○ Generic/ proprietary standards, interoperability</li> <li>○ Archive data (file not found)</li> <li>○ Education/ new knowledge social gap</li> <li>○ Drive technology not just use it</li> <li>○ Dynamics of software industry</li> </ul> </li> <li>• Skills, training/education</li> </ul>

In conclusion, VR will play a major role in the design, management and operation of the Built Environment embracing the “Cradle to Grave” concept. VR will be linked to other applications

with a natural interface. Following the advancement in the mobile technology, construction processes will be more intelligent and

will utilise VR technology. The drivers or change in Technology and Research towards 2030 will be:

- Customer understanding: Client lead required to force change
- Public Participation:
- End user involvement, urban and building development in planning process
- Government regulations, legislation
- Sustainability
- VR software to simulate and assess and analyse
- Incentive- low cost technology
- Competition to provide efficient and quality products/services
- Requirements for knowledge economy
- Internet and mobile technologies: E-submission, VR planning
- Increased partnering, and collaboration.
- Energy conscious stake holders (designers, builders, occupiers, owners)

## 6. BRAIN STORMING SESSIONS 2& 3: THE VR ROADMAP: VISION FOR 2030

Figure 1 shows an outline of the roadmap which was developed during session 2 and 3 of the workshops. There are three components to the roadmap: construction processes, function and specification of VR and R&D initiatives. It is envisaged that the deliverables of the roadmap in 2030 will be the creation and use of highly intelligent electronic product and processes descriptions within virtual environment for performing all business analysis of built environment that consider all aspects of the whole life cycle. This will allow built environment stakeholders (owners, designers, users, supply chain, etc) to develop, design, test, rehearse, procure, built and maintain their facilities in a concurrent and integrated fashion with high certainty of value, usability and very low environmental impact.

The Roadmap is highly influenced and focused on future built environment, business drivers and challenges. In delivering a 'VR Roadmap: A vision for 2030', the experts have asked defined what futuristic built environment they foresee and they agreed on the following specification:

“Sustainable Energy - renewable, Intelligent Controls, Smart Materials  
Common Standards, Advanced Security,  
Self Diagnostic & Healing  
Buildings/Facilities, Intelligent Interfaces  
With Buildings/Facilities, 100 % Certainty  
In Time, very high Cost Performance &

Quality & H&S, Space Efficiency and Flexibility”

This was important in order to focus the mind on the tools, methods and functions that are needed to deliver the futuristic built environment. In parallel to this, the experts developed futuristic business drivers and challenges. Figure 1 shows business drivers and challenges identified by the experts toward 2030.

VR prototyping was seen as being much simpler and efficient when it is assisted by the advent of standard object models of building components and structural members. As ambience is improved and global standards are developed, natural interfaces and immersive 3D usage will be able to better capture stake-holders and user requirements.

Design and VR modelling toward 2030 was seen as being much simpler assisted by the advent of standard object models of building components and structural members. As ambience is improved and global standards are developed, natural interfaces and immersive 3D usage will be able to capture client and user requirements and there will be a high diffusion of the use of augmented reality. The paradigm shift from the use of 2D CAD today to 3D visualisation will make it possible to provide visual simulation of the whole construction process enabling the simulation and testing of several scenarios in a VR environment before investment decisions are made. Moves towards full collaboration and potentially a polarisation of the industry will take place. The integration of the supply chain into the whole construction process will take place partially as a result of the adoption of modular construction methodology but also as a result of increased standardisation. Seamless supply chain streams to expert construction operations will speed up the construction process and improved efficiency/productivity will evolve from the capability to rehearse and simulate construction activities. Moves towards the integration of VR into university teaching courses were seen as being important in the further development of the knowledge and use of the technology in industry.

More intelligence will be incorporated into buildings with improved control applied to their maintenance. The interior fitting out process will be modelled with full involvements and modelling of end user/client requirements. Buildings will be constructed in a sustainable manner with smart materials and recognition given to the deconstruction process and the carbon footprint of the materials and components used during construction.

The view of the experts was that there would be movement towards the increased use of stereoscopic and immersive 3D usage as opposed

to pseudo 3D displays. R&D activity into the extended use of VR and simulation in the town and road planning aspects of the built environment was seen as being capable contributing major improvement in these areas. Finally, industry and academia will need to work more closely to develop simple methods to use VR tools that construction industry requires.

Academia has not proven the case, little measurement of the undoubted benefits from the use of VR platforms has been undertaken. With the availability of proven value benefits, industry will justify the need for taking more time planning and measuring the progress using VR, by improved efficiency and collaboration, inherent from the use of VR during the execution and the after build life cycle phases of a construction project. There are opportunities from the use of ambient interfaces, improved standardisation, image capture, end user involvement in design, laser scanning, object recognition and other emerging technologies that can be seamlessly integrated with VR technology. Breaking down the traditional construction approach was seen as greatest barrier to further development of the technology with major opportunities to increase collaboration, improve communication and efficiency from the adoption of the technology.

The industrial uptake of technology is currently low and to accelerate its utilisation in the Built environment, it is essential to set up priority by the government, overcome cultural barriers and train the workforce to use the technology. Once the industrial application catches up with other industries with reinforcement from research and development of application to match the requirement of construction industry, VR will be a common place for the construction industry towards 2030. The collaboration will include the virtual teams, integration of multiple machines and resources independent of geographical locations.

There was significant debate as to whether or not VR modelling was being pushed by academia or pulled by industry. The consensus was that it was still being pushed by academia though there are some positive signs of change. VR technology is currently used mainly for client walkthroughs, there is an essential need to change the industry culture from a fragmented structure, with adversarial relationships still existing in some areas. The current key business drivers were seen to be the need for; efficiency improvements, cost reduction, increased collaboration, ease of communication, involvement of the client and end users in the whole construction process, accurate progress measurement and modelling of the as-built environment.

## **7. CONCLUSIONS**

The objective of the paper was to report on the development a 'VR Roadmap: A vision for 2030' for the built environment. The methodology and process for delivering the VR roadmap was discussed and articulated.

The future thrust for R&D will be to make the technology simple to use and accessible/integrated to key new generation tools to aid collaborative design, concurrent engineering and provide digital architecture in the form of a single internet based interface that retrieves related and shared data in the form of images and drawings etc and visualises the whole-life cycle of projects.

The key challenge in VR development is to retain individuality and artistic design/creativity and have capability and flexibility to capture and model user/client requirements. Finally, industry, academia and technology developers will work more closely together in the future to develop simple to use VR tools to cater for the requirements of the construction industry.

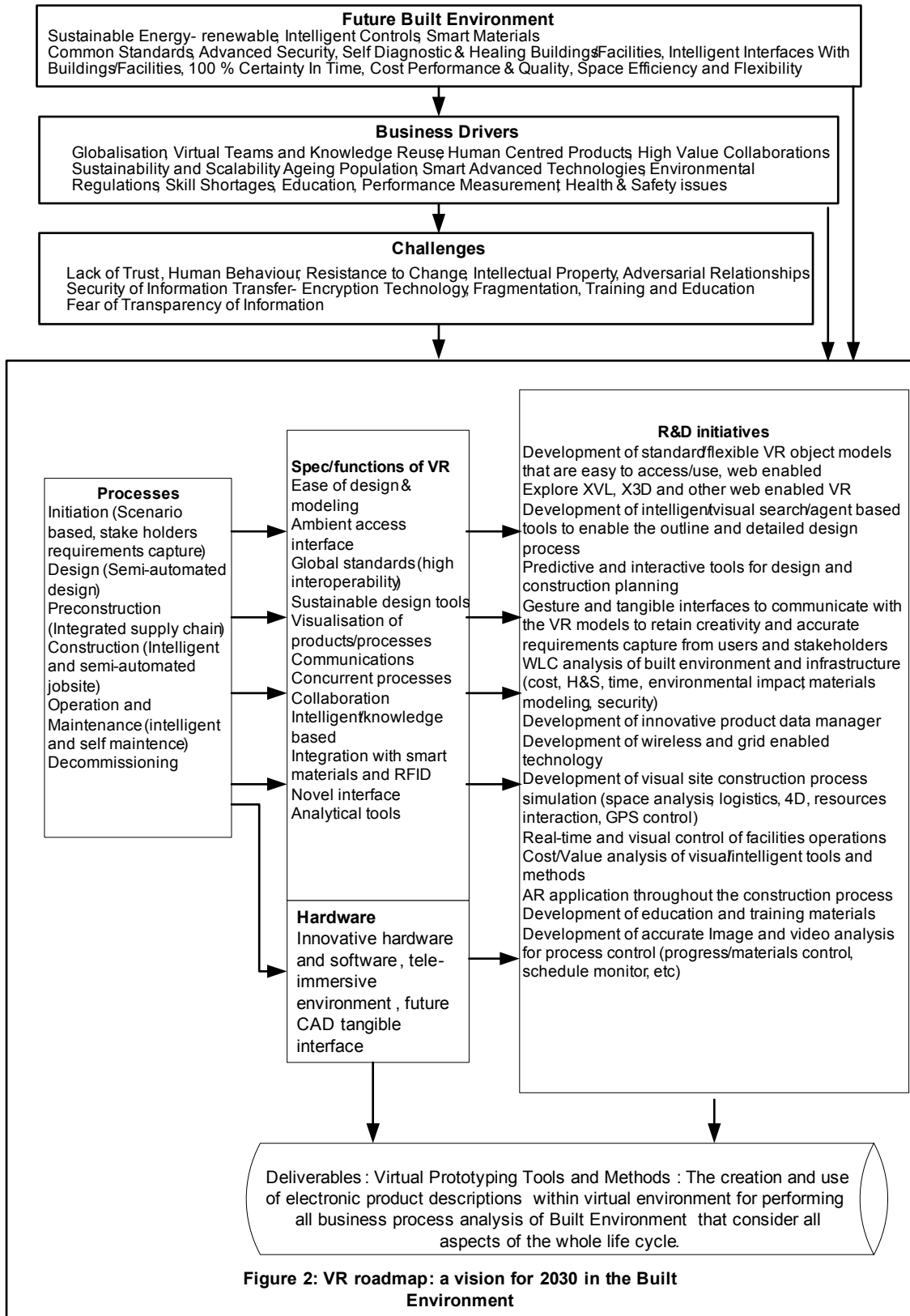


Figure 2: VR roadmap: a vision for 2030 in the Built Environment

Figure 1: VR-Roadmap, Vision for 2030



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