Connected industry

# Cement 4.0

Agrupación de fabricantes de cemento de España

In collaboration with:

SIEMENS

Ingenuity for life

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# Contents

# Presentation

The Spanish cement industry is a sector that constantly changes and develops, and despite a severe crisis in the domestic market and the resulting adverse economic results, it has succeeded in finding ways to lay the ground for the future.

Our industry is naturally no stranger to new technological developments, digitalisation and globalisation – processes which have been undertaken decisively, with a long-term view. The cement industry is striving to be competitive and sustainable so as to generate the high-quality and efficient construction materials that our society needs, and to continue creating stable and highly qualified employment.

In our sector we seek to be at the leading edge of technology, with innovation and efficiency as keystones of an industry-wide model.

Though much remains to be done, cement firms have for years been tackling digital transformation and global integration over their value chains, coordinating, connecting and optimising relationships between all the stakeholders forming their industrial ecosystem.

*Cemento 4.0* is a sample of our sector's ability and determination to undertake a paradigm shift which, beyond transformations in production processes, services and products generated for customers and society, also includes business model development, new forms of customer relations and value creation for customers, as well as the fields of staff training and capacity-building.

This transformation in the cement industry is driven by mass-data processing, real-time connectivity, on-demand custom production and a framework for smart plants. *Cemento 4.0* has its sights on optimising the use of raw materials and energy while enhancing information flows with higher efficiency so as to generate solutions for construction that meet the demands of the 21st century society, with high performance and greater added value in technical features and environmental contributions.

In partnership with SIEMENS, S.A. (Cement Department), in this document we have sought to set out a few existing examples of digitalisation in the cement industry along with some interesting reflections on the challenges faced by the sector, which may and indeed should carry on adapting its processes, products and business models to new technologies in an ever more competitive and complex environment, with many new opportunities.

**Jesús Ortiz Used**
President of OFICEMEN

# 1 Introduction

An age-old industry like the cement industry spearheaded earlier industrial revolutions, from the advent of the steam age through the age of electricity up to the use of automation and information technologies.

Nowadays, within the context of constant and unprecedented technological disruption that led to the current digital revolution, the cement industry wishes to demonstrate its capacity and willingness to assimilate this new transformation, by including new systems such as mass data processing, real-time connections, on-demand customised production and benchmark smart factories.

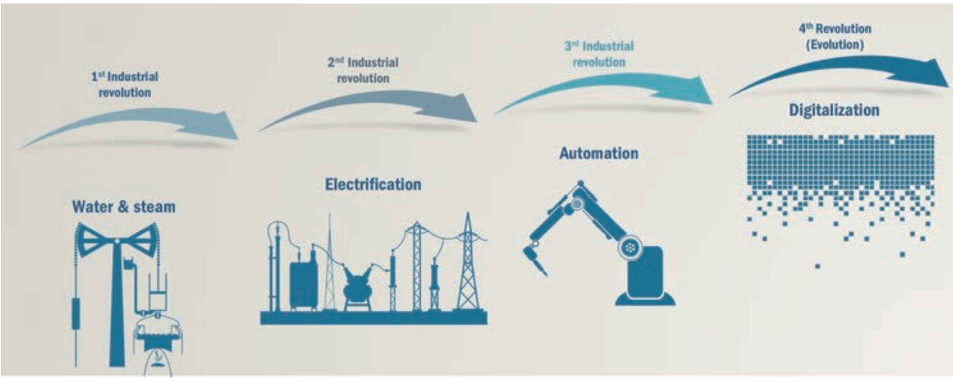
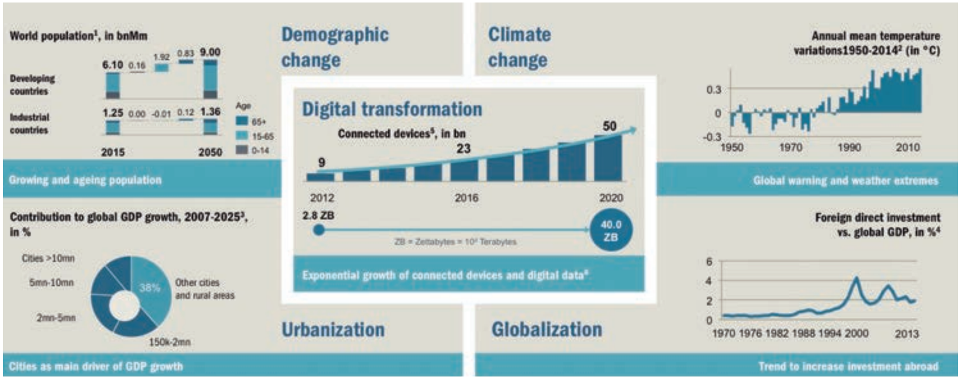



Figure 1. The stages of the Industrial Revolution

Furthermore, the world is facing global impact challenges such as environmental deterioration, a shortage of natural resources and demographic changes, which not only affect us all, but also affect industry. At the same time, there is greater rivalry in a global market and this requires greater efficiency and competitiveness; Europe will be greatly affected because of its very high production costs, a problem that can only be overcome with a process of ongoing innovation.

The present and future of our society are being determined by five major trends:

- Demographic changes and an increase in the work population.
- Climate change and extreme meteorological phenomena.
- Urban development requirements.
- Globalisation.
- Digital transformation.




**1** UN World Population Prospects (2015); **2** Met Office Hadley Centre observations (2014); **3** McKinsey Global Institute Cityscope (2011); **4** UNCTAD (2013); **5** Cisco: The Internet of Everything (2013); **6** IDC: The Digital Universe (2012)

Figure 2. The five trends characterising the present and the future

From an industrial perspective the digitalisation of the production and commercial processes will play a vital role in seeking and developing solutions for dealing with these trends. Digitalisation is the most effective medium to sustain a solid production base from which to expand, and one that has already begun to tackle the challenges of the associated industry.

Any delay in putting this digital transformation into operation could have very serious consequences, which would be even more serious if one takes into account the fact that the main indicators expect the world to be very different from what it currently is, i.e. a world in which market changes will be speeding up continuously.

# 2 The driving forces of change

From the viewpoint of the cement industry, the digital revolution will bring about a large number of rapid changes which will be based upon five singular technologies that will shape the transformation:

- Artificial intelligence and robotics.
- The Internet of Things (IoT).
- Autonomous vehicles.
- Blockchain.
- 3D printing.

## 2.1. Artificial Intelligence and Robotics

Artificial intelligence will progress towards deep learning, where machines and robots learn and will be able to anticipate decisions.[1]

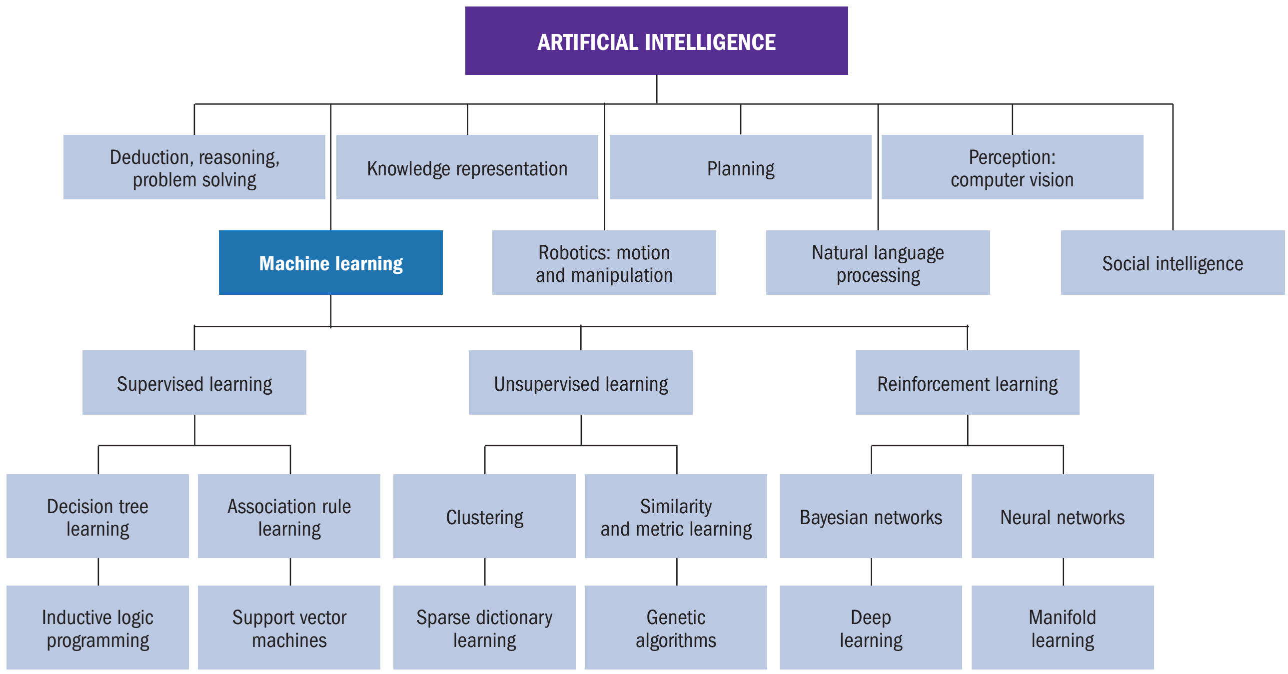



Figure 3. Types of Artificial Intelligence[1]

1 Source Robeco. AI: Our savior or humanity´s final invention? (2016)

This is already having a major impact on the preventive maintenance of equipment through the use of sensors connected to the network that analyse the state of assets in real time providing information about their performance and their maintenance and replacement requirements.

## 2.2. The Internet of Things (IoT)

This is a concept concerning digital interconnection via the Internet involving items of equipment and machines that are in communication with each other. It is the advanced connection of devices, systems and services that goes beyond the traditional M2M (machine-to-machine) and covers a wide range of protocols, domains and applications.

This technology will enable the user to obtain better optimisation of the operational efficiency of industrial production, making it more flexible, profitable and sensitive to market changes. It will also help to improve the health & safety ratios of the workers, as well as optimising inventory management.

## 2.3. Autonomous vehicles

Autonomous vehicles will bring about a revolution in industrial logistics and the relationship between suppliers and customers.

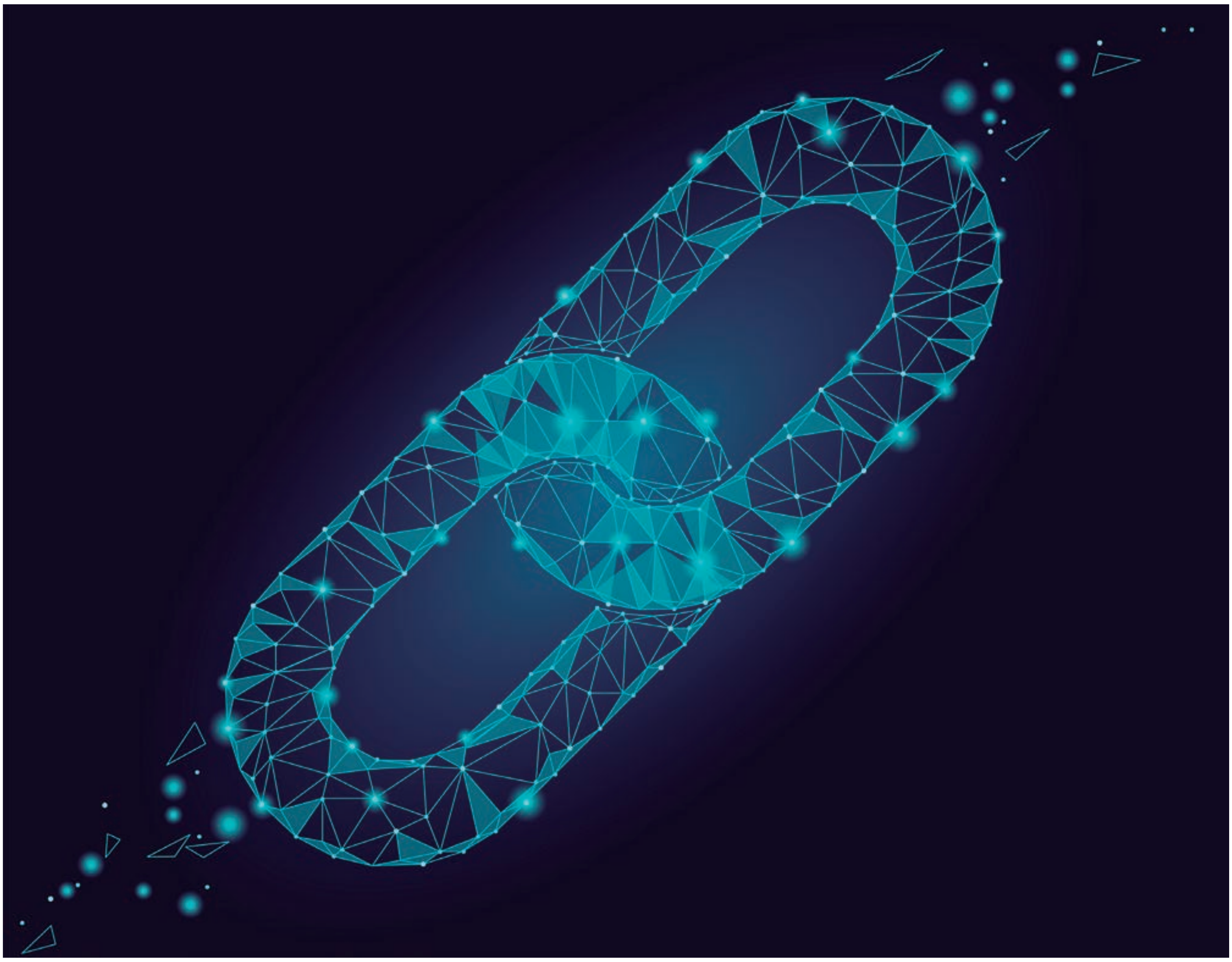
In spite of the fact that complete automation (Level V according to Figure 4) is not expected before 2050, considerable progress has been made towards increasingly automated vehicles, as is the case with platooning (also called road trains), whereby a group of vehicles can flow in a synchronised and autonomous way, optimising goods traffic, while at the same time reducing emissions. This also means an increase in road transport capacity, cost reduction and improved delivery times.

| Level 0: No automation | Level 1: Driver assistance | Level 2: Partial automation | Level 3: Conditional automation | Level 4: High automation | Level 5: Full automation |
|---|---|---|---|---|---|
| The human driver does all the driving. | An advanced driver assistance system (ADAS) on the vehicle can sometimes assist the human driver with either steering or braking/ accelerating, but not both simultaneously. | An advanced driver assistance system (ADAS) on the vehicle can itself actually control both steering and braking/accelerating simultaneously under some circumstances.<br><br>The human driver must continue to pay full attention ("monitor the driving environment") at all times and perform the rest of the driving task. | An Automated Driving System (ADS) on the vehicle can itself perform all aspects of the driving task under some circumstances.<br><br>In those circumstances, the human driver must be ready to take back control at any time when the ADS requests the human driver to do so. In all other circumstances, the human driver performs the driving task. | An Automated Driving System (ADS) on the vehicle can itself perform all driving tasks and monitor the driving environment – essentially, do all the driving – in certain circumstances.<br><br>The human need not pay attention in those circumstances. | An Automated Driving System (ADS) on the vehicle can do all the driving in all circumstances.<br><br>The human occupants are just passengers and need never be involved in driving. |

Figure 4. Levels of automation for driving[2]

It is estimated that the advantages of autonomous vehicles will include having a 10% effect on the GDP as a result of improvements in productivity and reducing the direct costs associated with a lower accident rate.

2 *SAE International, National Highway Traffic Safety Administration*



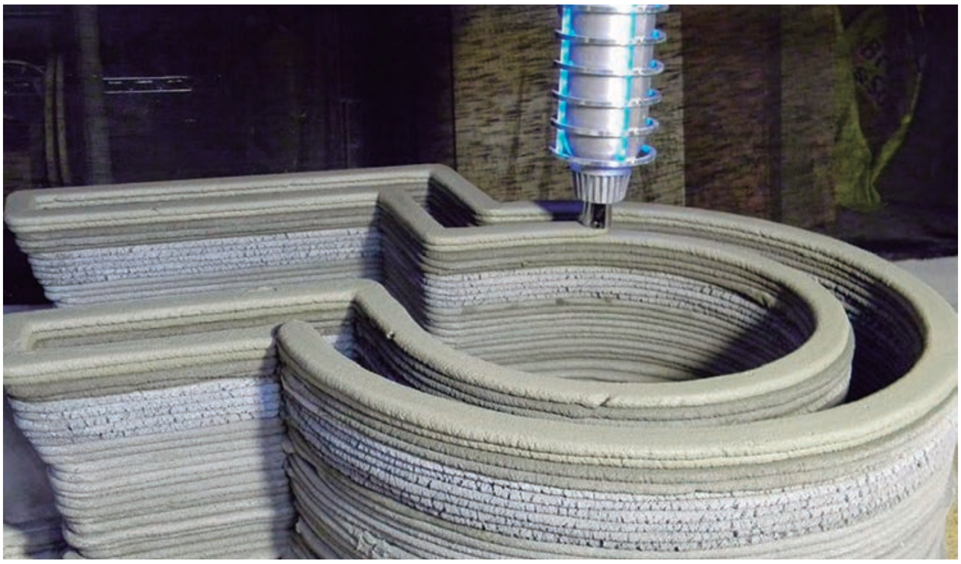
## **2.4.** Blockchain

As these technologies become more widespread it will be possible to manage smart contracts in a decentralised way, enabling users to invariably verify any kind of information, because all the transactions will be recorded without manipulation being possible.

Moreover, this technology will be applicable to guarantee the **traceability** of processes and products, which will lead to an increase in industrial quality and a reduction in the cost of verification.

## **2.5.** 3D Printing

Although this technology is still far from being fully optimised, it will make it possible, amongst other things, to alter the current supply chain lines, reducing dependence on outsourcing or subcontracting and dependence on the work force.



It will also lead to energy savings, time savings and minimised waste generation.

A new development level will add time as a fourth dimension (4D printing). Breakthroughs in nanotechnology will enable the user to combine 3D printing with materials that can change their form and can be self-assembled thanks to their memory.

## 2.6. Conclusion

The deadlines for the complete implementation of these technologies at an industrial level differ from one other. According to the Gartner Hype Cycle[3], it is expected that artificial intelligence and the Internet of Things will attain their optimum production level within 2 to 5 years, from 5 to 10 years in the case of the blockchain and over 10 years for autonomous vehicles and 3D impression.

*3 Gartner, INC: Gartner Report (technology consultant. Hype Cycle.(2017).*

# 3 The cement industry ecosystem

As is the case with all other industries, the cement industry has to evolve to become a self-organised sector within a “smart ecosystem“. Linear processes and isolated functions will be transformed into interconnected clusters that exchange information in real time.

The main driving forces behind this change will be digitalisation and information technologies (ICTs), which use a huge volume of data that is stored in the “value cloud”, so called because it acts as a virtual cluster that envelops the rest of the value clusters. The “value cluster“ will be connected to all members of the value chain (computation in the cloud or cloud service), enabling interoperability within and between the ecosystem value clusters.

However, the industry’s transformation into a smart ecosystem will be gradual. Transition into a transversal economy has only just begun, so we are at an initial stage where plants and firms with different value generation models coexist, all depending on the extent to which they have adapted to the change. If the adaptation has not yet commenced, or it has only just begun, the vision of the value chain will still be linear. The adaptation will cause this value generation model to evolve as the smart ecosystem gradually takes over.

Even at the initial stages of transformation, a top priority is to **make the value chain revolve around the customer,** making the latter the epicentre of the smart ecosystem. The rest of the industry value providers will be situated around the customer, namely, the raw material, the suppliers, the production, the maintenance and the logistics.

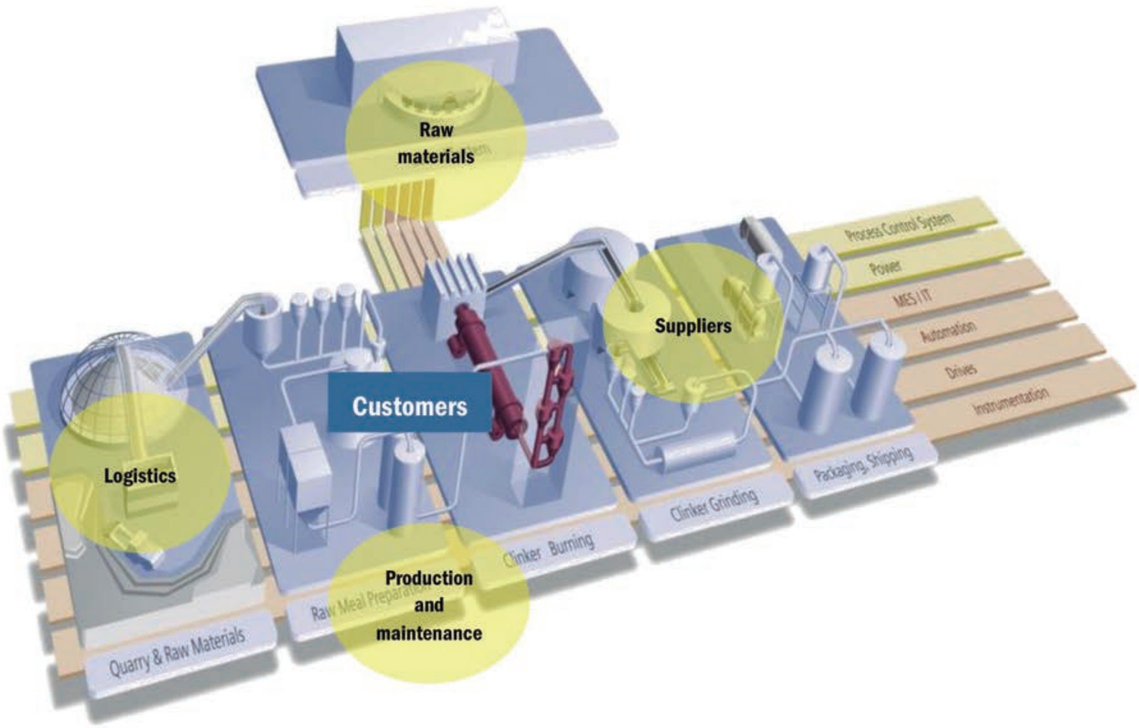



Figure 5. Value providers for defining the smart ecosystem in the cement industry with the customer as the epicentre

**Given that the Spanish cement industry has already begun its transformation into a connected industry, this document contains several actual examples where digital elements are used throughout the cement value chain.**

## **3.1.** Raw Materials

Information in real-time about the main data concerning the raw materials will be available: amount, condition and mineral reserves situation.

The quarries and the mineral reserves will inform about the suitability of their conditions or emit signals to the contrary. This information will be transmitted in real-time by the cluster to all value chain nodes and, as a result, the production process phases involved will be adapted accordingly.

**THE CEMENT INDUSTRY IS ALREADY USING DRONES** to measure the amount of raw materials stored in the open, blast design using 3D profilometry or photogrammetry and inspecting the interior of silos for cleaning and maintenance purposes.

## 3.2. Suppliers

The suppliers of materials, services, products and fuels, as well as alternative raw materials to be used in the manufacture of all kinds of cements will be able to have real-time connections to their customers and cement manufacturers and will thus be able to fulfil their requirements without delay. They will also be able to monitor the production process for the cements concerned, know the consumption predictions and even the existence of finished products, thereby being able to detect in time, the need to replace their supplies and any potential quality problems affecting them.

This ability to interconnect will enable the supplier to optimise his supplies without this adversely affecting the manufacture of customised cements or those with considerable added value. It could also help suppliers to collaborate with the manufacturers in issuing recommendations for improving end-product quality by analysing the process data or the customers‘potential future requirements.

Thanks to this interconnectivity, the provider would be able to adapt the supply while simultaneously being able to provide customised cement and added-value solutions, as well as recommendations for improving the quality of the product based on production data or the future requirements of the end customer.

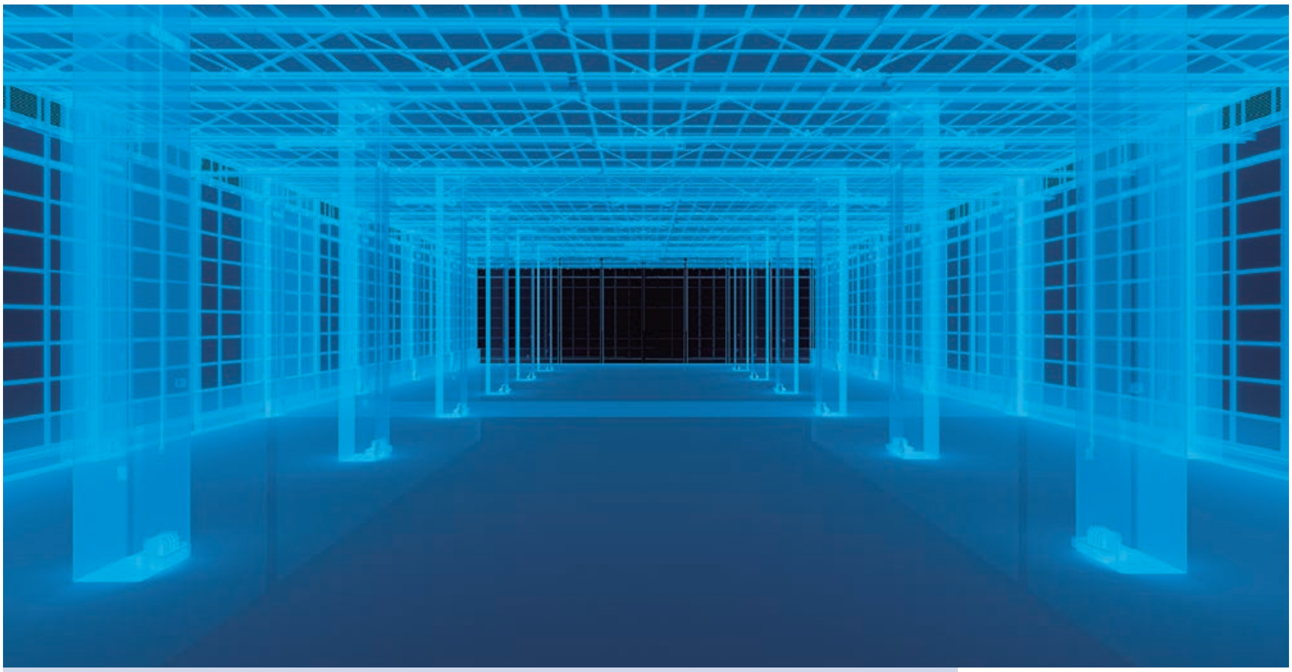
**The cement industry has carried out an ELECTRONIC INTEGRATION OF ADMINISTRATIVE DOCUMENTATION, thereby enabling it to cut the cost of the management involved in validating and reconciling documents.**

**PROGRAMS FOR CLOUD BILLING AND ONLINE PAYMENT SYSTEMS have also been implemented at the same time.**

## 3.3. Production and Maintenance

During the cement production phases, the different facilities and equipment can perform most of their tasks with only limited or more specific human involvement. Many support tasks and functions, such as planning, maintenance and sales, can be centralised to make them more analytical, predictive and proactive. Production will be optimised in real-time with respect to both supply on the basis of past information and demand and complete transparency can be achieved on the customer's production capacities, costs and requirements. New dynamic programming and optimisation algorithms will be developed and the current ones will be constantly updated.

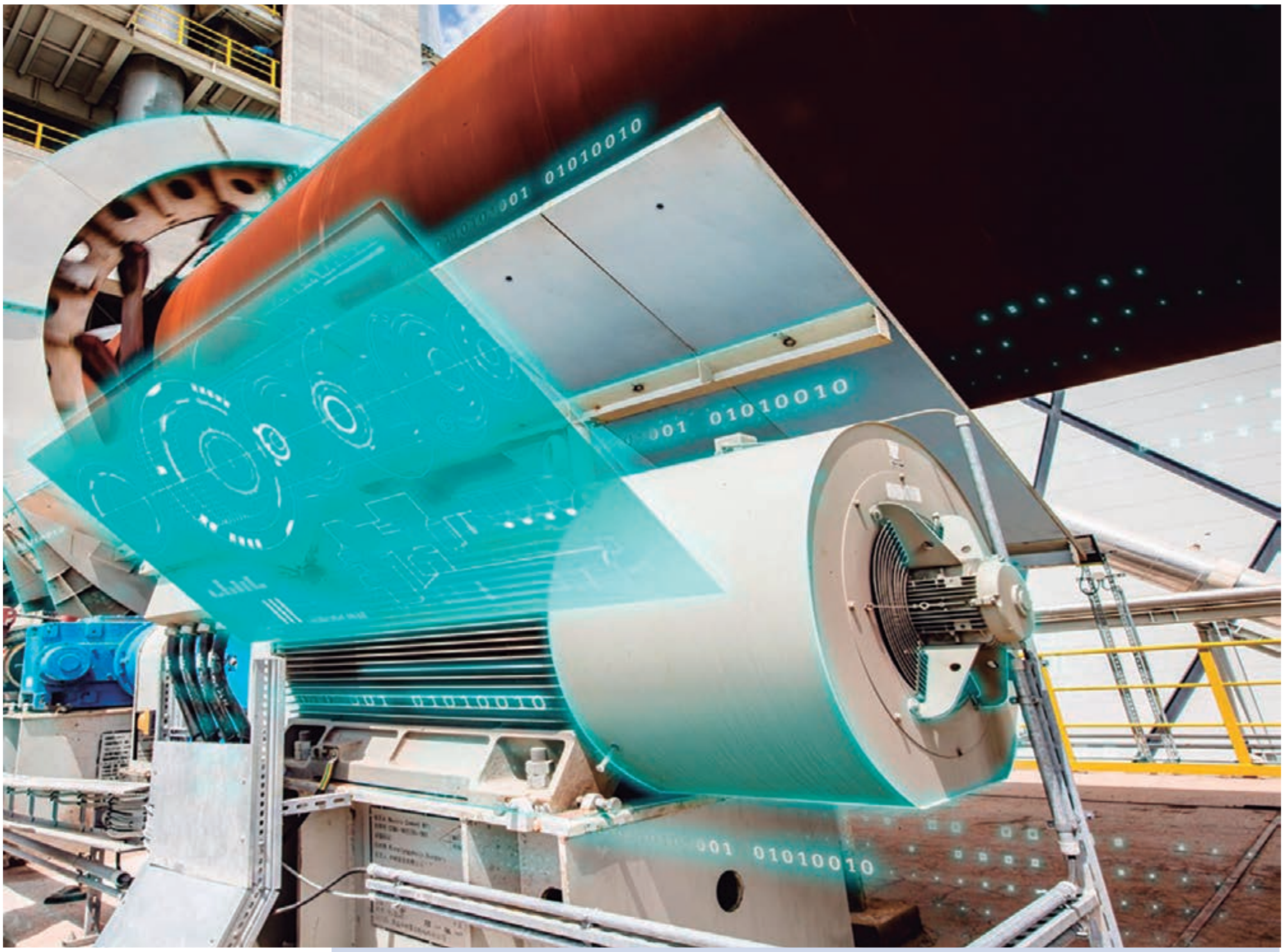
The new digitalisation technology will allow for the centralisation of specialist maintenance by remote control. Reactive maintenance will thus give way to statistical analyses of reliability and fault prediction that will in turn reduce stoppage times, increase task efficiency and lead to a model change with the establishment of minimum-cost **preventive maintenance.**



**KNOWLEDGE MANAGEMENT (KM), IS ALREADY BEING USED** as a computing tool that enables the user to see the production data for the entire factory (production and consumption) and laboratory, in real time and to do so from any point connected to the Internet.

**EXPERT EQUIPMENT MANAGEMENT SYSTEMS (PXPS) ARE ALREADY AVAILABLE,** installed in furnaces and cement mills, amongst other places, which enable firms to optimise the process on the basis of consumption and other parameters.

The new technology also enables firms to centralise specialist maintenance via a remote monitor. In this case, reactive maintenance practices will be replaced by **fault prediction analysis**, in such a way that stoppage times can be reduced, while at the same time increasing efficiency and carrying out complete maintenance at minimum cost.



**WE ALREADY HAVE DEVELOPED PREDICTIVE MAINTENANCE SOLUTIONS,** incorporating all the data sources (specific measurements, accident and incident background files, etc.) that enable the user to optimise maintenance schedules on the basis of predictive analysis findings, thereby reducing maintenance cost.

## 3.4. Logistics

Logistics can become self-organising and more flexible, as it is based upon real-time information about shipment orders. As a result, there will be a better distribution of skills and assignment of functions, higher filling rates, an increase in the precision of the shipments and, thus, fewer complaints. It will also be possible to further improve route planning thanks to the real-time information about conditions at the collection and delivery points.

**THE AUTOMATED LOADING OF CEMENT** makes it possible to operate all day long. The conductors unload the cement with digital cards. The data is processed automatically.

**ONLINE CONNECTION WITH ALL THE CEMENT SILOS LOCATED IN THE PORT OR ELSEWHERE:** enables the firm to know how full they are and unload from the factory.

**CONTROL THE CEMENT-MIXER FLEET UTILISING GPS SYSTEMS** thereby improving their traceability and service.

**PAPERLESS DELIVERY PROCESS, WITH DIGITAL DELIVERY NOTE AND SIGNATURE.**

**ONLINE SERVICE ASSESSMENT,** with root cause analysis.

## 3.5. Customers

Customers are an essential part of the industry's smart ecosystem, the vital link in the value chain and driving force behind the business model. The term is used in the broadest sense to include consumers, agents, institutions, universities, associations, administrations and others, whether private or public, that purchase, use, research, discover new applications, promote, standardise, innovate and make decisions with a view to enhancing cement consumption and improving the product's image as a construction material.

Strictly speaking, a distinction is made between two types of customers where interaction with the ecosystem is concerned: end consumers and demand drivers; the former are the agents that place the orders and the latter are the rest of the aforementioned groups. The two types are equally important for the industry's future.

Customers may access supply & demand information in real time. Direct and open communication between end consumers, other customers, cement producers and distributors will permit better planning and completion of orders with the specified requirements.

All the nodes in the value cluster will receive information about new orders and about any variations affecting those that are in the process of being manufactured, enabling those responsible for all the links in the value chain to make decisions to adapt to production and supply. The customer node will also feature updated information about recommendations for using the products, different applications and the development of new products and applications. Updated information will also be available regarding standards, regulations, codes and certificates of conformity for the bidder's cements.

# 4 Cement 4.0

Cement 4.0 is an example of the sector's capacity and willingness to bring about a paradigm shift, a genuine transformation of the production model that not only considers processes, services and products, but also business models, and the way human resources are trained and acquire their skills.

**The aim of the Cement 4.0 initiative is to encourage the use and exploitation of the best technologies available and of digitalisation to take advantage of the potential for improvement in terms of efficiency and flexibility through strategic positioning on the market.**

When preparing a roadmap for Cement 4.0, synchronised with the steps that have to be taken until the digitalisation factor is generalised in the industry, it is proposed that the "5 values - 5 pillars - 12 components of the digital portfolio" method be applied and subjected to an assessment using an external tool with which the cement industry can compare its results:

- **5 value holders:** in the future, the cement industry will be characterised by being a self-organised and smart **ecosystem.**
- **5 pillars:** that combined, enable firms to make the most of the potential for improving efficiency and flexibility in order to obtain a better positioning on the market than their competitors.
- **12 portfolio elements for Cement 4.0:** key aspects in the process of digitalising the firms in the cement industry.

Once the elements in the **digitalisation 5-5-12 programme** have been defined, it will be necessary to measure the digital maturity of the cement industry and to set a series of targets for the next 5 years. Many cement industry facilities have already begun to digitalise their businesses, but the process has been carried out with a compartmentalised mentality rather than a holistic approach. The cement industry must take all the time it needs to assess the above-mentioned digital maturity regarding all the matters covered by Cement 4.0. It will thus be able to use its strengths and find out which systems/processes should be incorporated into future solutions.

Furthermore, the advanced digital self-diagnosis tool HADA[4] from the Ministry of Economy, Industry & Competitiveness (MINECO), complies sufficiently with requirements to be able to initiate the assessment process.

4 https://hada.industryconectada40.gob.es/hada/

# 5 Connecting the industry pillars

The pillars of digitalisation constitute the set of investments that firms must make not only to develop their potential as much as possible, but also to occupy a strategic position in the market above their competitors.

Cement 4.0 is founded on five pillars that, once developed under an integrated strategy, will enable companies to make the most of the information & communication technologies (ICTs) developed in the last two decades.

These five pillars are the smart equipment, network activities and connectivity, value chain integration, smart products and data analysis.

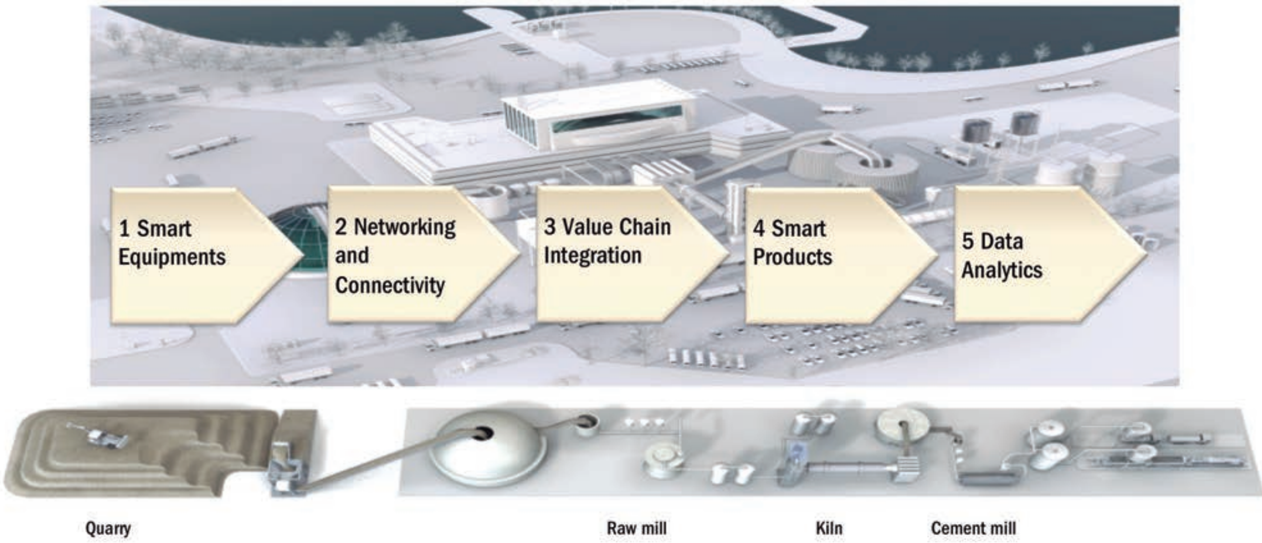
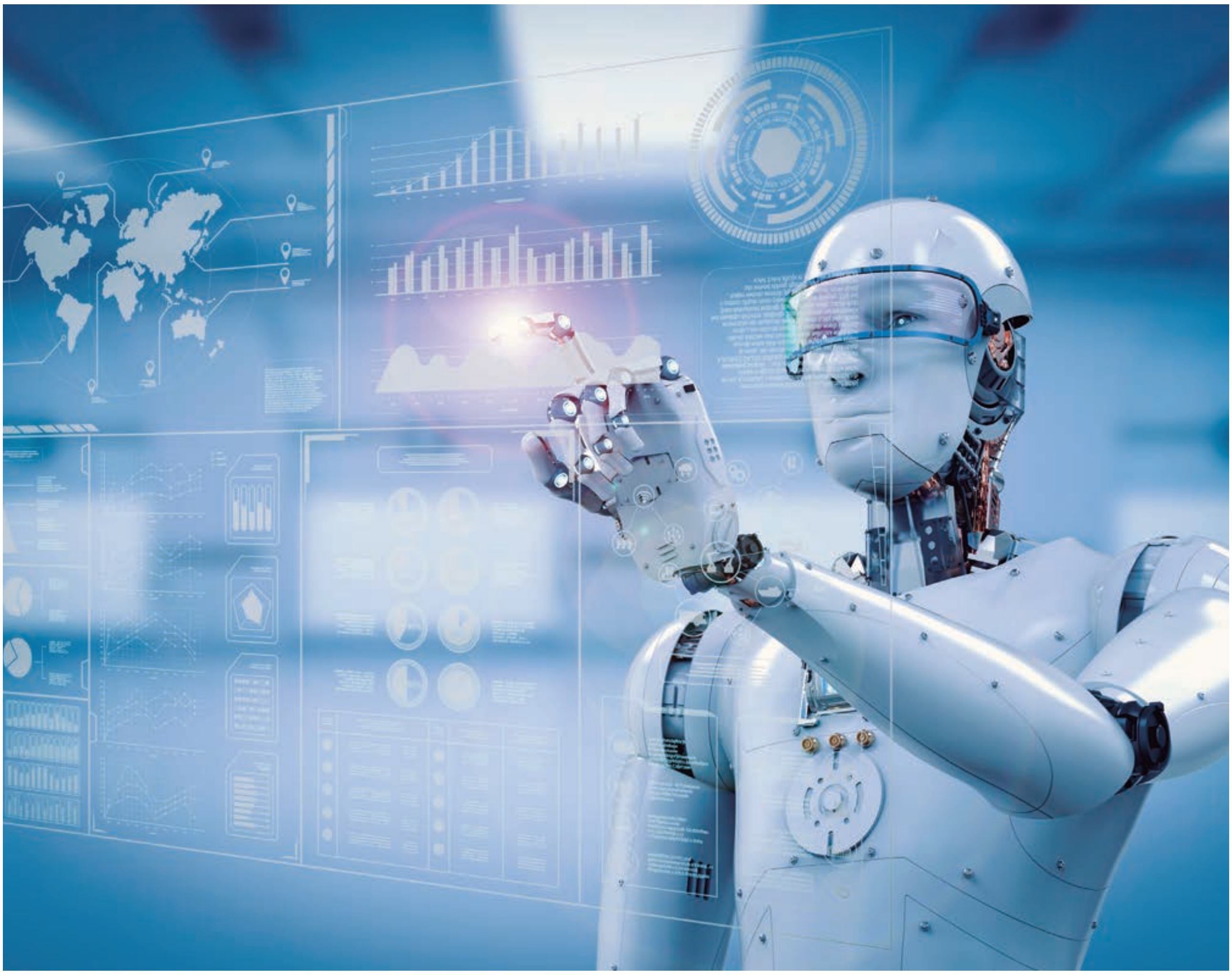



Figure 6. The five pillars of information technology

## 5.1. Smart Equipments

Smart items of equipment are fixed assets in the manufacturing process, autonomous and able to interact with their environment, often with the help of sensors that trigger response actions.



Automation of the processes and smart equipment are the cornerstones of Cement 4.0. Although much progress has been made, the growth of the Internet of Things offers a huge range of possibilities whose limit has yet to be found.

The plants of the future will produce using smart autonomous equipment that is able to interact with its environment via flexible sensors and to adapt to unforeseen circumstances. Such items of equipment will also be able to communicate with each other and with human operators.

All the resources at a cement plant, both materials and human, will be connected via the Internet, creating an innovative technical-social interaction. Soon, not only the pieces of equipment but also the products will be intelligent, arranging the production process themselves and issuing instructions to the machines about the next actions they must take or the special characteristics that must be obtained.

**Use of QR (Bidi) codes at cement plants**

- QR codes on workers' helmets to control skills and work permits for the different teams (safety).
- QR codes on chemical products for the in situ display of safety data files and product technical files.
- QR codes on equipment for the *in situ* display of work procedures, equipment characteristics and spares.

## 5.2. Networking and Connectivity

Network activities and connectivity are based upon **decentralised ICT systems** that cover every aspect of production, form the habitat for an ecosystem to incorporate new applications and equipment and can create a virtual vision of production.

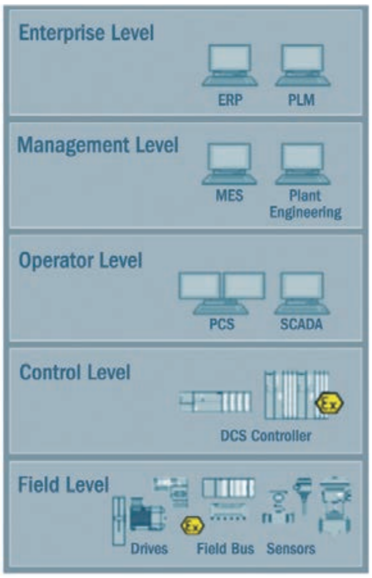



Figure 7. Value chain integration

If one is to make use of the growing availability of information that will lead to the digitalisation of the cement production processes, it is essential to connect all the functional levels of every company through one single decentralised ICT system. The company levels, management, operation, control and field level will be connected from top to bottom. The connection will be complete in the value cluster for each plant and will cover all the aspects of the operations performed there: from reception logistics to distribution logistics, including product engineering and manufacturing.

The role of a system thus described is to bridge the gap between the physical and digital worlds. Hence its name: **cyber-physical system.**

## 5.3. Value Chain Integration

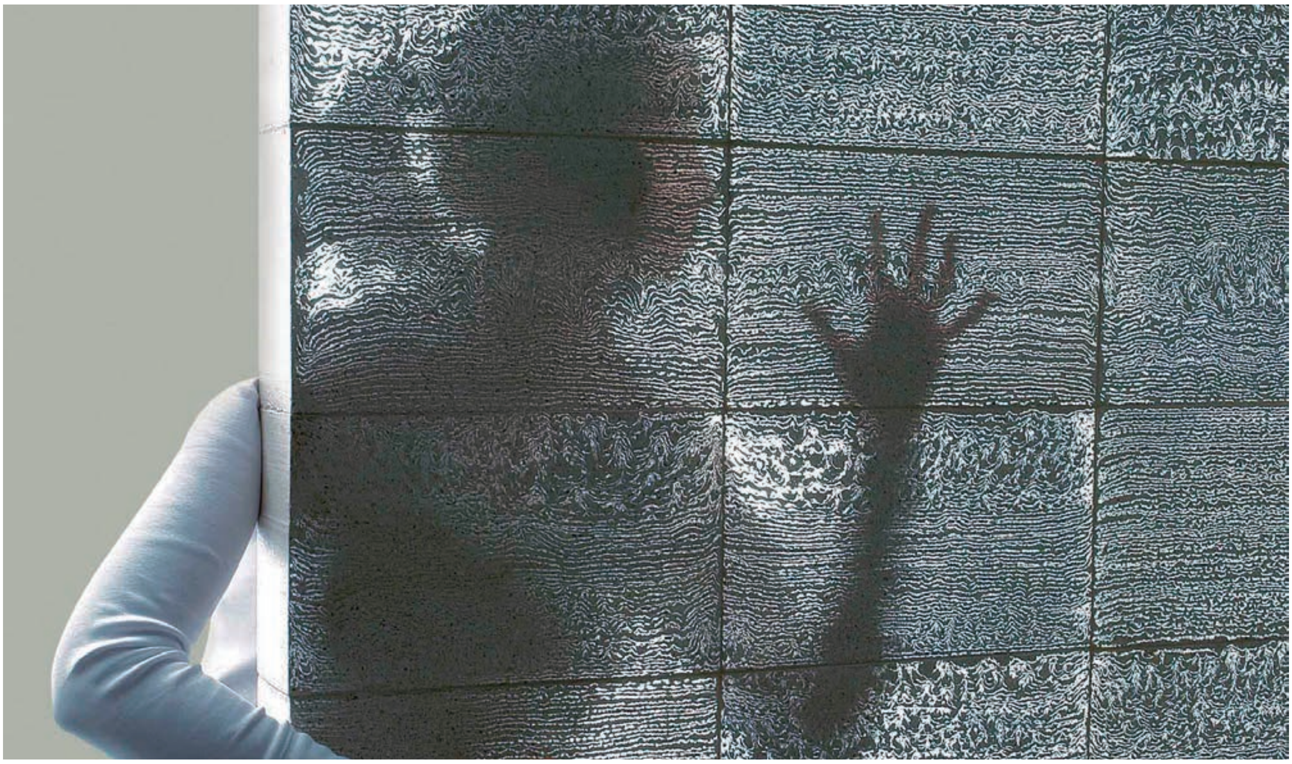
Value chain integration will be the consequence of integrating the ICT systems. The operations carried out on a daily basis at a company will be coordinated better when the value chain integration has been implemented in all the decision variables and methods and this has taken place in an optimised way, often automatically. Complete and real-time connection for all the links in the chain, thanks to value clusters and automation, will be the factors that integrate the entire value chain.

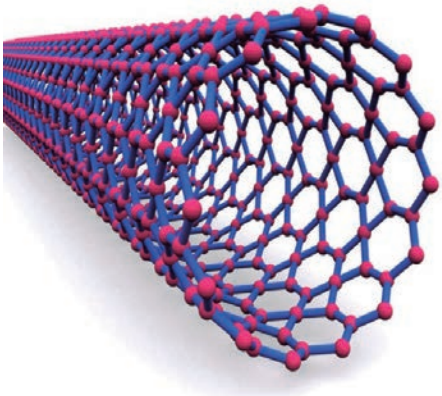
This integration enhances the power of the decision-making mechanisms, because the information is available in real-time. If it is suitably processed and summarised, this constitutes a sound base for managing the processes. Changes in supply and demand will be directly and automatically supplied to the production process, in such a way that companies can react swiftly and efficiently to more volatile marked phases; this will make companies considerably more agile and more capable of evolving from static production models to those that are more dynamic and market oriented.

## 5.4. Smart Products

Smart products are the ones that participate in the production process providing the equipment with data about the next steps to take, specifications, requirements, etc. They can interact with the customers and provide **extra services and benefits in addition to their immediate function.**

If a firm is able to combine the four pillars described so far and integrate them into its processes and activities, it will be able to pinpoint new customer requirements rapidly, even intuitively, and react in a shorter space of time than at present. The firm will also be able to detect new lines of business that are not currently in its portfolio, such as production contracts or shared assets, cloud services or knowledge and skills transfer.





**CARBON NANOTUBES IN CONCRETE.** A nanotube is the material resulting from grouping a sheet of carbon in the form of a cylinder. If it is added to concrete in small proportions, it increases this material's strength fiftyfold and gives it piezoresistive properties. It is thus possible to obtain self-sensitive structural elements, i.e., structural elements that in themselves would provide information about their tenso-deformational state, especially about their state of repair and any potential preventive maintenance activities.

**MAGNETIC SENSORS AND "SMART CONCRETE":** magnetic tracers embedded in cement, able to emit an identifiable acoustic signal will enable the development of smart cements that provide the user with real-time information about their type, origins and benefits.

The use of concretes with these **PHASE-CHANGE MATERIALS (PCMS)** in buildings in order to store energy, combined with management systems based upon artificial intelligence, ICTs and Big Data that take into account the availability of renewable energies, the cost of that energy, weather forecasting and user behaviour, will make it possible to manage the demand of the building using only renewable energies and stabilise the grid, minimising the need for further investment in generation material.

Its use in other fields within the concrete will make it possible to detect any irregularity affecting the work mechanism of the element in which they are embedded.

**BIM** (Building Information Modelling) is a collaborative work methodology for creating and managing a construction project. Its aim is to centralise all the project information in a digital information model created by all its agents. BIM means the evolution for traditional drawing-based design systems, because it contains geometrical information and data concerning deadlines and cost, as well as environmental and maintenance information (7D). BIM.

The use of BIM includes the project design and performance phases and is also applied throughout the life cycle of the building or unit, enabling it to be managed and reducing operating costs. One can be very optimistic about its potential for improving actual knowledge about concrete.

## 5.5. Data Analytics

The statistical tools currently available for data analysis are fantastic, all the more so when the mobile sample is extremely abundant in short periods, almost instantaneous periods, as is the case. The analyses will often be of the predictive type, and the results will be used to improve maintenance and production activities. The data samples utilised will come from processing large amounts of signals emitted in real-time, generally stored in the value cloud.

To make the most of the opportunities provided by investing in the first four pillars of digitalisation, companies must develop or acquire data analysis tools. Applying statistical algorithms to multi-dimensional time series data obtained in real-time will enable the user to make the most of them because of the huge amount of data furnished by Cement 4.0. The potential benefits of data analysis in such a favourable scenario range from cost-saving owing to preventive maintenance and the virtual non-existence of stockpiling (thanks to the predictive analysis of potential bottlenecks), to optimisation of production-associated assets and an improvement in managerial strategy (due to its being based upon better information and a greater potential for action).

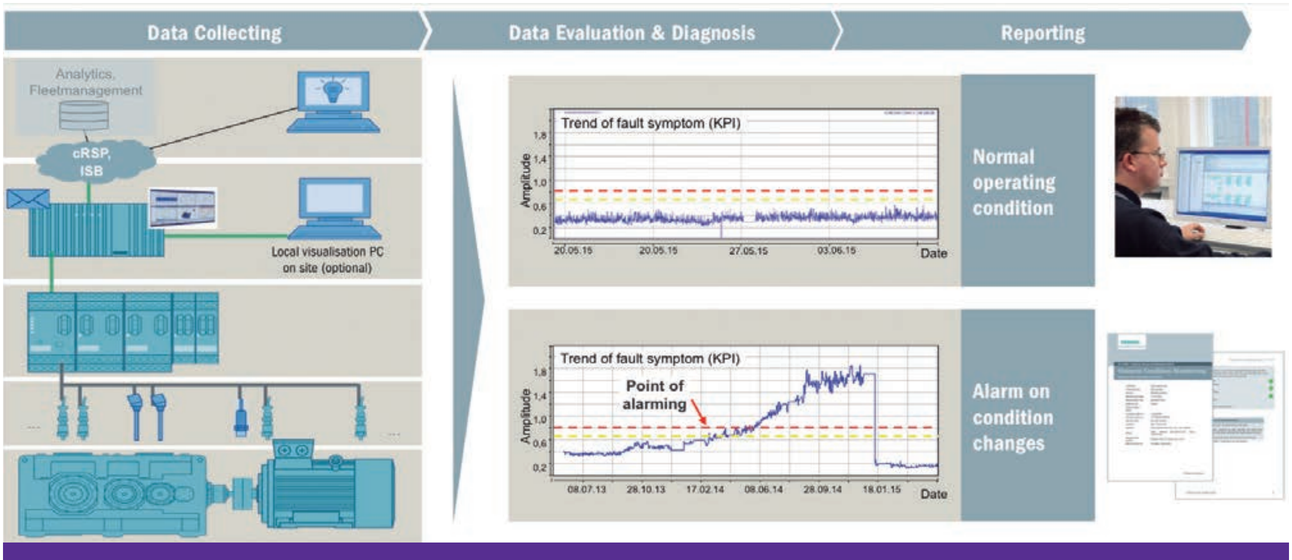



Figure 8. Data Analytics

The five above-mentioned value providers should coexist integrated horizontally and vertically throughout the product's life cycle.

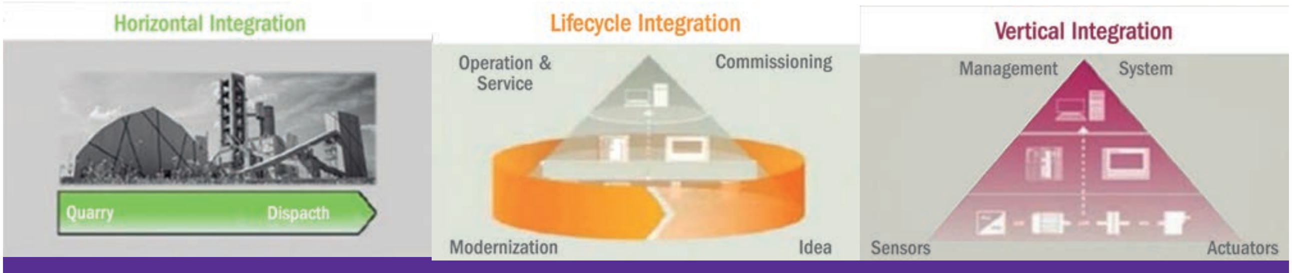



Figure 9. Triple integration diagram

# 6 Digital portfolio elements

The elements in the Cement 4.0 digital portfolio are:

1. Solid cement process automation.
2. Systematic energy saving.
3. Advanced process control.
4. Information security concept.
5. Industry information structure (IT).
6. Smart sensor and equipment technology.
7. Condition monitoring and and diagnosis of state.
8. Intelligence manufacturing operation.
9. Digital twin and simulation.
10. “MindSphere” plant data.
11. Plant life cycle engineering.
12. Autonomous operation.

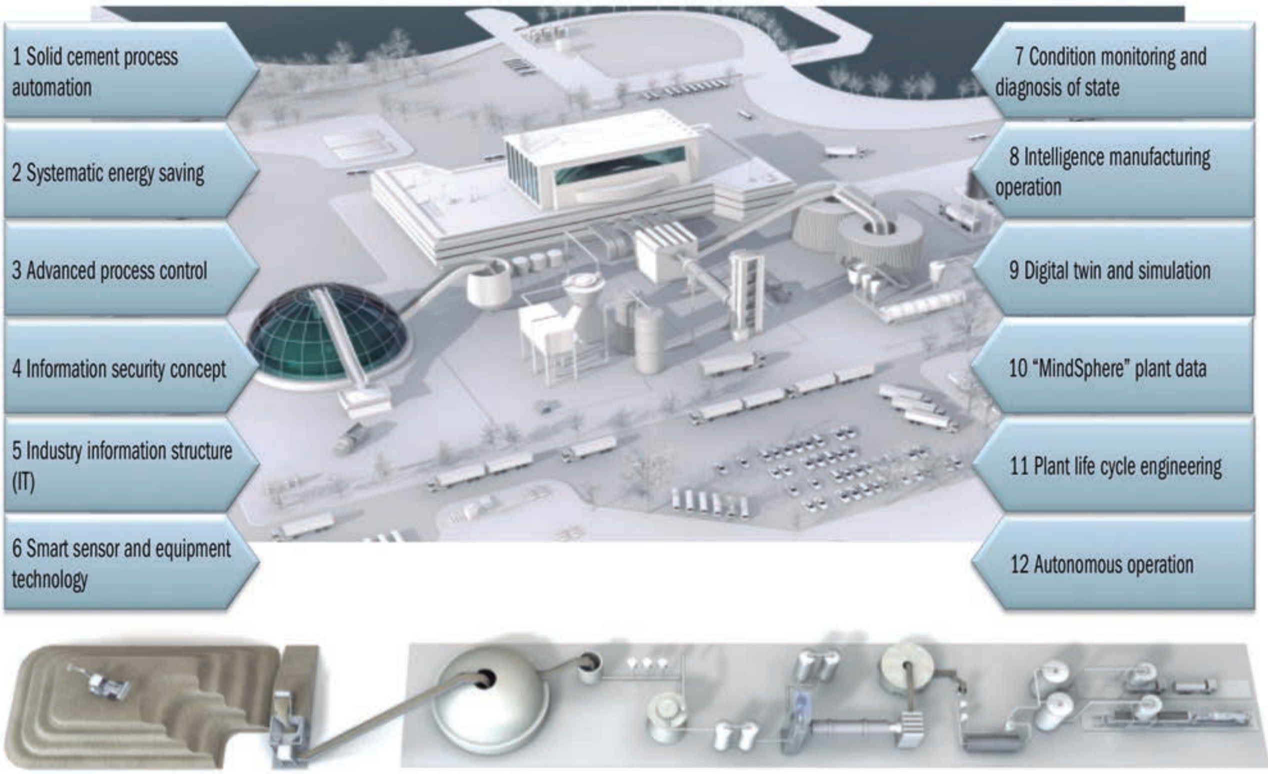



Figure 10. Elements in the Cement 4.0 digital portfolio

# 7 Assessment models

Many of the industry's facilities have already embarked on the digitalisation of their businesses. However, the process has frequently been carried out with a compartmentalised mentality instead of making a holistic approach. It will be necessary to devote time to assessing the degree of digital maturity in the areas covered by Cement 4.0 as a starting point. It will then be possible to find out in which areas it is possible to continue the process, perfecting what has already begun and what areas need to be digitalised in the near future. This initial assessment process ought to be utilised at plant, company and industry levels to establish the path to be followed to ensure that Cement 4.0 becomes fully operational.

It is proposed that this initial task be tackled with a "maturity model" as the tool that could speed it up. Other potential tools are "Digital IQ Benchmark 5" and the aforementioned HADA (MINECO).

The transformation process is shown synthetically in the following table:

| | 1. Digital novice | 2. 2. Vertical integrator | 3. Horizontal collaborator | 4. Digital leader |
|---|---|---|---|---|
| Digital business models and customer access | First digital solutions and isolated applications | Digital product and service portfolio with software, network (M2M), and data as key differentiator | Integrated customer solutios accross supply chain boundaries, collaboration with external partners | Development of new disruptive business models with innovative product and service portfolio, lot size 1 |
| Digitisation of product and service offering | Online presence is separated from offline channels, product focus instead of customer focus | Multi-channel distribution with integrated use of online and offiline channels; data analytics deployed, e.g for personalisation | Individualised customer approach and interaction together with value-chain partners. Shared, integrated interfaces | Integrated Sustomer Journey Management accross all digital marketing and sales channels with customer empathy and CRM |
| Digitisation and integration of vertical and horizontal value chains | Digitised and automated sub proccesses. Partial integration including production or with internal and external partners. Standard processes for collaboration partly in place | Vertical digitisation and standardised and harmonised internal procceses and data flows within the company; limited integration with external partners | Horizontal integration of processes and data flows with customers and external partners, intensive data use through full intergration across the network | Fully digitised, integrated partner ecosystem with self-optimised, vittualisec procceses, focus on core competency; decentralised autonomy. Near real-time Access to extended set of operative information |
| Data & Analytics as core capability | Analytical capabilities mainly based on semi-manual data extracts; selected monitoring and data processing, no event management | Analytical capabilities supported by central business intelligence (BI) system isolated, not standardised decisión support systems | Central BI system consolidating all relevant internal and external information sources, some predictive analytics specific decisión support and event management systems | Central use of predictive analytics for real-time optimisation and automated event handling with intelligent databes and self-learning algorithm enabling impact analysis and decisión support |
| Agile IT architecture | Fragmented IT architecture in-house | Homogeneous IT architecture in-House. Connection between different data cubes developing | Common IT architectures in partner network. Interconnected single data lake with high-performance architecture | Single data lake with external data integration functionalities and flexible organisation, partner service bus, secure data exchange |
| Compliance, security, legal & tax | Traditional structures, digitisation not in focus | Digital challenges recognised but not comprehensively addressed | Legal risk consistently addressed with collaboration partners | Optimising the value-chain network for compillance, security, legal and tax |
| Organisation, employees and digital culture | Functional focus in “silos” | Cross-functional collaboration but not structured and consistently performed | Collaboratoin across company boundaries, culture and encouragement of sharing | First digital solutions and isolated applications |

Figure 11. Capacities that have to be developed via seven dimensions and four stages of Cement 4.

# 8 Initial pilot project and objectives proposal

## 8.1. Initial pilot project

It is recommended that a limited zone be selected to develop the pilot projects, but one that invariably takes into account the final aim of the Cement 4.0 initiative. One possible option is to include the vertical integration at one or two manufacturing plants, adding production planning with engineering and real-time data integrated. Another option would be to reduce the scope of the project placing the emphasis on horizontal integration with key suppliers and distributors, for example by installing monitoring devices and placing the shipments in such a way that it is possible to have an overview of them.

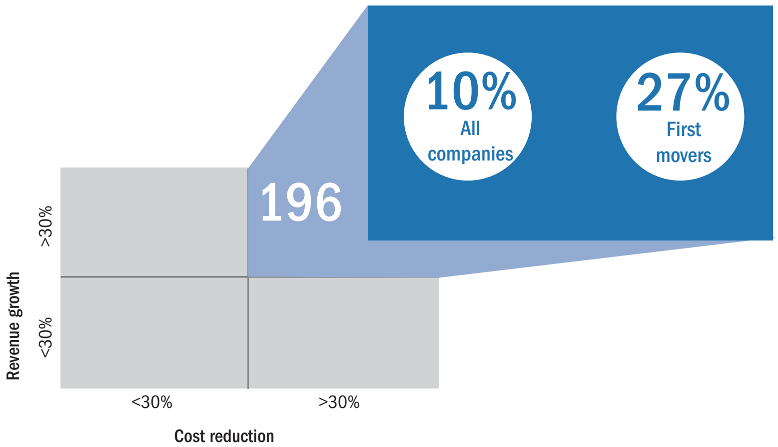
<table>
<tr><th>New digital business models</th><th>Digital engineering</th><th colspan="2">Vertical operations integration</th><th>Horizontal integration</th><th>Smart maintenance & service</th><th>Digital workplace</th><th>Digital sales & marketing</th></tr>
<tr><td>Digital hardware digital optimisation and uptime guarantee</td><td rowspan="3">Digital collaboration in R&D</td><td rowspan="6">Digital manufacturing coordination control</td><td>E2E product lifecycle mgmt.</td><td>Integrated E2E planning and real-time execution</td><td rowspan="2">Predictive maintenance</td><td rowspan="2">E-finance / controlling</td><td>Digital customer relationship mgmt.</td></tr>
<tr><td>Pay-per-use model</td><td>Digital factory</td><td>Logistics visibility</td><td>Omni-channel commerce</td></tr>
<tr><td>Total platfomr management</td><td>Machine automation</td><td>Prescriptive supply chain analytics</td><td rowspan="2">Integrated digital engineering</td><td rowspan="2">Digital HR</td><td>Self-sservice portals</td></tr>
<tr><td rowspan="3">Big data analytics & performance management</td><td rowspan="3">Digital modelling, mockup & simulation</td><td>MES</td><td>Digital sourcing</td><td>Dynamic pricing</td></tr>
<tr><td rowspan="2">Advanced asset mgmt.</td><td>Smart warehousing and logistics</td><td rowspan="2">Augmented reality solutions</td><td rowspan="2">Internal knowledge sharing</td><td>Personalised sales & marketing services</td></tr>
<tr><td>Smart spare parts management</td><td>E-payments</td></tr>
</table>

Figure 12. Opportunities table for the Cement 4.0 pilot projects in the vertical and horizontal dimensions of the value chain.

Consideration could also be given to installing sensors and activators in vital pieces of manufacturing equipment and using data analysis to examine predictive maintenance solutions. The following table provides a summary of potential areas of activity in pilot projects.

## 8.2. Proposal targets

It is a well-known fact that pioneer companies are, on average, three times more successful than later starters at combining high turnover increases with additional cost-reduction benefits.




Q.: What cumulative benefits from digitisation do you expect in the next 5 years?
Lower costs, increased revenues.

Figure 13. Lower cost and higher profit are the two benefits that are most sought after by companies

Where cost is concerned, the main opportunities provided by Cement 4.0 arise from **optimised processes and the efficient use of available resources utilised with the best technology on the market.** This will be possible not only because smart equipment is available but also because of the ability to analyse a large number of data.

Firms will become more flexible when faced with the ever-changing market circumstances and consumer requirements. This target will be reached by removing barriers between the different participants in the value chain and improving information flow between them.

The targets proposed for cost reduction in the cement industry smart ecosystem are shown in the figure below, with estimations for every material in the Cement 4.0 digital portfolio:

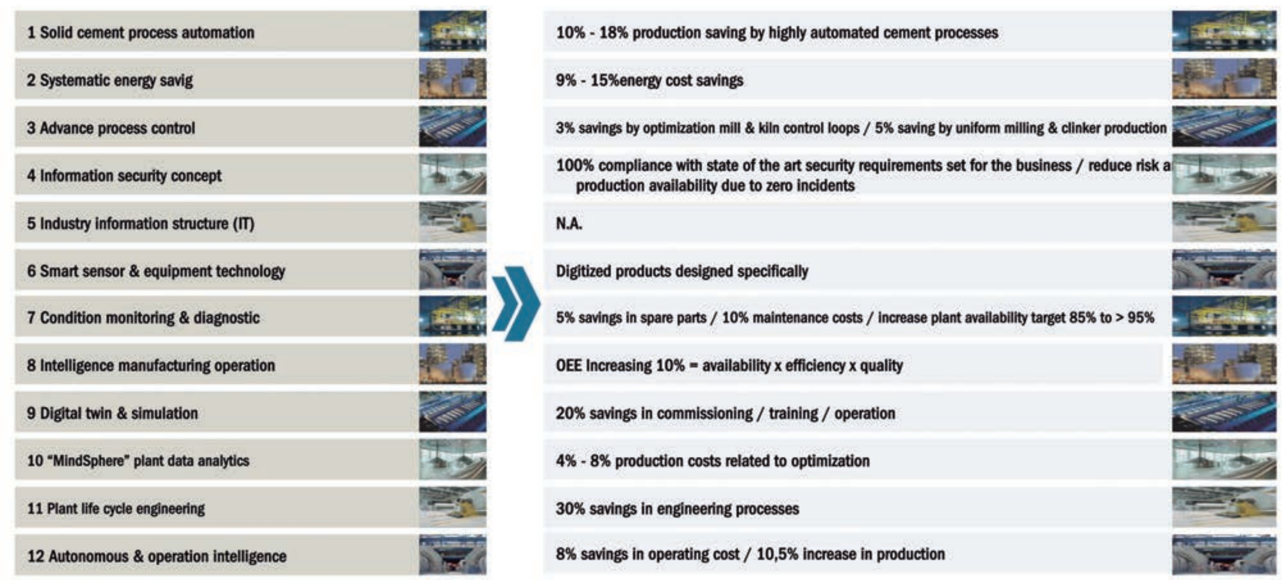



Figure 14. Components of the Cement 4.0 digital portfolio and estimated benefits of implementing it

# 9 Potential challenges ahead

A lot of difficulties have to be overcome before the widespread implementation of Cement 4.0. The first and biggest obstacle could be the lack of a general awareness about the potential benefits of Cement 4.0. However, the following aspects must also be dealt with:

## 9.1. Standards

Applying common and internationally accepted standards helps to create global added value by interconnecting people, machines and systems, via the network. In such a context, the standardisation of interfaces is particularly important, but greater connection flexibility could be seen as giving a competitive edge.

## 9.2. Legal aspects

Data privacy and intellectual property protection are as yet unresolved. The efficiency of a global network would be greatly increased if the data could be shared and analysed jointly by the network participants. However, the practice clashes with current understanding and data protection regulations.

## 9.3. Organisation aspects

Enhanced R&D capacities and proactive management in innovation are basic requirements for a company when it comes to initiating and developing Cement 4.0 with guaranteed success. A forward-looking culture, a willingness to open up to changes and ongoing training to lead the change process are also necessary.

## 9.4. Costs

The high investment costs involved in modernising the machinery hinder the transition towards linked production systems. Therefore, it is necessary to obtain sufficient financing to implement the innovation projects and invest in digitalised assets. Difficulty in estimating the return on these investments is a further obstacle to be overcome when making the decision to invest in Cement 4.0.

## 9.5. IT: Information technology security

One prerequisite to sustainable success for Cement 4.0 is information security and network security. At present, having a secure ICT infrastructure depends on the location, but in the future and for Cement 4.0 it is clear that the greater the number of interconnected value clusters, the greater the risk of cyberattacks with general impact will be.

Apart from cyberattacks, there are also other threats to the information security system, such as industrial espionage, identity theft, zombie networks, Trojans and hackers. These risks, plus other viruses or malicious software sent by email, USB drives or the Internet, amount to a threat to company operations and intellectual property. At the same time, the use of inadequate security systems by ICTs can create uneasiness concerning the potential risks associated with using advanced technologies, thereby impeding the utilisation and implementation of Cement 4.0.

Furthermore, an advanced and stable infrastructure is required if Cement 4.0 is to be implemented. The system includes numerous hardware and software components, sensors, an infrastructure of networks and systems for controlling processes, data management and redundant solutions.

The network and bandwidth infrastructure requirements, plus the stability and reliability of the algorithms used, are also aspects that must be considered. The technology utilised has

to comply with the advanced technical requirements of Cement 4.0 and must guarantee continuity for the interconnected operations.

Finally, suitable resource allocation is required to develop and maintain the ICT infrastructure needed by Cement 4.0. Centralised and exhaustive coordination is essential for the ICT infrastructure, for the automation activities for all the systems, for the locations and for the networks. Furthermore, all the knowledge must be transferred throughout the value chain.

## 9.6. Social aspects

Although technological breakthroughs have traditionally favoured work as opposed to capital, reducing social inequality, sudden changes can bring about temporary and specific employment loss in certain sectors. Although this will give rise to different jobs in the medium- and long-term, this might generate transitory social unrest in the industry concerned.

Cement 4.0 must adequately manage in a way that suitably responds to the demand associated with rapid technological progress. Ongoing training will be essential if maximum benefits are to be attained.

# 10 Next steps

The cement industry is still at the initial stage of development and participation where the Cement 4.0 initiative is concerned. Nevertheless, there are promising cases of firms that are taking their first steps in line with the initiative which are leading to the opening up a range of opportunities that are vital for the future.

The companies that have embarked on any of the Cement 4.0 pilot projects should carry on with their development and seek new ways of developing and deploying the skills acquired and experience built up. The industry ought to share Cement 4.0 development strategies both at company level and value chain level, with the aims inherent to each particular case.

The cement industry can study, learn and draw conclusions from what other industries are doing in the digitalisation field and analyse how to apply those experiences to its own activities. Communication and relations with other industries will help the cement industry to learn, either through lectures, conferences, similar pilot schemes or via informal exchanges.

Whatever the case may be, an assessment of Digitalisation@Cement 4.0 is a **digitalisation** activator:

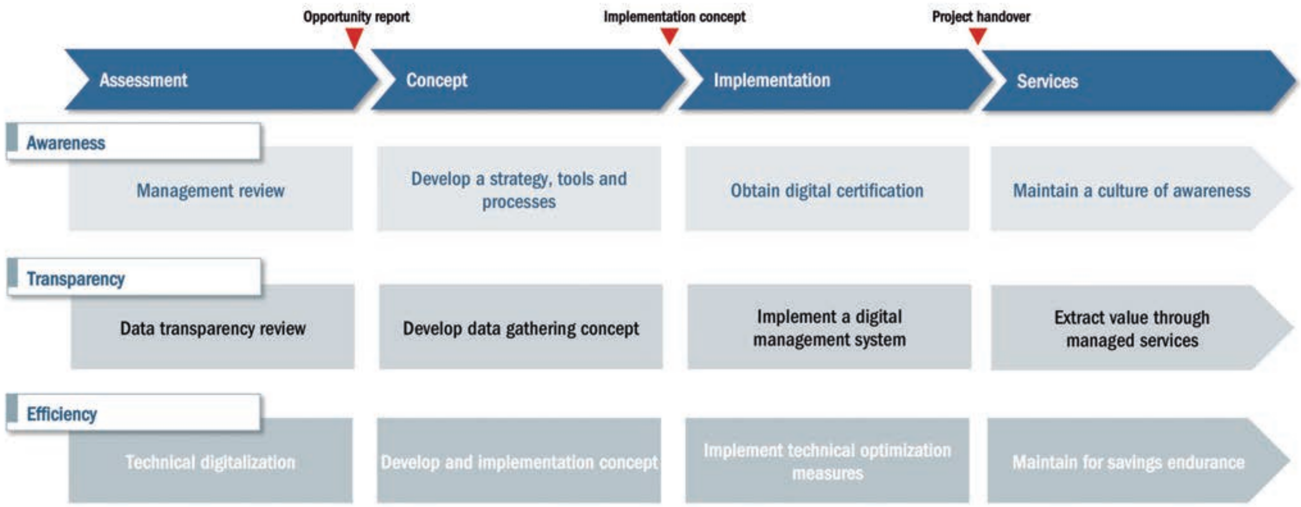



Figure 15. Assessment of Digitalisation@Cement 4.0 as a digitalisation activator


Furthermore, companies can improve industrial cohesion and strengthen relations with customers by jointly planning, developing and financing pilot schemes.

The industry should increase its collaboration with different suppliers, distributors and spokesmen, who are motivated by the ambitious target of preparing a joint strategy for implementing Cement 4.0.

Cement 4.0 will not develop on its own initiative. It will need a great deal of financing, partly supported by the Authorities. The recent initiatives taken by the European Commission and the Member States regarding connected industry can help to ensure that this development goes ahead.

The digitalisation process must begin with the management of the product's life cycle all with a view to firstly, increasing productivity and, secondly, opening up a wide range of business opportunities. However, all the parties have to be convinced and aware of the fact that this Digitalisation@Cement 4.0 will not be an immediate process and that there will be adaptation and implementation difficulties, but that a brilliant future lies ahead for it.

# Acknowledgements

This document would not have been possible without the participation of the companies associated with OFICEMEN and without the collaboration of SIEMENS, S.A. (Cement Department), which midway through 2017 set up a task force with the specific aim of preparing a roadmap towards a connected industry in the cement sector.

At the initial stage, the nine cement groups that make up OFICEMEN complied with the dictates of the Advanced Digital Auto-Diagnostic Tool (HADA) from the Ministry of Economy, Industry & Competitiveness, to assess the extent to which companies are capable of facing up to the challenges of Industry 4.0.

This information was used to prepare an initial draft that was completed with the contributions of the companies that form part of OFICEMEN. These contributions basically consisted of examples that already existed in the cement industry (robotised laboratories, use of drones, analytical prediction models, use of “big data”, etc.), as well as very useful reflections concerning the integration of this digital challenge throughout the cement sector value chain.

Finally, the document is completed with the contributions from Mr. Juan Carlos López Agüí based on his experience of more than 30 years in the cement sector.

The fact that so many have participated has made it possible to present this basic document for the complete digitalisation of the cement sector.

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