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INTEGRATED CONSTRUCTION ORGANIZATION – CONTRIBUTIONS TO THE PORTUGUESE FRAMEWORK

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To my family

"Qui autem audivit et non fecit, similis est homini aedificanti domum suam supra terram sine fundamento; in quam illisus est fluvius, et continuo cecidit, et facta est ruina domus illius magna ".

Lucam 6:49

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ABSTRACT

Construction is an activity that has a direct and significant impact on the economies and life quality of the populations. The Global and European Strategic visions, establish intentions that necessarily involve the action of the industry, requiring, in some way, its readjustment regarding determined aspects. Among several factors, it has been highlighted the need for improved sustainability of the outcomes/objects, in terms of resources consumption, during the construction phase and increased energetic efficiency, during the use phase.

This dissertation takes as its starting point, the notion of the importance of the sector and the challenges that it will face, particularly in terms of competitiveness, sustainability and efficiency. The subject is so wide that the approach is necessarily sectorial, focusing on issues that may be considered side, but that decisively condition the implementation of the intended changes. The sector mechanisms towards the efficiency and sustainability achievements must embody the ability to integrate the processes and the knowledge about the materials and their behavior across the life cycle. The reuse of information and the evolving vision of the construction process is essential for the practitioners, as their task cannot be faced as constrained to a determined phase. Instead, it should be seen as an effective contribution for the following phases.

Thus, the integration and organization of the construction processes is assumed as critical to the achievement of the strategic visions.

In this context, several issues related with the professional activity of the author are explored. This work is not intended to be a comprehensive report of the author's professional activity. Instead, it has the purpose of collecting some results of the referred activity, mostly the one published in journals and conferences, with the researched information and the knowledge systematization that it was possible to perform. Assuming these, it identifies discussion topics, funding opportunities and strategies that can contribute to deepen reflections, to actions already under development and/or considered relevant within the guidelines for the coming years.

Specifically, chapter five presents and explores three proposals that may contribute to the improved information consistency, to the process management gains, and to the implementation of comprehensive information and communication technologies in the industry. These, were developed based on international practices, and attending to the specificities of the legal framework, as well as current national practices.

From these work objectives it is worth highlighting the systematization of knowledge, the identification of discussion topics that should be included in the sector strategic documents, namely at national level, as well as the potential interest actions identified as future research objectives.

KEYWORDS: management, information, integration, collaboration, sustainability

RESUMO

A construção é uma atividade que tem um impacto direto e significativo nas economias e na qualidade de vida das populações. As visões estratégicas de nível Mundial e nomeadamente as de nível Europeu, apontam para desígnios que envolvem necessariamente a ação do setor e exigem, de alguma forma, a sua readequação em determinados aspetos. Entre os vários fatores, realça-se a necessidade de uma maior sustentabilidade das realizações ao nível dos recursos consumidos na fase de construção e crescente eficiência do ponto de vista energético na fase de utilização.

A presente dissertação tem como ponto de partida a noção desta importância do setor e dos desafios que se lhe colocam, designadamente em termos de competitividade, sustentabilidade e eficiência. A temática é de tal modo vasta que a abordagem será necessariamente setorial, centrando-se em questões que poderão ser consideradas laterais, mas que condicionam de uma forma decisiva as mudanças que se pretendem implementar. Os mecanismos para a obtenção da eficiência e sustentabilidade do setor passam pela capacidade de integrar os processos, pelo domínio do conhecimento sobre os materiais e o seu comportamento ao longo do ciclo de vida, bem como pelo reaproveitamento e visão evolutiva do processo de construção, que termina no fim da vida útil do objeto construído e não no fim do envolvimento de determinado agente nesse processo.

Desta forma, a integração e organização dos processos de construção é assumida como fundamental para o cumprimento das visões estratégicas.

Neste âmbito, são abordadas várias matérias que estão relacionadas com a atividade profissional do autor. Este trabalho não pretende ser um relatório exaustivo da referida atividade. Antes, tem como propósito a reunião de alguns dos resultados obtidos, nomeadamente os publicados em revistas e congressos, conjuntamente com a recolha de informação e com a sistematização do estado de conhecimento, sendo apontados tópicos de discussão, oportunidades de financiamento e estratégias que contribuam para o aprofundamento de temáticas atualmente em desenvolvimento e/ou consideradas relevantes no âmbito das estratégias e linhas gerais de investigação dos próximos anos.

Concretamente são apresentadas e exploradas três propostas que contribuem para uma maior coerência da informação, para ganhos na gestão dos processos e para a implementação de tecnologias de informação e comunicação abrangentes no setor. Estas têm como base práticas internacionais, bem como as especificidades da legislação e das práticas correntes do setor a nível nacional.

Dos objetivos deste trabalho, destaca-se a sistematização do conhecimento, a identificação de tópicos de discussão que deverão constar nas estratégias para o sector, designadamente de nível nacional, bem como potenciais ações de interesse que se constituem como objetivos de investigação com potencial evolutivo.

PALAVRAS-CHAVE: gestão, informação, integração, colaboração, sustentabilidade.

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SYMBOLS, ACRONYMS AND ABBREVIATIONS

A/E – Architect / Engineer

AEC – Architectural, Engineering and Construction

AIA – American Institute of Architects

AIMS – Asset Information Management System

APCMC – *Associação Portuguesa dos Comerciantes de Materiais de Construção* – Portuguese Association of Building Materials Traders

ASTM – American Society for Testing and Materials

BEM – Building Element Model

BIM – Building Information Modelling

BoQ – Bill of Quantities

BS – British Standard

CAD – Computer Aided Design

CADD – Computer Aided Design and Drafting

CADFM – Computer Aided Design and Facility Management

CAWS – Common Arrangement Work Sections

CC – EUROSTAT Classification of Types of Constructions

CC – PT – *Classificação Portuguesa das Construções* – Portuguese Classification of Types of Constructions

CCP – *Código dos Contratos Públicos* – Public Procurement Code

CD – Compact Disk

CDE – common data environment

CESMM3 – Civil Engineering Standard Method of Measurement, third edition

CI/SfB – Classification Index / Samarbetskommitten for Byggnadsfragor

CIB – International Council for Research and Innovation in Building and Construction

CIC – Construction Industry Council

CIC-NET – *Rede de Cooperação Estratégica entre Empresas do Processo de Construção* - Construction Process Strategic Cooperation Network for Companies

CICS – Construction Information Classification System

CNBS – *Classificação Nacional de Produtos e Serviços* – National classification of goods and services

COBIM - Common BIM Requirements

CPA - Classification of Products by Activity

CPV – Common Procurement Vocabulary

CSC – Construction Specification Canada

CSI – Construction Specification Institute

eB – Enterprise Bridge

EC – European Commission

eCl@ss – Classification and Product Description

ECTP – European Construction Technology Platform

EDMS – Electronic Document Management System

EPIC – Electronic Product Information Co-operation

ERP – Enterprise Resource Planning

eSPap – *Entidade de Serviços Partilhados da Administração Pública* – Public Administration Shared Services Unit

ETICS – External Thermal Isolation Composite System

EU – European Union

EUROSTAT – European Statistics

FEUP – *Faculdade de Engenharia da Universidade do Porto* – Faculty of Engineering of the University of Porto

GDP – Gross Domestic Product

GS1 GPC – Global Product Classification

GSA – General Services Administration

HM Government – Her Majesty's Government

IC – *Instituto da Construção – FEUP* – Construction Institute - FEUP

ICE – Institution of Civil Engineers

ICS – Information Classification System

ICT – Information and Communication Technologies

IDDS – Integrated Design & Delivery Solutions

IFC – Industry Foundation Classes

InCI – *Instituto da Construção e do Imobiliário* – Institute for Construction and Real Estate

INE – *Instituto Nacional de Estatística* – Portuguese National Statistics Institute

IPD – Integrated Project Delivery

ISO – International Standard Organization

KPI – Key Performance Indicator

MEP – Mechanical, Electricity and Plumbing (design disciplines)

MOP – *Ministério das Obras Públicas* – Portuguese Public Works Ministry

NHS - National Health Service

OJEU - Official Journal of the European Union

OmniClass – OmniClass Construction Classification System

PAS – Publicly Available Specification

PPD – Preliminary Project Descriptions

PRACE – *Programa de Reestruturação da Administração Central do Estado* – Program for Government Central Administration Reorganization

PREMAC – *Plano de Redução e Melhoria da Administração Central do Estado* – Plan for Government Central Administration improvement and Staff Reduction

ProNIC – *Protocolo para a Normalização da Informação Técnica na Construção* – Protocol for Construction Information Standardization

PTPC – *Plataforma Tecnológica da Construção Portuguesa* – Portuguese Construction Technology Platform

PWSSU – Public Works Shared Services Unit

R&D – Research and Development

RIBA – Royal Institution of British Architects

RICS – Royal Institution of Chartered Surveyors

SfB – Samarbetskommitten for Byggnadsfragor

SPSC – Standard Product & Services Code

SPMS – *Serviços Partilhados do Ministério da Saúde, E.P.E*. – Ministery of Health Shared Services Unit

UCI – Uniform Construction Index

UK – United Kingdom

UN – United Nations

UNCCS – United Nations Commodity Coding System

Uniclass – Unified Classification for the Construction Unit

UNSPSC – United Nations Standard Products and Services Code

WBS-CW – Work Breakdown Structure – Construction Works

1
INTRODUCTION

1.1. CONTEXT AND RELEVANCE OF THE SUBJECT

The construction industry plays a major role on the global economy due to, among others, the creation of wealth, number of employments and resource consumption. The first two factors are positive, as it generates, in Europe, almost 10% of GDP and provides 20 million jobs, mainly in micro and small enterprises [1].

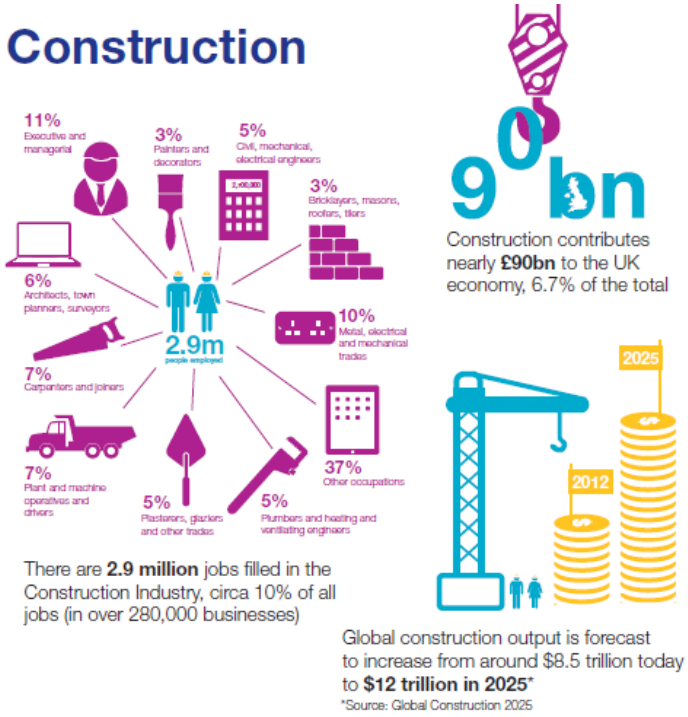

Fig.1.1 – Infographic of the UK Construction Sector [2]

Contrariwise, the environmental impacts of the activity are quite sizeable and it is becoming necessary to find ways to decrease them. Some of the environmental issues that are placed on a daily basis involve reducing greenhouse gas, mitigating existing polluted areas, enhancing energy efficiency and conserving natural resources such as green field spaces, water, energy and balanced ecosystems [3]. When it comes to the vital issue of energy, construction can perform a leadership role in reducing its use and finding alternative sources of generation. Energy consumption and build more energy efficient

buildings are some of the most referred phrases. Yet, the energy and effort spent on the processes during the design and construction stages/phases are far away from being optimized and they have crucial impact on the efficient buildings and infrastructures achievement. There are large amounts of waste during the construction life-cycle [4]. They can arise from wrong design solutions, waste of materials during construction or re-work, errors and misunderstandings due to lack of organization and engagement on the supply chain.

Construction needs to become more sustainable. This sustainability to be effective must be reflected on the resource consumption, on the energy savings, on the skills of all the practitioners from managers to workers, and on the advanced and efficient use of the technology (smart construction). The two last , constitute the main scope of this work. It is envisaged that in order to achieve a more sustainable industry, it is necessary to revitalize the sector in what concerns management methodologies, supporting technologies and information production and flow. For these new processes, the development of a workforce with enhanced skills and supported by information and knowledge technologies is necessary. It is necessary people aware that the processes need to be more collaborative and communicative supported by pervasive, but nearly transparent, knowledge and information based technology. These professionals will be working towards continuous improvements across every phase and significant task of the project: conceptual planning and making the business case; all parts of design, supply chain, construction, commissioning; operation; retrofit; and even decommissioning and capturing the lessons learned into subsequent projects [5]. This vision and the work to be performed on the referred topics (management, technology and information) find a common agreement on the concept Integrated Construction Organization, based on the wide achievement of Integrated Design and Delivery Solutions.

1.2. AIMS AND PURPOSES

The present work aims:

- The systematization of information related with the construction sector in what regards the industry, the strategic references, and the technical documents, standards and regulations associated with construction management, technology and information;
- To structure the most relevant professional experiences of the author in terms of research and training related with the subject under discussion;
- Discuss and propose initiatives that can contribute to the sector regeneration at national and international levels.

The dissertation has as main purposes:

- Give an overview on the industry trends;
- Deepen some initiatives and dynamics that are reorienting the sector technologically and procedurally the sector;
- Explore the integration of construction organization, through construction management, technology and information fields of research, based on the IDDS research roadmap;
- Frame the research topics with the challenges and opportunities of the Horizon 2020 program and other local funding programs;
- Present specific initiatives for the sector, with national and international projection, showing their reason, interest and benefits;
- Explore and discuss possible actions and contributions that need to be placed on the strategic agendas for the industry sustainability;

- Set a current situation regarding the author's knowledge and information systematization upon the discussion subject. It is not an end it is a step with concrete achievements from an evolving process.

In resume, Fig.1.2 tries to synthetize the brainstorming terms:

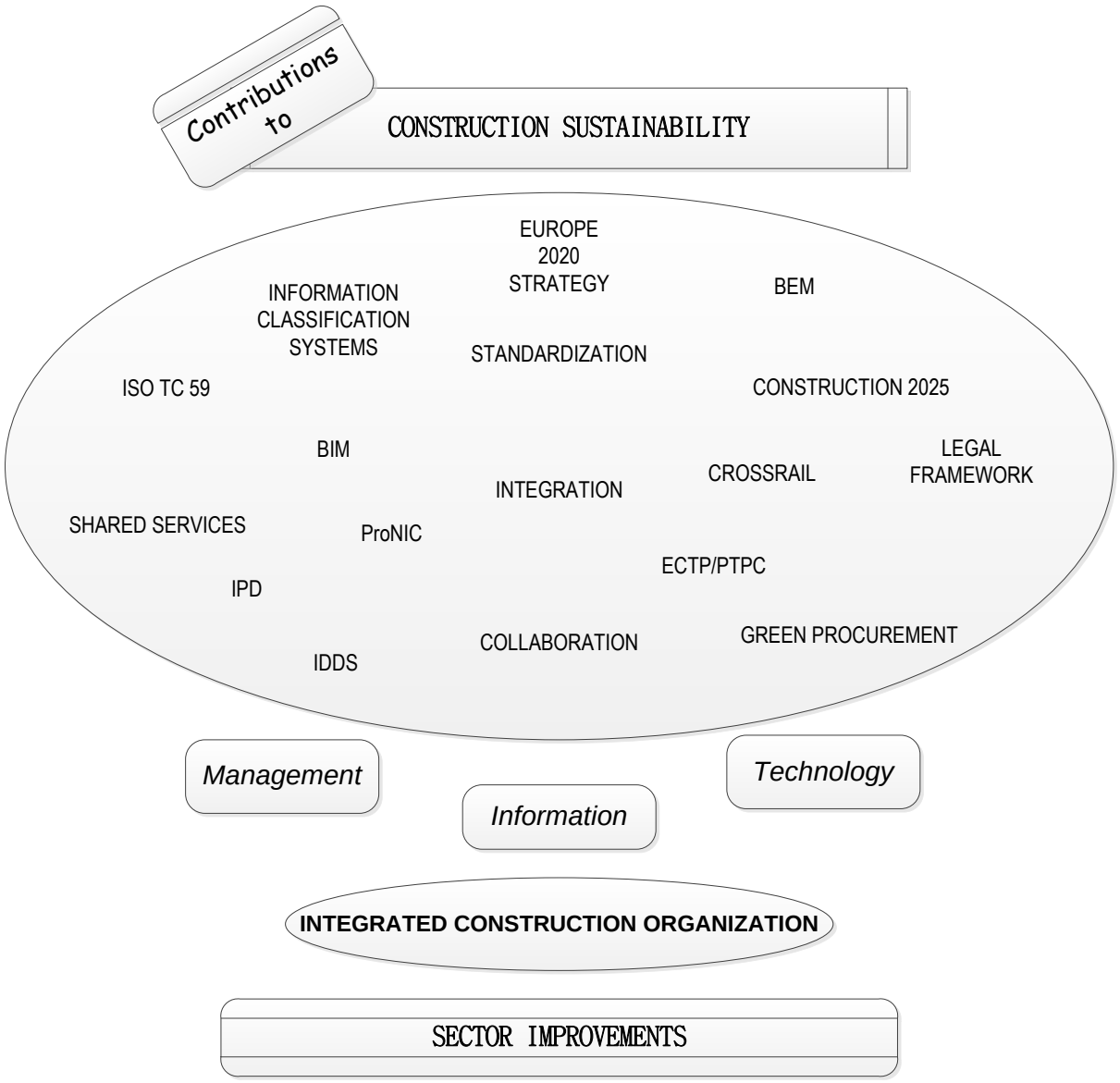

Fig.1.2 – Demands, topics/roadmap and discussion scope

1.3. STRUCTURE OF THE THESIS

The present dissertation is divided in six chapters.

Chapter one is the introduction, where a general overview of the subject is presented and where the aims and purposes are highlighted.

Chapter two initiates the state of the art, focusing on the construction sector or AEC industry. It explores the importance of the activity at a global level, performing an overview on the present situation, and the different realities in terms of overall behavior, investment dynamic, technological development and work production culture. A detailed focus is performed on the condition of the Portuguese construction in terms of global statistics. The trends and strategies are also explored as they envisage and establish the priorities and targets for the years to come. Different levels of documents are explored, from the global documents such as, Europe 2020 targets, EC Construction Strategy, to Portuguese Commitment for the Industry, passing by the ECTP Vision for 2030, the Construction 2025 Industrial Strategy from HM Government or the CIB reflections. Their visions and relevant information for the subject are presented for further discussion.

Chapter three is dedicated to the environment that surrounds the discussion theme. It presents and explores broadly the main technical documents, standards and legal diplomas. Highlights and remarks are set, establishing and framing the main lines for the contents and concepts of the following chapters.

Chapter four is dedicated to the author's testimony about his professional experiences. The description will only focus on the main topics from the activity performed during the years as researcher. Even these will be explored from a generic point of view and turned to the discussion's main goals. Two major experiences are presented. The first to be described addresses the main initiative in which the author has been working, the ProNIC project. General overview on the objectives, its development, implementation and the current situation is presented. The second experience addresses a training action performed at Crossrail. This participation is explored in detail given the substantial contributions for the discussion topic, as it represents a real testimony of the envisaged and ongoing innovations for sector.

Chapter five is dedicated to the discussion and proposals. General lines of the CIB IDDS roadmap are explored setting the targets and major topics for IDDS achievement. From the topics few were selected, as they are more centered on the objectives of Integrated Construction Organization, namely on the related issues management, information and technology. For each topic the main lines are structured and the discussion is performed taking in consideration the strategic documents and their prescriptions in order to identify funding opportunities. Generic actions and proposals are envisaged. Regarding three of these topics it is identified and developed one specific proposal. These are framed with each specific issue and crossed with the topics "*Coherent information flow and reusable knowledge development*", "*Information systems life cycle & interoperability*", "*Collaborative project development process & legal framework*". For the first a prototype is settled, for mapping between information classification systems for the types of constructions, regarding communication it is explored the possibility of technological interoperability/information exchange between ProNIC and 3D virtual design tools. In what relates the management of the processes and their legal framework, it is discussed the possibility of the adoption of a Shared Services management unit for construction.

Chapter six is devoted to the final remarks.

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2

ARCHITECTURAL, ENGINEERING AND CONSTRUCTION – THE SECTOR, THE INDUSTRY

2.1. CHAPTER OVERVIEW

This chapter is dedicated to the construction sector/AEC industry. It is explored the importance of the activity at global level, performing a present time overview and the different realities in terms of overall behaviour, investment dynamic, technological development and work production culture. Special attention is drawn up to the Portuguese construction in terms of global statistics. The trends and strategies are also explored as they envisage and establish the targets and priorities for the years to come. The vision from these different documents and the relevant information for the subject will be presented and discussed.

2.2. A GLANCE ON THE INDUSTRY

2.2.1. OVERVIEW

The AEC industry plays an important role in Global economy. It is a diverse activity, with broad and varied markets. Starting with mining, quarrying and forestry, the industry runs all the way from design, product manufacture and construction through to the maintenance of our buildings and infrastructure assets and, at times, into their operation and disposal. The relevance of this industry is such that international studies point to medium values of 10% of GDP on European countries [1] [6]. For the next years, it is expected that on the emerging economies, construction will make up 16.5% of GDP [7].

The whole life value of construction is critical. Modern societies have forgotten how construction has influenced their progress and the impact that has on the people's daily life. Construction creates, builds, manufactures and maintains the workplaces to enable our businesses to flourish, the economic infrastructure which underpins how the economy functions, and our schools, hospitals, and homes, among others.

The supply chain can be hugely complex. Firms in the industry range from world renowned design practices working on some of the most prestigious projects across the globe, to the plumber who turns up to fix a dripping tap. Most of the employments are on micro and small enterprises and given the variety of roles, tasks and phases on the construction process life cycle, they present large differences between them in terms of practice, processes and strategic approach. This scenario has an impact on the performance and considerable hinders the spreading of good practices. What unites the industry is

the fact that it touches all our working, social and home lives, every day in a very tangible and visible way. A simple exercise of structuring one day leads to the conclusion that more than 90% of the time is spent using products from construction (construction entities or complexes). Thus, it directly and immediately impacts on our quality of life. Decisions about what we build today, how and with what we build, and how it can be maintained, have very long term consequences.

Until the middle of the XIX century, construction played a central role on the technological development. Since then is has been losing it to other industrial activities, and nowadays there are two major factors located on opposite ends that put pressure on construction to reinvent itself and define strategies towards modernisation, competitiveness and sustainability.

The major factors are:

- the crisis that affected some economies;
- the potential growth of construction in emerging economies;

A first glance may lead to the conclusion that the main concerns are different. Yet, looking in detail, both visions intend to improve the act of build or maintain, spending less money, less time and less resources.

From the referred, it is possible to conclude that construction has played an important role on the countries' economies contributing to their evolution. Changes on the industry will be needed to raise the bar on the productivity and desired leadership. Before the strategies discussion a look on the foreseen the trends will be presented.

2.2.2. CONSTRUCTION 2020 FORECAST

This document [7] constitutes a strategic overview on global construction. It is meant to help construction sector organizations to understand the needs and impacts of construction outputs in key markets. The information is considered critical to shape global businesses and make appropriate investment decisions, namely in which geographies. Some findings, numbers and figures are highlighted to enhance the importance and the future trends of the industry.

It is expected that construction will grow by 67% from 7.2 trillion dollars from today to 12 trillion in 2020, being pushed by Asian countries (China, India, middle-east countries like Qatar, Saudi Arabia) and South and Central America countries, namely Brazil. By 2020, it is expected that emerging markets will account for 55% of global construction, compared with the present time 46%. China and India are identified as major markets. It is foreseen that China will lead the construction markets by the end of 2020, overtaking the United States of America.

The drivers of these developments are the populations rising, the rapid urbanization needs and the strong economic growth. The last factor is very relevant in terms of construction outputs. Since ancient times the countries rely on construction to build landmarks for their worldwide affirmation. One of the most recent examples is the Burj Khalifa skyscraper, in Dubai.

The United States recovery is foreseen, being estimated a strong rebound with growth that will achieve double digits for the residential and non-residential markets. The growth on the infrastructures market is uncertain, marked by the limited budgets and the public sector high level of deficit.

The sports competitions constitute opportunities for the construction sector. Countries like Brazil, Russia, Qatar and South Africa are performing major investments on facilities for the competitions and all kind of support infrastructures.

It is worth mentioning in detail, the forecasts for the African continent, were many of the Portuguese companies (design, supervision and construction) are already operating. Many of the major African cities had European influence and most of the constructions were built by them. Nowadays, the demands point to the construction of buildings and infrastructures with similar quality levels for many people. The African governments are starting to get worried with the life quality and tourism potential of their cities. There are just four places from a list of one hundred tourism destinations within Africa. All of them are on the last twenty. They are Port-Louis (82º), in Mauritania, Cape Town (89º) and Johannesburg (94º), in South Africa and Victoria, in Seychelles. It is envisaged a global project to elevate the quality level of ten African cities, many of them with touristic purposes. Cities as Casablanca, Tunis, Dakar, Marrakech or Abidjan are few examples [8]. The previously referred demographic rising will lead to increased real state demands. It is expected that Nigeria will double the population living in its cities. The second biggest city in Africa, Lagos, will pass from 10.79 million inhabitants in 2010, to 18.86 million in 2025. This country will concentrate five from the top thirty major African cities. Therefore, special attention should be given to this continent as there are several markets with fast growth and yet to be explored [9].

One of the countries where construction is expected to suffer the most is Japan. Nowadays, it is the third largest construction market. It is expected that by 2020 the activity will be 16% lower than the registered in 2005.

Europe's forecasts point to an overall shy recovery. In this territory it is expected that demography will set the pace on the construction activity, playing a major role. Countries like Germany, Italy or Portugal where the population is decreasing will suffer from the shrinking of the working-age population, which will contribute to economic constrains and as such, to the construction performance and outputs. On the contrary, positive demographic trends on UK and Sweden will contribute a little to the residential market rebound [7].

From the referred, there are many opportunities and constraints that will mark the construction investment policies within the next decade. In what concerns the European reality, the static/declining of populations will lead to other needs in terms of constructions (health and palliative facilities), the built environment will have growing maintenance needs and the high public deficits and investments constrains will demand different behaviour from construction in terms of performance.

2.2.3. THE PORTUGUESE SITUATION

The construction industry played in Portugal during the past 20 years a major role on the country development. The activity was mainly supported by the residential market and public works, namely the construction of highways. According to EUROSTAT and INE, the indicator that measures the value of the works performed by construction companies with twenty or more employees varied during the last decade, between almost 19.7 billion euro, in 2008 and 14.7 billion euro in 2012, representing a medium value of 17.6 billion euro that is more or less 10.5% of the Portuguese GDP [10] [11]. On previous years it had even more relevance. The decelerating trend was notorious from the end of the past century. However, events like Expo 98 and Euro 2004 contradicted this rate. Several works under public-private partnerships also had a substantial contribution.

Notwithstanding the knowledge that over time, the industry would need to change to other markets and even pass through a reshape (contraction) process, all stakeholders, including the Government, remain focused on the "traditional" construction segments. Figure 2.1 presents a graphic that evidences the differences between segments for the Portuguese reality in 2010 and the reality of the Western Europe countries.

Many construction companies maintain their activity and business core, as they have skills to successfully compete in foreign markets. Looking out borders, the activity of the Portuguese construction companies is proliferating as they are participating on the construction of major civil engineering works like the new Panama Canal and several road and railway infrastructures on Africa and Central and South America.

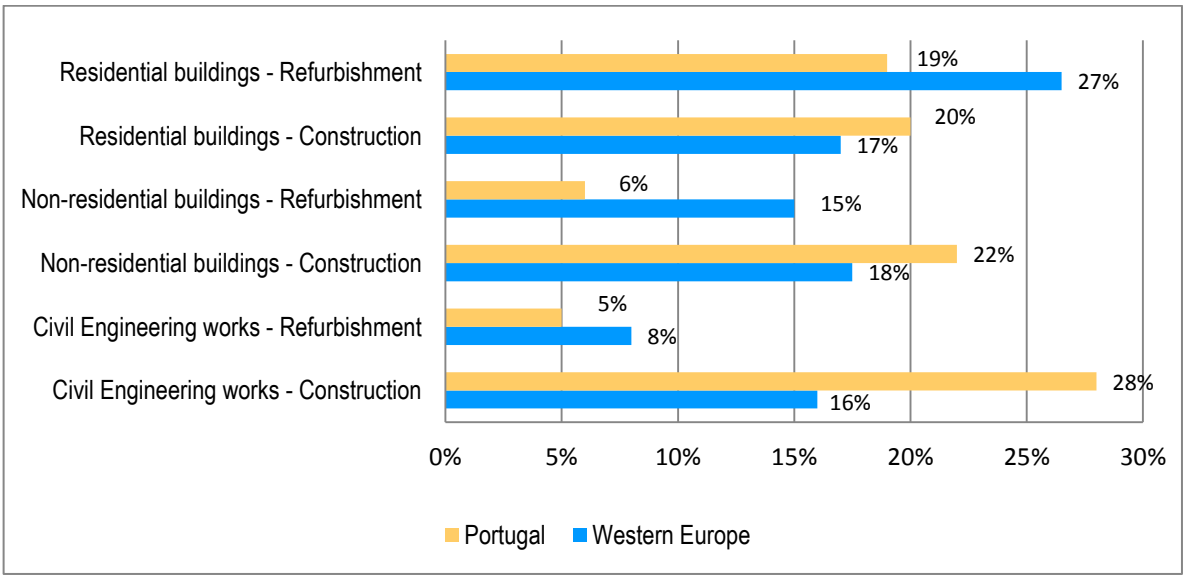


Fig. 2.1 – Weight of different construction segments Portugal and Western Europe, in 2010 [12]

Nevertheless, looking to the internal market it will be required the contraction and reconfiguration of some companies to attend the levels of activity and the segments that necessarily will have some investment.

It is predicted that by the end of 2013 the volume of investments in construction will stand near 8 billion euro, representing more or less 5% of the GDP [13] [14], representing more or less an activity contraction around 50%. This scenario is largely influenced by the absence of public investment [15].

2.2.4. Conclusion

A quick glance over the sector intended to raise awareness to the history, the importance, the difficulties and the opportunities of the AEC industry. The activity is global and many companies, even the smaller ones, will improve their skills to compete on this market. In which concerns the countries' economies there are different situations that vary from powerful economic growth to crisis scenarios [16]. Yet for both, the demands of the sector are similar, build more and better with less, being these less resources, money, effort, and time, among others.

To help accomplish these and other demands, several actions are being traced. Many of them are not construction exclusive, yet their deployment and adoption will contribute for the overall construction supply chain improvement.

The next point will address some of those actions. The focus will be the EU territory, knowing that the outcomes for the construction sector companies will be wider.

2.3. THE FUTURE OF THE INDUSTRY – TRENDS AND STRATEGIES

2.3.1. THE SITUATION

The AEC industry, as previously referred, lost the leadership for other activities, in terms of technological development. This situation occurred due to the economy's health that enabled construction to prosper without having to strive for innovation. There are also other often pointed arguments to distinguish construction from other activities. One of the most common is that it produces unique objects or prototypes. This statement is true, yet it cannot be seen as the main issue that drives construction to its identified problems. The complexity and heterogeneity of the industry, as well as the fragmentation of the production chain, have significant contribution [17]. However, an aspect that is extremely relevant is that there are few industries that think all the process without having very specific and definite ideas of the final product. Without this global vision there is no high level of control over the supply chain, over the different processes and its inherent costs in each stage, which can lead to misappropriated results. From the time of the "*Rethinking Construction*" report, written by Sir John Egan [18], that these issues where placed. Yet, the priorities were other and the progresses were few and nowhere near enough. New documents start to come now and one major question urges in the heads of many practitioners:

What will make the industry change now when it has failed to do so before?

There might be countless answers to this question that might vary from the belief that some things will change to the more sceptic vision that the industry will fail to perform even few changes.

The opinion is that some changes might occur due to the sum of problems (internal and external to the sector) that might put in risk the activity.

Some of the evidenced problems that haven't been pointed on this work are the shortfall of skilled workers in many companies, low attractiveness to young people due to the working conditions, limited capacity for innovation and the phenomenon of undeclared work [1]. From a wide point of view the current situation can be also characterized by three basic elements:

- The industry was one of the hardest hit by the financial and economic crisis;
- The increasing competition from non-European operators in international markets with conditions that many times are not fairly, and internal market competition, particularly on infrastructure projects;
- The new dynamics in terms of energetic and environmental objectives;

The strategies point to several demands at distinct levels, i.e., global economy, and construction industry global and local. If there is the ambition of amending the construction process making it "greener" in terms of effort, resources, environmental impacts, and at the same time improving the quality of the products, it will be necessary to have a very precise view of all the phases, actions, processes and agents, as well as a high level of knowledge regarding materials and technologies [19]. This requires improved management skills, technologies to support and integrate the supply chain and

its different agents and standards [20]. The information must be valid and cognizable by all, and adapted to meet the different needs across the construction life-cycle. Some EU strategic documents where explored from this point of view. The next point presents excerpts that were found more meaningful for the discussion scope.

2.3.2. EUROPE 2020

Europe 2020 is the EU ten-year growth strategy. It is geared not just to the overcoming of the crisis that continues to afflict many of the economies; it addresses the shortcomings of our growth model, creating the conditions for a different type of growth. The strategy focuses on priorities, flagship initiatives and targets. Many of them are connected with the construction industry. In what regards the different type of growth Europe 2020 demands the delivery of a Smart, Sustainable and Inclusive growth. A smart growth based on more effective investments in education, research and innovation; a sustainable growth thanks to a decisive move towards a low-carbon economy; and inclusive growth with a strong emphasis on job creation and poverty reduction. Each of these priorities has flagship initiatives that are supported by strategic roadmaps. These are:

- Smart growth
    - Digital agenda for Europe;
    - Innovation Union;
    - Youth on the move;

- Sustainable growth
    - Resource efficient Europe;
    - An industrial policy for the globalization era;

- Inclusive growth
    - An agenda for new skills and jobs;
    - European platform against poverty;

To measure the progress towards Europe 2020 goals, five headline targets have been agreed for the all Union. Other lower level or detailed targets should be defined by each nation. The targets for the EU on the year 2020 are:

- **Employment** - 75% of the 20-64 years-olds to be employed;
- **R&D** - 3% of the EU's GDP to be invested in R&D;
- **Climate change and energy sustainability** - greenhouse gas emissions 20% (or even 30%, if the conditions are right) lower than 1990, 20% of energy from renewables and 20% increase in energy efficiency;
- **Education** - reducing the rates of early school leaving below 10% and at least 40% of 30-34–year-olds completing third level education;
- **Fighting poverty and social exclusion** - at least 20 million fewer people in or at risk of poverty and social exclusion [21];

As referred, given the importance of the construction activity on the economies and given the presented targets, the sector will play indirectly a major role on Europe's transformation and it will contribute for many goals. Relevant topics from different roadmaps were quoted to support further discussion.

2.3.3. SMART GROWTH - DIGITAL AGENDA FOR EUROPE

Relevant topics:

- **A vibrant digital single market -** Making online and cross border transactions straightforward;
- **Interoperability and standards** - Effective interoperability between IT products and services to build a truly digital society. Understanding that to reap the full benefits of ICT deployment between devices, applications, data repositories, services and networks interoperability must be further enhanced;
- **Research and innovation -** Step up efforts and efficiency. Comprehensive research and innovation articulated with the "Innovation Union" roadmap, built on the European strategy for leadership in ICT. Focus on urgent needs to keep its competitive edge in this field and continue to invest in high-risk research, including multi-disciplinary fundamental research. Need to build innovative advantage in key areas through reinforced infrastructures and through the targeted development of innovation clusters in key fields. Development of a wide strategy on "cloud computing" notably for government and science [22] [23];

2.3.4. SUSTAINABLE GROWTH - AN INDUSTRIAL POLICY FOR THE GLOBALIZATION ERA

Relevant topics:

- **Improving framework conditions for industry -** Competitiveness-proofing and implementing smart regulation;

  "Despite a well-developed body of EU legislation and regulation, there is still significant scope for better regulation at the European and the national level. Increased and more systematic efforts need to be made by Member States to reduce administrative burden, to pursue better regulation and e-government policies, to apply the "think small first" principle and to simplify support schemes. The exchange of best practice among policy makers can allow policy objectives to be achieved in less burdensome ways."

- **Strengthening the single market –** Standardization;

  "Standards need to become an integral part of research and policy development from the outset. The efficiency and effectiveness of European standardization must be optimized, by fostering stronger structures for harmonized standards, improved standard setting processes at all levels and rapid adoption of the best available global standards, where global standard making practices are well established such as in the ICT sector. Standards should not create an additional burden, e.g. to Small and Medium Enterprises. Instead, they should lead to efficiency gains and act as an incentive for innovation."

- **A new industrial innovation policy** - Industrial innovation;

  "*Meeting the challenges of global competition and increased sustainability requires the achievement of excellence in innovation. European industry must also strengthen its knowledge base to remain competitive, investing in research and innovation for a smart, sustainable and inclusive economy."*
  "Since 2004, that Commission has supported the creation of European Technology Platforms to bring industry stakeholders together at EU level, develop a shared vision on R&D, and encourage feedback on EU policies."
  "Improve the use of ICT for industrial competitiveness, resource optimization and innovation."
  "More innovative use of ICT throughout industrial value chains needs to be encouraged to streamline business transactions."

The two last quotes should be developed in close contact with the definitions set on the Digital Agenda roadmap.

- **Promoting industrial modernization -** Resource, energy and carbon efficiency;

  "Review the Sustainable Consumption and Production / Sustainable Industrial Policy and consider the possible extension of the Eco-design Directive to new products (2012)."
  "Foster closer coordination between policies for environmental technologies to maximize synergies and complementarities in technology deployment, including policies for boosting demand, in particular in eco-innovation."

- **A targeted approach -** Tackling societal challenges

  "The construction sector can also make a substantial contribution to respond to climate change and other environmental and societal changes. The revised Directive on energy performance in buildings sets the ambition of the transition to nearly zero energy buildings in Europe as of 2021, whilst the reinforcement of the energy performance requirements will set new standards for buildings. This is an opportunity for the construction and renovation sector." [24]

2.3.5. SUSTAINABLE GROWTH – STRATEGY FOR THE SUSTAINABLE COMPETITIVENESS OF THE CONSTRUCTION SECTOR AND ITS ENTERPRISES

This document arises from the finding of the need for specific strategies for some industries. In paragraph 8.3 of the roadmap for an industrial policy for the globalization era, comes the following quotation:

> *"EU will develop a strategy for the Sustainable Competitiveness of Construction to ensure appropriate framework conditions for the Internal Market of construction products and services, improve resource efficiency and environmental performances of construction enterprises, and promote skills, innovation and technological development to meet new societal needs and climate risks."*

The following parts were considered the most relevant for this scope:

- **Stimulating favourable investment conditions** – section 3.1.2;

  "Identification of technological gaps in construction value-chain. Development of an action plan to address these gaps."

- **Improving the human capital basis –** section 3.2.2;

  "Partnerships for vocational education and training schemes at national and regional levels to respond to current and emerging needs of the construction sector, in particular in the field of ICT."

Performed in close articulation with the roadmaps "An agenda for new skills and jobs" and "Digital Agenda for Europe", these parts worth highlighting:

- **Improving resource efficiency, environmental performance and business opportunities -** section 3.3;

  "Mutual recognition of risk assessment methods taking into account environmental performance, in particular within the context of EU standardization activities and insurance schemes."
  "EU wide life cycle costing (LCC) methodology for buildings for Green Public Procurement."
  "Increasing the use of Green Public Procurement in regional policy in coming programming period."
  "Harmonized rules on the declaration of the performance characteristics of construction products in relation to a sustainable use of resources."
  "Evaluation of the performance of construction sub-sectors in terms of competitiveness and sustainable development at national and regional levels."

- **Strengthening the Internal Market for Construction** - section 3.4;

  "Fitness checks" of EU legislation to identify excessive administrative burdens, overlaps, gaps, inconsistencies and obsolete measures." [1]

All the referred topics on this and on the other documents have reflections on training and skills and therefore on the Inclusive growth roadmap for "An agenda for new skills and jobs". Due to this, the target will not be further explored.

2.3.6. SUSTAINABLE GROWTH – PORTUGUESE COMMITMENT FOR THE SUSTAINABLE COMPETITIVENESS OF THE AEC INDUSTRY

This document [25] intends to be the first national and targeted approach on the implementation of the principles set by the EU level reference document that was explored on the previous point. It aims the implementation of policies that can stimulate in short term the growth and employment, performing not only a rebound on the present situation, but also launching the main ideas for the sector restructuring. The document has fifty two measures that are organized on seven main targets. These are:

- Promotion of employment and skills;
- Improvement of the access to finance and promotion of private investment;
- Promotion of a public investments structural policy;
- Business innovation and internationalization encouragement;
- House renting and urban rehabilitation streamline;
- Promotion of the reduction of administrative costs;
- Promotion of the sector environmental sustainability;

The measures that were found directly related with the research topic are the following:

- Promotion of employment and skills:

  Promote, through training, the reorientation of professionals to areas defined as strategic for the AEC sector, particularly on urban regeneration, sustainable construction and energy efficiency.

- Business innovation and internationalization encouragement:

  Develop an Economic Diplomacy with the objective of recognizing the weight, the importance and specific needs of the AEC sector.
  Evaluate the creation of a national competitiveness and technology cluster.
  Support the implementation of programs towards the "Low Carbon Economy".

- Promotion of the reduction of administrative costs:

  Publish the standards work breakdown structure and construction specifications for different types of construction, for a more accurate definition of the construction works base price, namely under the scope of the ProNIC project.
  Enshrine the mandatory use of standard forms for contract documents, by types of construction.
  Develop a building code with the entire technical legal framework applicable to the construction activity.

- Promotion of the sector environmental sustainability:

  Promote the efficient management of resources, namely buildings energy efficiency and environmental performance improvement.
  Promote research and innovation activities geared for sustainability requirements and efficient management of resources, namely buildings energy efficiency.

Develop standard indicators, codes and methods for the environmental performance assessment of the equipment, products, processes and construction works.
Develop standards on the characteristics of construction products, oriented for the use of materials, durability and environmental compatibility.

2.4 CONCLUSIONS

This chapter presented an overview of the importance of the construction industry. The present situation in different economies, the opportunities and internal problems of the sector were explored. Detailed look was given on the Portuguese situation.

The general lines of worldwide strategies and in particular the EU strategy for the next decade was as well explored. The targets that directly or indirectly may have contact with the AEC were studied and the main lines from different documents that are relevant for the research topic were presented for discussion on the following chapters.

3

STATE OF THE ART – STANDARDS, REGULATION AND TECHNICAL REFERENCES

3.1. CHAPTER OVERVIEW

This chapter presents and explores broadly the main technical documents that address to the research topics, i.e. construction management, technology and information. Remarks for the discussion topics are highlighted.

3.2. STANDARDS AND LEGAL FRAMEWORK

3.2.1. ISO 12006 - BUILDING CONSTRUCTION — ORGANIZATION OF INFORMATION ABOUT CONSTRUCTION WORKS

The ISO 12006 family results from the work developed by the Technical Committee ISO/TC 59, Building construction, Subcommittee SC 13, Organization of information about construction works, and it is composed by two standards:

- Part 2 – Framework for classification of information [26];
- Part 3 – Framework for object-oriented information exchange.

The development of these standards came in the sequence of the production of a Technical Report, designated International Technical Report ISO/TR 14177:1994 [27] that resulted from a discussion on CICS that will be explored on point 3.3.

The ISO 12006 are considered the group of the most important documents in terms of organization and classification of information in construction. Its terms and definitions play also an important role for the mutual understanding of the different concepts.

This standard has the ambition of, respecting the differences in terms of technologies, materials, culture and legislation, establish a set of common and general principles based on Table titles supported by definitions to fit different needs. It does not have the intention of providing a complete operational system. Hence, it defines the generic roadmap to the CICS evolution, leaving open field to suit to local needs. National classifications can be difficult to change and there may seem insufficient reason to do so. The most widely used classifications are work sections (namely for specifications) and elements (mainly for cost analysis). They are also the most widely varied, not only in their itemization and structure but also in the range of purposes to which they are used. There are other classifications,

potentially just as important, which have not yet been used to the same degree, e.g. construction products and properties/characteristics [26].

The Annex A of the standard presents seventeen tables for information classification, presenting examples of titles and headings, without being exhaustive. The following table presents the table titles:

Table 3.1 – Tables and Titles from ISO 12006-2:2001 [26]

Table	Title
A.1	Construction entities by form
A.2	Construction entities by function
A.3	Construction complexes
A.4	Spaces by degree of enclosure
A.5	Spaces by function
A.6	Construction entity parts
A.7	Elements
A.8	Designed elements
A.9	Work results
A.10	Management processes
A.11	Construction entity lifecycle stages
A.12	Project stages
A.13	Construction products
A.14	Construction aids
A.15	Construction agents
A.16	Construction information
A.17	Properties and characteristics

It worth also referring few of the most important terms for the present work:

- **object** - any part of the perceivable or conceivable world;
- **construction object** - object of importance to the construction industry;
- **construction result** - construction object which is formed or changed in state as the result of one or more construction processes utilizing one or more construction resources, e.g. asphalt surface;
- **construction entity** - independent material construction result of significant scale serving at least one user activity or function, e.g. Building, bridge, road, dam, tower;
- **construction complex** - two or more adjacent construction entities collectively serving one or more user activity or function, e.g., airport, sewage treatment works, business park;

- **element** - construction entity part which, in itself or in combination with other such parts, fulfils a predominating function of the construction entity, e.g., external wall, floor, roof, foundation, column;
- **work result** - construction result achieved in the production stage or by subsequent alteration, maintenance or demolition processes;
- **construction process** - process which transforms construction resources into construction results;
- **construction product** - material construction resource intended for incorporation in a permanent manner in a building or another construction entity;
- **construction agent** - human participant in a construction process [26].

The technical revision process of ISO 12006-2 is undergoing and it aims the implementation of the lessons learned from 2001 until the present moment. There are several inputs that are related with the development of new CICS and with the update of others towards the main principles of the standard. Also, the scope is now more addressed to the all project life-cycle and to the developments and implementation of information technologies, namely BIM and modern forms of procurement. The new Standard will try to look forward in terms of information management and speed up the information management and search by extending some tables and simplifying their number [28]. It is known that the most used tables continue to be those addressed for Work Results (mainly for specifications) and Elements (mainly for cost analysis). Others more related with Construction products and Properties might be as important as the others. Nevertheless, they are less used. One of the reasons might be related with the existence of other systems construction non-exclusive. This topic and its impacts will be further explored on the following points.

The revision of the standard is, as mentioned, essential to BIM implementation because of the information requirements, namely the use of the construction object classes and the free exchange of information of all types, all along the project time line, and between all participants and applications [29].

This revised standard will provide updated main principles for worldwide construction classification systems, allowing the development of further work towards new versions and envisaging an easier and improved cross referencing of information within the country and beyond national barriers [30].

3.2.2. ISO 21500 - GUIDANCE ON PROJECT MANAGEMENT

ISO 21500:2012 is the international Standard that provides generic guidance and high-level description on the concepts and processes of project management, that are considered important for and that have impact on the projects achievement. It was prepared by the ISO/Project Committee 236 – Project Management [31]. The standard identifies as target readers the:

- *"Senior managers and project sponsors so that they may better understand the principles and practice of project management to facilitate providing appropriate support and guidance to their project managers and project teams";*
- *"project managers and project team members so that they may have a common base of comparison of their project standards and practices with those of others";*
- *"developers of national or organizational standards for use in developing project management standards, which are consistent at a core level with those of others"* [32].

Beyond the concepts and processes it sets out terms and definitions that are also essential for a mutual understanding and that should be carefully followed. Some of the most important and more used on the present work are the following:

- **project life cycle** - defined set of phases from the start to the end of the project;
- **stakeholder** - person or organization that can affect, be affected by, or perceive themselves to be affected by any aspect of the project;
- **tender** - document in the form of an offer or statement of bid to supply a product or service usually in response to an invitation or request;
- **work breakdown structure dictionary** - document that describes each component in the work breakdown structure;
- **project** - A project is a unique set of processes consisting of coordinated and controlled activities with start and finish dates, undertaken to achieve an objective. Achievement of the project objective requires deliverables conforming to specific requirements, including multiple constraints such as time, cost and resources. Although many projects may be similar, each project is unique as differences may occur in the deliverables provided by the project; the stakeholders influencing the project; the resources used; and the way processes are adapted to create the deliverables [32].

This standard is not specific for construction. Yet, its main principles are defined to be applicable to all sectors.

3.2.3. ISO 22263 – Organization of information about construction works — Framework for management of project information

The ISO 22263:2008 is the standard that specifies a framework for the organization of project information (process-related as well as product-related) in construction projects. It is a construction specific standard that aims the specification (on a higher level of detail) to facilitate control, exchange, retrieval and use of relevant information about the project and the construction entity. It is meant to be used by all agents involved on construction life-cycle and it gives examples of activities, inputs and outputs for the construction phases [33]. It is geared to the complement of the project management main principles approaching on the specificities of the AEC industry.

The recent review of ISO 21500 and the ongoing revision process of ISO 12006-2 will lead to this standard revision as their terms and contents are related.

3.2.4. Portuguese Public Procurement Code

A Government in order to acquire some service or work, namely construction works, needs to contract in accordance with the legal framework. In Portugal, until 2008, there were several legal diplomas that need to be followed according to the type of procedure and service or good. In what concerns construction works, there were two main diplomas, the Decreto-Lei nº 59/99, of March 2nd [34] and the Decreto-Lei nº 223/2007, of August 9th [35]. There were also several other loose laws and prescriptions related with technical aspects and public procurement.

During 2008, important changes were introduced on the regulation of public contracts. A new diploma was published and it was designated as Public Procurement Code – CCP (Decreto-Lei n.º 18/2008 of January 29th) [36], transposing EU legislation under the Directives 2004/18/EC [37] and 2004/17/EC [38] to Portuguese regulation. Most of the previously mentioned prescriptions were withdrawn, and

included on the CCP or gathered in other new and specific legal documents. The new diploma is applicable to all the public contracts of goods, services and public works. Associated with this document others were produced. It worth's mentioning those that are geared for construction works. The most important of them is the Portaria n.º 701-H/2008 of July 29th [39], that sets the rules for the design phase documents.

The publication and implementation of the CCP, as well as the attached legislation, contributed to the definition of many aspects fostering, among others, the role of each actor during the projects life-cycle. In what concerns construction industry, the provisions were addressed mainly to the design and construction phases [40].

The CCP provides different types of procurement procedures that depend of the nature and value of the contract. For public construction works one of the most used situations is the public competition procurement procedure. This has the following documental requirements:

- Tender notice, according to the template provided by Portaria n.º 701-A/2008 [41], published in the Portuguese Republic Electronic Journal and the Official Journal of the European Union (specific situations related with the value of the contract – international competition);
- Procedure parts comprising:
  - Procedure program – document that sets the terms and rules for contractual clauses.
  - Contract Specifications - set of documents containing the provisions and clauses to be included in the contract in what regards its implementation. The following elements are mandatory:
    - legal and administrative provisions, that may be prepared in accordance with the form defined in the Portaria n.º 959/2009, August 21st [42];
    - detailed/technical specialist design, according with the provisions set by Portaria nº 701-H/2008.

All the detailed/technical designs from the different disciplines must be formed by:

- Project memory, descriptions and justifications;
- Design calculations;
- Detailed measurement sheets and BoQ with detailed presentation of the works to be performed, its measurement criteria and quantities;
- Budget estimate, based on the BoQ and unitary prices;
- Drawings;
- Technical specifications [39].

It worth's mentioning that from this process of adaptation of the Portuguese public procurement procedures towards the EU Directives, Portugal became the first country to implement electronic procurement on public contracts [43]. This determination led to several opportunities and many difficulties that were overcome. Among them, the commitment of the communications sector was determinant, contributing with improvements on the internet infrastructure to support the needs. Nowadays, there are several electronic procurement platforms operating, and are responsible for a significant percentage of public and private procurement processes. All report to a single database, managed by the Government that publishes all the contracts.

One of the underlying goals of this framework is the possibility of improving the tracking and monitoring of the sector activity. The Observatório das Obras Públicas [44] is an instrument that is tutored by InCI [45]. Its constitution and operation rules are defined by Portaria nº 701-I/2008 [46].

With this authority is intended, as stated in the legal document:

"constitute a system based on a large database, continually expanded and updated, with the possibility of processing information for the monitoring of the public works contracts procurement and construction phases, thus contributing to a better knowledge and transparency of the sector" [46].

Within this authority jurisdiction is the collection, processing and dissemination of data regarding the two referred phases. These elements, which should be provided by the contracting authorities, include data for statistical analysis and, with respect to each work, the development of two key documents:

- the contract report;
- the final report of the work.

The forms for data record and for the report preparation are defined by Portarias nº 701-D/2008 and nº 701-E/2008 [47] [48].

All the referred topics and requirements cut across the entire construction process, from the design to construction stages, implying more responsibility from the different practitioners. In general, the application of the CCP raises new needs particularly in the aspects related with:

- Technology for the electronic communication, exchange and storage of data, obeying to requirements of simplicity, integrity, security and transparency;
- Methodologies to support and streamline the dispatch of design to competition (implementation of e-procurement on all the procedures);
- Specifications in formats that allow the creation of simplified interfaces in electronic systems (electronic procurement platforms);
- Production of more completed technical documents, foremost defined in terms of work and quantity, to limit the problems of vagueness during the procurement and construction phases. Within these documents are included drawings, written parts (technical specifications), detailed measurements and BoQ;
- Wider distribution of responsibilities embracing all the agents throughout the construction process;
- Preparation of more stringent budget estimates;
- Development of processes that enable an effective monitoring of the sector at various levels [40].

3.3. CLASSIFICATION SYSTEMS

3.3.1. OVERVIEW

Classification Systems are methodologies based on common relations or affinities that are used as a guidance or roadmap on many different subjects. Moreover, the definition of a classification fosters the organization and standardization as it enables the stabilization of terms, methods and concepts.

Using pre-established terms, a classification is a spatial, temporal, or spatio-temporal segmentation of the reality. A classification system is a set of boxes (metaphorical or literal) into which things can be placed to perform some kind of work - bureaucratic or knowledge production. In an abstract, ideal sense, a classification system exhibits the following properties:

- Consistency - unique classification principles in operation;
- Mutual exclusivity of categories;
- System tends to be complete [49].

Complex issues may lead to the creation of relations based on a distribution of classes. Usually, classification systems define codes, numerical, alphabetical or alphanumerical, for the different classification classes, levels and, in broadly form, for objects.

One of the most familiar examples of the definition of different classifications is the human body; parts, systems, organs, among others.

Fig.3.1 – Result of classification systems applied to human body [50]

Since the beginning of the 20th century, many organizations related with the construction industry began developing classification systems for specific construction related issues [51]. The main objective was solving specific problems, most of them regarding the design phase. From construction materials to building works or measurement rules, several efforts were made by organizations of different countries. The construction industry can be rather different in some topics from country to country. This hampered a wide adoption of some of these systems [52]. Nevertheless, and as referred on chapter two, the AEC is so wide and complex in terms of resources and outcomes, that most of the developed classifications quickly began to evidence disabilities to answer to slightly different situations from the initial focus ones. Some of the most successful systems were the Standard Filing System and Alphabetical Index, the CSI Format for Building Specification, the UCI and the SfB, later reshaped and renamed CI/SfB [53]. This will be explored in more detail on the following points.

The growing need for wider and more effective CICS, led to an international reflection about the subject. The need to combine efforts and know-how to develop/define wide and multi-country base points, took this issue to CIB. Later, a joint effort with ISO, allowed the publication of the International Technical Report ISO/TR 14177:1994 [27]. The activity of the group continued and ISO 12006-2:2001 came up. The revision process of this standard is undergoing, as it was mentioned.

Other classifications non-construction exclusive must be known and integrated as much as possible, has their role is substantial in some processes. Some of them are related with e-business and transaction of products and services. These activities belong to a very dynamic market, with a different pace when compared to the AEC in terms of production. Some of the most prominent classifications are the CPV [54], eCl@ss, GS1 or UNSPSC. They are not compatible with each other. What was previously referred for the CICS's is repeated in this specific situation. Confronted with the growing adoption of several different systems, ISO fostered a large study to look deep into each one of these classifications [55].

One example of other classifications more geared for statistical purposes is the CC-EUROSTAT [56] or the Portuguese adaption CC-PT [57], that pertain the classification of works, by types of construction.

The following points will present some general lines of some of these classification systems.

3.3.2. CI/SfB - Classification Index/SfB

This classification system is one of the ancient and most widely used by the construction industry. It was has its roots on the Swedish SfB, developed on the late 40's of the twentieth century. During the 60's a new version was developed by RIBA [53] [58].

In terms of structure it consists of five tables that cover [59]:

- Table 0 – Physical Environment (wide range of building typologies);
- Table 1 – Elements (standard classification of building elements);
- Table 2 – Construction Forms (classifies main construction forms);
- Table 3 – Materials (classifies materials that form a product);
- Table 4 – Activities, requirements (functional activities and product characteristics);

This CICS is specifically geared for products and building elements.

It has several applications from project information coordination to office libraries, passing through checklist for collection and storage of briefing information, outline technical specifications for preliminary budget estimates and building regulation approval.

It is mainly used by small and large architectural firms or by quantity surveyors, engineers and contractors, with multiple purposes.

It provides a satisfactory mean for structuring sets of detailed design drawings, working drawings and specifications.

The classification of general information using the CI/SfB is simple. Yet, the system was created before the existence and use of current technologies, including the simple use of a computer on a day-to-day basis when working in construction and project processes [60].

With the intention of superseding the CI/SfB it was structured a team to develop a new system. This aimed to perform an update on the themes, industry developments and concerns that were not reflected, namely the notation change towards computerization and the expansion of the number of tables to other themes or visions [61]. This system would be called Uniclass.

3.3.3. EPIC - ELECTRONIC PRODUCT INFORMATION CO-OPERATION

EPIC as its roots on the European discussion about the need for co-operation between European product information houses on the development and operation of databases for building product information. This occurred in London, in 1990, on a meeting promoted by RIBA that gathered representatives from ten countries, among them Belgium, UK, Sweden, France and the Netherlands [60].

It was designed to be a common reference system to the European construction industry for access to product information across national boundaries. The first version was edited in 1994 and it was a system based on the ISO Technical Report [27]. Later, a new version adapted to fit the ISO 12006-2 philosophy. It provided a common basic structure for product databases and for international communication between national databases.

In terms of structure it is a faceted system that classifies one specific product according to his:

- Role - that is the product performance/role within the construction;
- Shape - that is the mode in which the product arrives to the construction yard;
- Material - that is the product main material (wood, steel, sand,…) [62] [63].

The relation of these three properties defines and classifies the generic material. The classification is alphanumeric as the "role" table has alphabetical classification (from A to N) and the others are numerical. The product classification is achieved through a letter and a sequence of numbers [62]. Later, this system was integrated as a table of Uniclass. Also, other systems non-construction exclusive were developed based on EPIC contents.

3.3.4. UNICLASS AND UNICLASS 2

3.3.4.1. Uniclass - Unified Classification for the Construction Unit

Uniclass is a classification system based on a number of high level classifications. It comprises fifteen tables that address different broad facets of construction information. It is used for the organization of many different forms of information, including documents in libraries, project information, cost information and specifications. Each table can be used to classify a particular type of information or combined with others. Uniclass covers a significant part of the construction industry. It is the result of a three-year project that aimed the unification of classifications used in the UK. Has its roots on the already mentioned work performed by ISO and its first publication was in 1997. It aggregates, harmonizes and updates several smaller systems, some of them already referred, like CI/SfB, CAWS, CESMM3 and EPIC. It was developed by a committee that gathered the UK's Construction Confederation, RIBA, RICS, the Chartered Institution of Building Services Engineers and ICE.

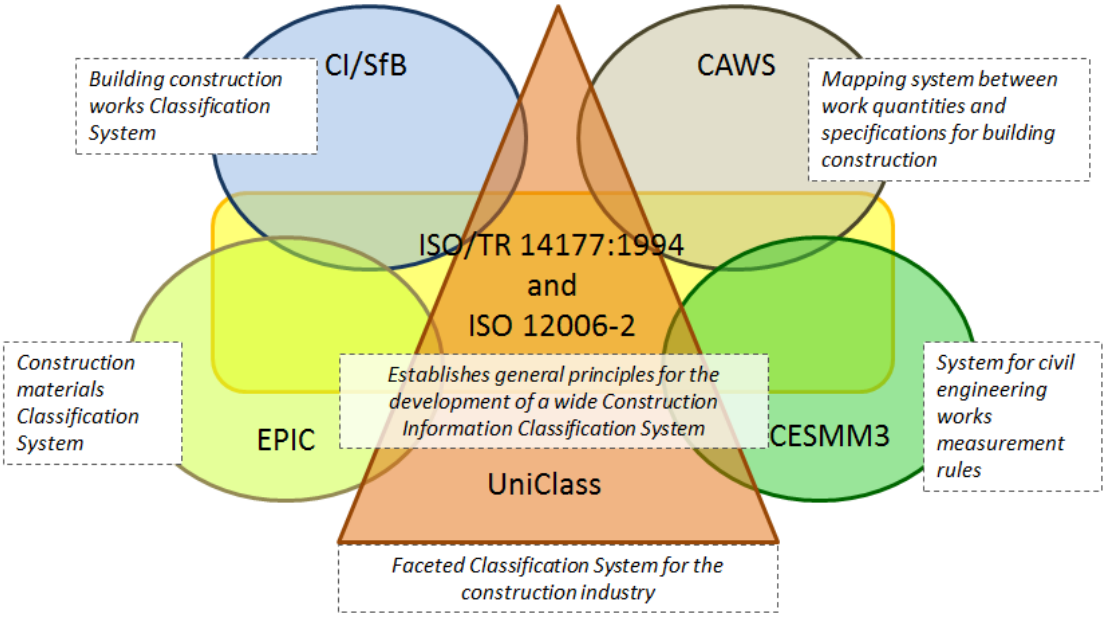


Fig.3.2 – Uniclass influences [64], by Pedro Mêda

From the first publication until present days, several updates have been performed [61].

3.3.4.2. Uniclass 2

UK is raising the bar of the construction industry. One of the major decisions is the adoption of BIM for information management from concept to demolition, thus requiring the ability to properly share information with all the stakeholders during the entire life-cycle. In order to fulfil this requirement, the information needs to be organized by all the interested parties using the same structure, which means a unified approach to classification. One other aspect is related with the logic sense of the information development at each phase of the life cycle of any construction project [65].

The UK standard classification presently in use is Unicalss. This system provides an overall satisfying framework, however, it is not perfect, seeing as there are topics involving the use of multiple tables that are not correctly mapped. Unification of Uniclass must be performed in order to meet the new needs. Uniclass is aligned with ISO 12006-2:2001. Yet, as referred, this standard is being reviewed to account for the use of BIM methodologies, although the timeline defined by the UK Government might not be compatible with the release of the revised version of ISO 12006-2.

Parallel work is currently ongoing to address this issue and there are very interesting results being published every day [66]. Given the importance of this system for the theme in discussion and for the BIM strategy, that will be later explored, it was found useful to perform a brief evaluation of the current status of the development of the system.

The Uniclass working group responsible for the Uniclass 2 development was established in 2006. Since then it has been considering the proposals of very different entities and verifying the background information regarding previous CICS developments. The first set of results (Stage 1) consisted on the release of a new Table, Z, for CAD, an online layer-generating tool for AutoCAD DWG and Bentley

MicroStation DGN CAD systems, and the development of an online classification request tool. The Stage 2 embraced the overhaul of Uniclass based on the following proposals:

- **Scope:** All Tables will cover architecture (buildings and landscape), and civil and process engineering.
- **Coding**: All Tables will use numeric coding below level 1. This means that the alphanumeric CAWS codes (e.g., H45) will continue. Coding for level 1 (Tables) will be revisited, but may be numerical also. All level codes in all Tables will be double-digit, potentially from 00 to 99.
- **Depth**: All Tables will have four levels, where possible, and five levels otherwise. The four levels would be the "Table" (e.g., Ee), the "Group" (e.g., 30), the "Subgroup" (e.g., 65) and the "Object" (e.g., 88).

An object code might then be Ee-30-65-88, for example [67]. The process lead to the definition of the Tables presented in Table 3.2.

Table 3.2 – Tables and Titles on Uniclass2 [68]

Table	Title	Additional information
Ac	Activities	New on ISO 12006-2 and Uniclass
Co	Complexes	Replaces parts of Table D (facilities)
Ee	Elements	Replaces Table G (elements)
EF	Entities by Form	Replaces parts of Table D (facilities)
En	Entities	Replaces parts of Table D (facilities)
PP	Project Phases	New on ISO 12006-2 and Uniclass
Pr	Products	Replaces Table L (constr. products)
Sp	Spaces	Replaces parts of Table D (facilities)
Ss	Systems	New on ISO 12006-2 and Uniclass
WR	Work Results	Replaces Tables J and K
Zz	CAD	New on ISO 12006-2 and Uniclass

At present time, many tables are available on their final version or still in elaboration/revision process. Tables Zz and PP are closed. The tables Co, En, Ac, Sp, EF, Ee, Ss and Pr have different 2013 versions. The WR Table is the most extent and complex to perform. There was a version released on February 2013 but due to the discussion that raised it was withdrawn. This Table has the intention of gathering Work Results from Buildings and Landscapes, taking advantage of the Uniclass table J (CAWS) and Civil Engineering works using Uniclass table K (CESMM3) [69]. On last December it was released the Uniclass 2 latest revision. Table WR is not on the current release and it will continue to be worked. The release of this version is useful to identify and set compatibility problems with previous systems and documents. Nevertheless, the production of the WR table is the ultimate effort as, in essence, it was the primary subject that motivated the CICS rise.

3.3.5. UNIFORMAT II

UNIFORMAT II is a single table classification framework that intends to provide references for the description, economic analysis and building management during all the phases of the construction life cycle. It is composed by 4 levels that endorse to major components (construction elements) common to most buildings and site work. Uniformat II results from the extension and update of Uniformat. It was released in 1997 and it was accepted as an ASTM standard. It was developed by AIA and GSA [70]. Several updates have been performed since then. It is a very simple classification system and because of that, it is applicable to a narrow spectrum of construction entity types. It is mainly used on houses and residential buildings. The first updates extend its application to service buildings. Code set of Uniformat was adapted in 2008 to establish relationship with the code system of Masterformat. Sitework was expanded in order to answer to other construction entity types (roads, railroad, others), as well as the new division Z – GENERAL [71].

3.3.6. MASTERFORMAT

Masterformat is together with CI/SFB the most successful CICS. It is composed by one table for work results, that lists titles and section numbers for the organization of data about construction requirements, products and activities. It aims the standardization of terms in order to ease up the communication between all the agents on throughout the construction phases. It was developed by CSI and CSC. The first publication comes from the 60's [72]. The most known versions that brought considerable changes were the 1995 and the 2004 versions [73]. Nevertheless, every year amendments are processed. The standardization of work results for buildings was the main objective. With the development of larger systems that use Masterformat on their tables (namely Omniclass), several updates have been performed since 2004, geared to the extension to other works.

3.3.7 OMNICLASS

Omniclass Construction Classification System was, until the development of Uniclass II the most recent CICS initiative with international scope. Its purpose is the organization of library materials, product literature and project information, to provide a classification structure for electronic databases. It has a wide scope and aims the classification of the entire industry. It was designed to work as standardized basis for organizing, sorting and retrieving information produced and used by the North American AEC industry. It covers all the life-cycle from conception to demolition and all the different types of construction or construction entities types that compose the built environment. It is constituted by fifteen tables, each one of them representing a specific facet of the construction. Many organizations collaborate on its development, with the coordination of CSI.

As many other systems, it is based on the main principles set out by ISO 12006-2:2001 and it incorporates contents from other (smaller) systems, like Masterformat, Uniformat and EPIC.

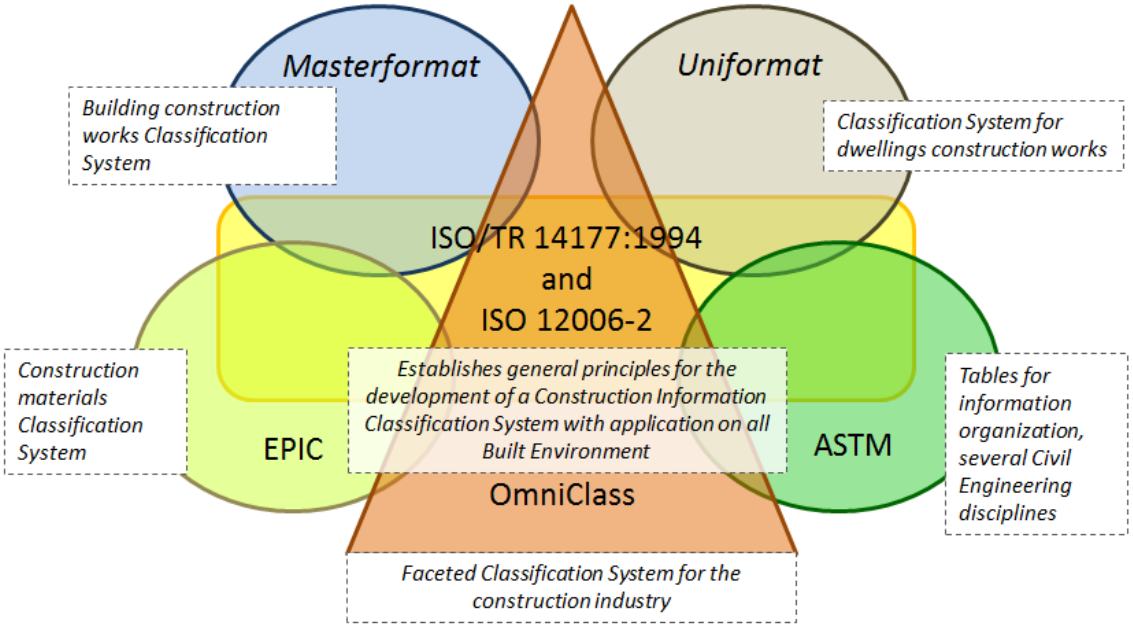


Fig.3.3 – OmniClass influences, by Pedro Mêda

Regarding the operation, it is very similar to Uniclass. It is structured with tables that can be used alone or combined. The information in each table is organized differently, being adapted to the needs and specificities of the construction on the United States. The fifteen tables of Omniclass organize the information as it follows [74]:

- Tables 11-22 – organization of construction results;
- Tables 23, 33, 34, and 35, and to a lesser extent 36 and 41, organization of construction resources;
- Tables 31 and 32, classification of construction processes, including the stages of construction entity life cycle.

The trends will lead Omniclass and Uniclass to become closer and closer. The developments regarding BIM implementation and ISO 12006-2 revision will be essential to the following updates.

3.3.8. CPV

3.3.8.1. Introduction

The Common Procurement Vocabulary is a mandatory classification system, constituted by a single table [38] [39] used for EU public procurement. It is construction non-exclusive and it has application on products, services and works. It consists of 9,454 codes structured in a five-level tree hierarchy. Each code is made up of nine-digits and a wording. The CPV is based on the CPA nomenclature. The first version of the CPV was published in 1993 and it has been revised extensively three times since then. The last version dates from 2008. Originally, the CPV was provided due to Commission Recommendations and its use was therefore only a recommendation to contracting entities/authorities when publishing contract/tender notices. Since 2002, the CPV has been embedded in the regulations and in 2006 the application of the CPV has become mandatory for tender notices [75]. Nowadays,

public procurement notices in the EU need to comply with the CPV. Other classification systems can be used in the descriptive parts of public procurement notices or in the tender documentation.

3.3.8.2. Structure and objectives

In terms of structure, it comprises two parts defined as the main and the supplementary vocabularies. The second has the intention of giving additional information about the products. It is not much used and thus, studies point to its withdrawn. Therefore, it won't be further explored. The main vocabulary consists of the previously numbered codes and follows a five level hierarchy leading to numerical codes with nine digits. The main level of information is the "Division" followed by "Group", "Class" "Category" and "Subcategory" [54].

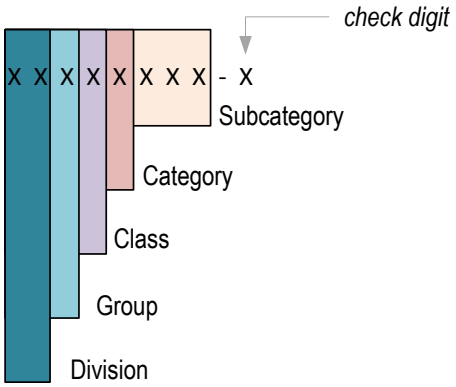


Fig.3.4 – CPV five level structure, adapted from [55]

Given the context of the present work, it is worth mentioning some of the CPV objectives:

"*The use of standard codes makes it easier to implement the advertising rules and facilitates access to information, thereby:*

- *boosting transparency in public procurement;*
- *making it easier to identify business opportunities published in the supplement to the Official Journal of the European Union;*
- *making it possible to set up an information system for public procurement and reduce the risk of error in translating notices, since the CPV is translated into 22 official languages of the European Communities;*
- *simplifying the task of drafting notices, and in particular describing the subject matter of contracts, for contracting authorities and contracting entities;*" [54]

Recent studies where performed to evaluate the CPV, by direct comparison with other similar systems [55] and to assess its functioning [75]. The results express some of the feelings already observed by the author, and that have direct implication on further developments using CPV. These will be further presented and discussed in the proposals and final remarks.

3.3.9. UNSPSC - UNITED NATIONS STANDARD PRODUCTS AND SERVICES CODE

The UNSPSC is a hierarchical convention (single table) that is used to classify products and services and has the purpose of enabling electronic commerce and providing the foundation for spend analysis. It is construction non-exclusive system. It was first developed in 1998 by Dun and Bradstreet as the proprietary code set called the SPSC. On the same year it was merged with the United Nations Development Programme's UNCCS. Nowadays it is managed under contract by GS1.

In terms of structure it is organized with four levels (segments, families, classes and commodities) with a code set of eight digits (two digits for each level).

Fig.3.5 – Example of toner UNSPSC code [55]

The segment represents the highest level of the hierarchy. There are fifty segments arranged according to a logical sequence that reflects big themes:

- Segments 10-15 – Raw Materials;
- Segments 20-27 – Industrial Equipment;
- Segments30-41 – Components and Supplies;
- Segments 42-60 - End Use Products;
- Segments 70-94 – Services;

This classification is available for free download in several languages (pdf documents) and there is a release policy of two updates each year. There is also a mechanism on UNSPSC site [76] that allows suggesting new items. The translations do not follow the new versions, so there are situations where a desired language corresponds to an older version. Yet, there is the guaranty of compatibility between versions and it is possible to call in a document (written in English) with the mapping process.

In terms of use, the UNSPSC is an open domain and royalty free code set. It is the dominant classification system embedded in software. Many software companies provide versions of this classification on their products.

Without being mandatory, this classification, given its structure, versioning dynamic and the release on worldwide used products, it is gaining importance and achieving high levels of use.

3.3.10. EUROSTAT CC AND INE CC-PT

3.3.10.1. Introduction

The Classification of Types of Constructions has its roots on the provisional version of the United Nations Central Product Classification that it was published in 1991. CC is designed to serve different purposes such as statistics on construction activities, construction reports, building and housing censuses and price statistics on construction work and national accounts. In addition, CC is to be used on the definition of constructions which will be needed for the provision of information for specific variables (e.g. building permits, production), concerning short term indicators. Also, CC is designed to be used for the whole construction life cycle, namely changes in use, transactions, renovations, demolition. [77] The CC development guidelines tried to follow the UN recommendations in this field, such as the definitions concerning the current housing and construction statistics for the countries of the UN region [78] and the recommendations for the 1990 censuses of population and housing in the EU region [79]. The most recent version of this classification is from 1998. It worth's note the reference of the CC presentation document that states:

"CC could be used as classification standard for the procurement and tenders on public works contracts initiated by the Commission." [77]

This role is being played by the CPV across all the economic fields of activity.

The Portuguese Classification of Types of Constructions derives from the CC. It was prepared by INE in collaboration with representative bodies from the construction industry and other economic activities. This classification goes to a detailed level of information and beyond following the previously mentioned recommendations it follows the main principles of other classification, the CNBS [80]. CC-PT was adopted in 2004, by approval of the Portuguese Statistical Council [81].

3.3.10.2. Classification principles and structure

CC uses four levels of information and the codification follows decimal system. The main level of information is the "Section" followed by "Division", "Group" and "Class".

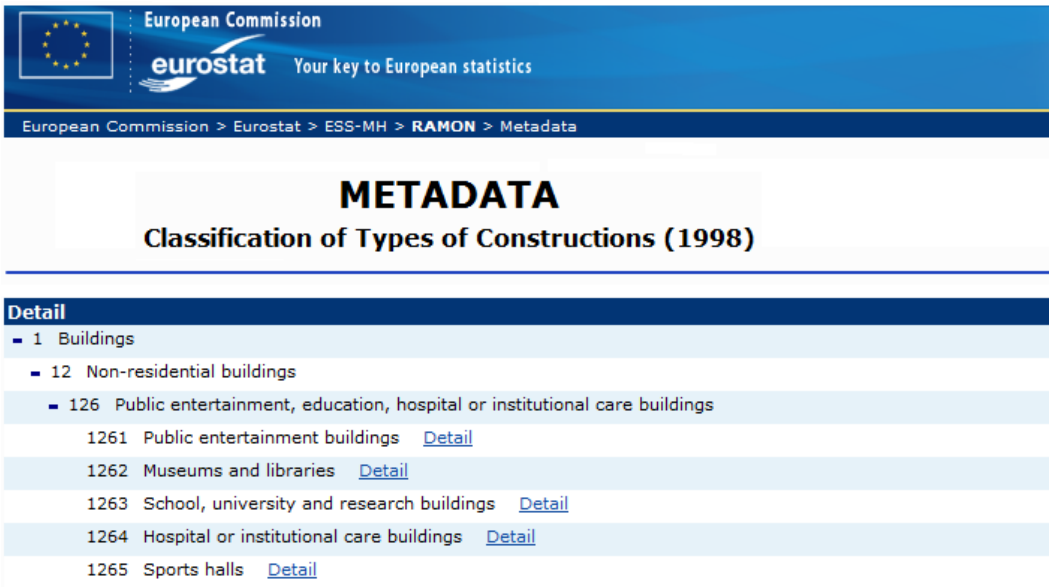


Fig.3.6 – Example of the CC four level structure [56]

There are two Sections, six Divisions, twenty Groups and forty six Classes, with codes from 1 digit to 4 digits. The first level "*Section*" subdivides constructions into "*Buildings*" and "*Civil engineering works*". Within these sections CC differentiates primarily according to the technical design which results from the special use of the structure (e.g. commercial buildings, road structures, waterworks, pipelines) and, in particular for buildings, according to the main use (e.g. residential, non-residential). The construction site, its ownership and the institution to which it belongs are considered irrelevant criteria for this classification and have not been taken into account, except in a few cases. The civil engineering works are mainly classified according to the engineering design which is determined by the purpose of the structure [77].

3.3.10.3. CC-PT main differences

CC-PT, as previously mentioned goes to a detailed level of information. It is therefore composed by five levels of information, in which the fifth level corresponds to the "*Subclass*". There is a full equivalence (code and designation) between both classifications on the higher levels, "*Sections*", "*Divisions*" and "*Groups*". The CC-PT number of classes is higher, yet they correspond exactly to the unfolding of the original ones.

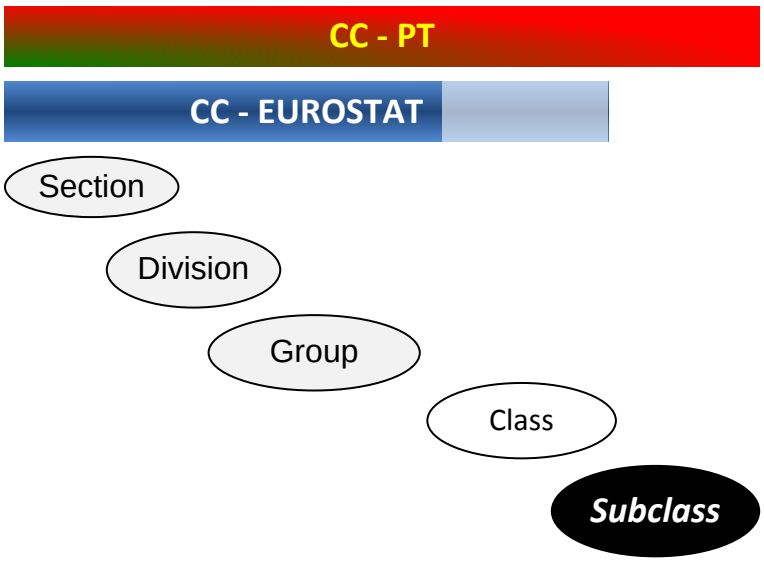


Fig.3.7 – CC-PT and CC structures, adapted from [57]

From the comparison performed, were identified thirteen differences on the "Class" level (forty six Classes on CC and fifty nine Classes on CC-PT). These differences reflect splits related with buildings, namely distinctions on:

- "Residences for communities" – CC_1130;
- "Other short-stay accommodation buildings – CC_1212";
- "Office buildings" – CC_1220;
- "Communication buildings" – CC_1241;

- Classes from "Public entertainment, education, hospital or institutional care buildings" – CC_126;

The Subclass level consists of two hundred and fifty nine items.

3.3.11. REMARKS

As it can be confirmed, there are many systems that have application on the construction industry. Most of them and namely those that were developed or that have versions after 2001 follow the main principles of the ISO standards. The CICS and others non-construction exclusive systems have a wide range of subjects and because of their use/application they follow specific principles on their lower levels. Yet, it is possible to state that there are intersections among them. Figure 3.7 as the intention of showing the potential intersections regarding most of the previous mentioned classification systems. The general organization is set by ISO and the systems are displayed by scope of application.

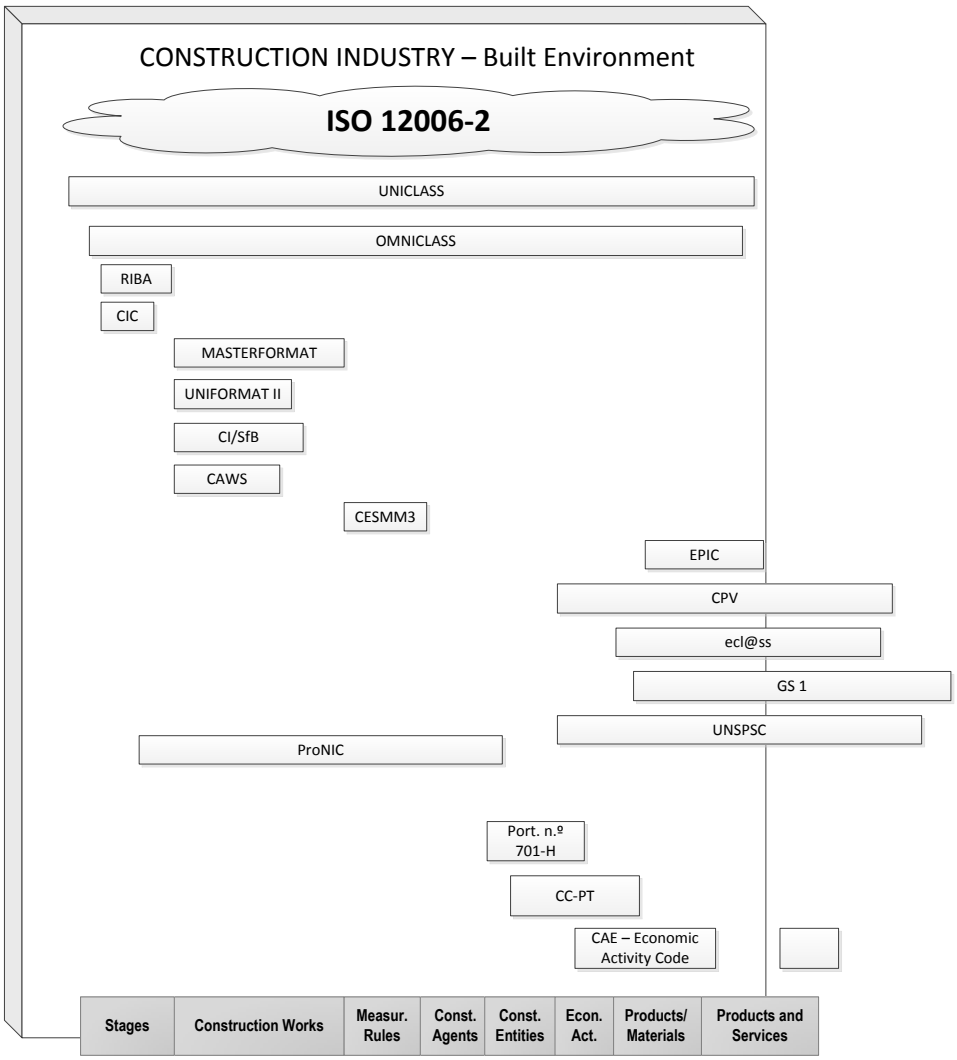


Fig.3.8 - Schematic overview of the classification systems related with construction

The proliferation of these systems and their individual development should be closely followed because of the influence they have on the construction production chain. The possibility of the aggregation or decommissioning of some of them must be studied. The closest relation between CICS and construction non-exclusive systems occurs at the level of the Products, Materials and Services, most due to procurement and acquisition needs. Like stated above, the lower level of implementation of CICS Tables related with "Construction products" and "Properties" might be related with the existence of these other systems.

Facing this, the relation/integration of the "Products" and "Materials" tables (among others) from the CICS with the topics of these classifications should be foreseen. Also, the development of these construction non-exclusive systems should look to the construction standards for the development of that specific part.

3.4. OTHER TECHNICAL DOCUMENTS

3.4.1. BS 1192 AND PAS 1192-2

BS 1192 [82] is the British Standard that sets the main lines and methods for managing the production, distribution and quality of construction information, including the one that is produced with CAD systems, using a disciplined process for collaboration and a specified naming policy. BS 1192 is applicable to all practitioners involved in the preparation and use of information throughout the construction supply chain and construction life cycle, from design to deconstruction. This standard comes from the times of simple drawing procedures to today's sophisticated object technology. One of the evidenced problems is that BS is driven for the UK construction reality. Yet, and although the Government sponsors its development, most of the companies state that it does not fit their needs and as so, they all develop individually their own standards with the same purpose [59].

PAS 1192-2 [83] is the result of an initiative that, among others, had the objective of set common understandings with wide application by companies, allowing the definition of concepts and contents for a future version of the BS 1192, for this to become a used and wide accepted reference. The production of this document was based on the actual version of BS 1192. It was sponsored by the CIC and authorized by the British Standards Institution. It involved many organizations (approximately twenty four) construction and Government related, that gave inputs and ratified all the produced information. One of the most important aspects that have influenced this development was the UK Government Construction Strategy that sets the adoption of BIM Level 2 by 2016. [2] Thus, PAS 1192-2 provides specific guidance for the information management requirements associated with projects delivered using BIM. Not all the information on a project will be originated, exchanged or managed in a BIM format. This information will also need to be managed in a consistent and structured way to enable efficient and accurate information exchange. On these, BS 1192 provides the details of the standards and processes that should be adopted to deliver these outcomes. Furthermore, and for the avoidance of doubt, all project information, whether in BIM environments or in conventional data formats should be shared using a single and common collaborative data environment, CDE [83].

3.4.2. RIBA PLAN OF WORK

The RIBA Plan of Work has been for the last half century a model for the organization of the process of managing, designing building projects and administering building contracts into a number of key work phases. The sequence or content of the work phases may vary or may overlap to suit the

procurement method [84]. The Plan of Work framework has served both the architects' profession and the wider construction industry well, but although it has been amended over time to reflect developments in design team organisation and alternative procurement arrangements, these changes have generally been incremental rather than strategically driven [85]. Given the wide adoption by architects and other practitioners in UK and internationally, the 2013 revision was faced as an opportunity to undertake fundamental reviews, ensuring the alignment with best practice from all the specialists within the integrated construction team, and to provide a renewed framework which will be fitted for purpose on the years to come.

One of the main concerns regarding the development of the new version was the mapping of the new Plan with the older version (2007) and with the phases defined by the Construction Industry Council, Figure 3.9.

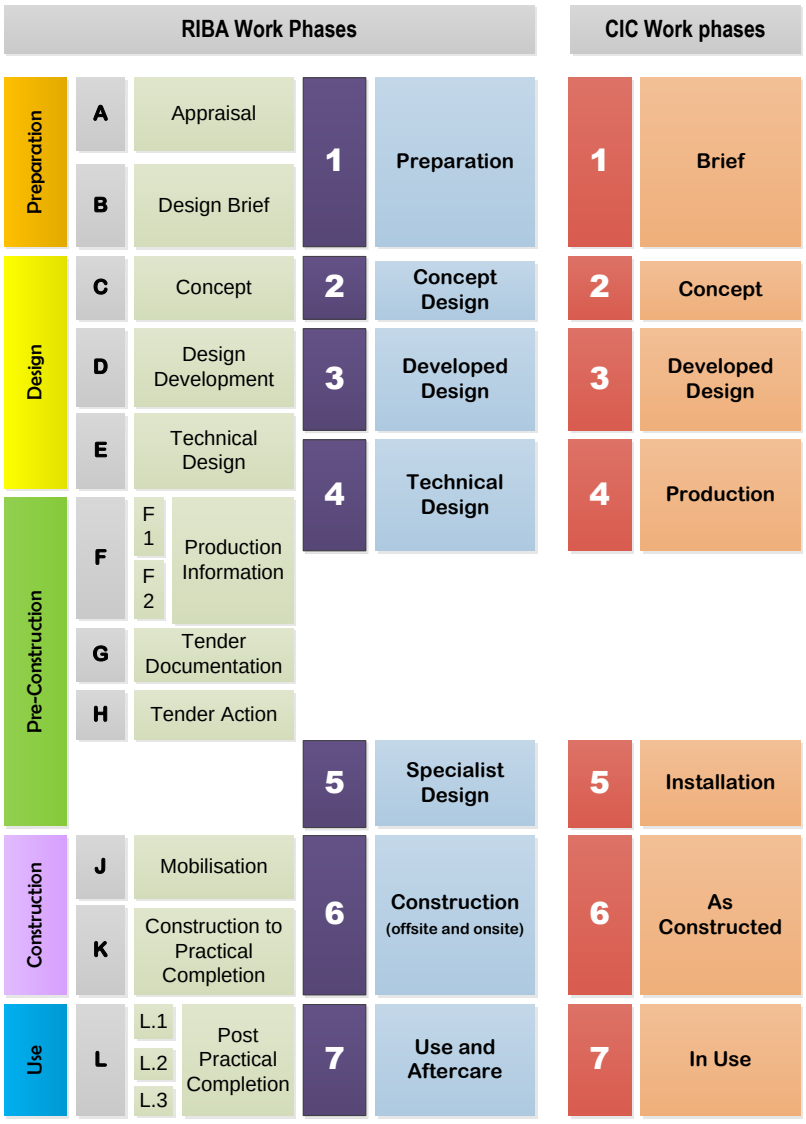


Fig.3.9 – Mapping the new Plan of Work, based on [85]

The revision team evaluated the 2007 version of the Plan of Work and found a very strong methodology for the phases A to D. Nevertheless, they have also found weaknesses that consisted on the interpretation ambiguity of phases E and F, the focus on the traditional procurement methods and the absence of emphasis on the whole life cycle. Other key issues that were found relevant for the revision were the following:

- Integration of the sustainable design philosophy;
- Mapping with BIM processes;
- Flexibility of planning procedures;
- Changes in the way building services design are delivered;
- The recommendations of the UK Government Construction Strategy;
- Straight forward mapping and flexibility provision for all forms of procurement.

The reviewers also attended to the use of the document. Because of that, the development considered the production of a Plan that could fit and be used within and outside UK and by the public and private sectors. In addition, the scope that was initially addressed for few building projects intends to be wider, giving answer to different project sizes and complexities. The strategic diagram for the 2013 Plan of work implementation is shown on Figure 3.9

This document is found very interesting, namely because it aims to summarize many requirements that are scattered across different strategic documents, standards, legislation, recommendations, among others. Yet, the performed analysis reveals that it lacks compatibility with some standards, namely those previously addressed. There is an effort on arranging the information on a friendly and attractive way, building empathy with the target practitioners. This streamlines the study, the understanding and the adoption of the principles. New versions should be more close and in line with the international references.

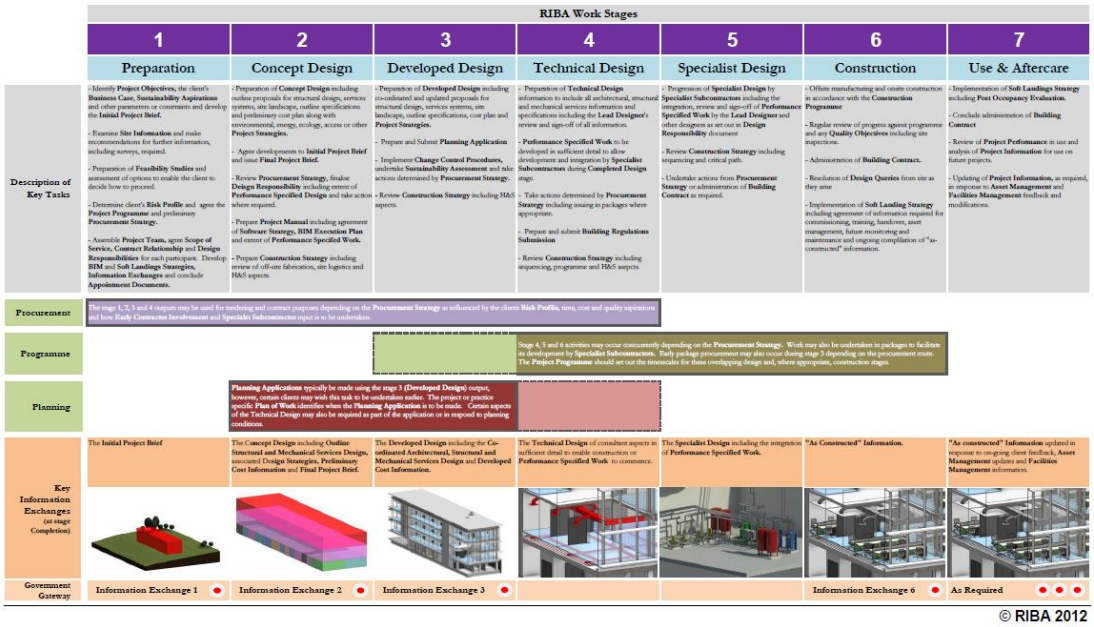


Fig.3.10 – Draft of the 2013 Plan of Work overall framework [85], Annex 1

3.4.3. CSI PROJECT DELIVERY – PRACTICE GUIDE

CSI has a large experience on the production of Manuals of Practice to aid owners, designers, specifiers, contract administrators, contractors, construction product representatives, and facility managers in the performance of their tasks/roles. This manual presents a detailed overview of the processes needed to envisage, design, construct and maintain the built environment. It is geared to the description of the processes, seeking the inter-related role of the various agents involved on each specific process, across the all construction life-cycle, working as a tool for the agents involved to deliver projects. It is in fact, a classification system as it identifies, defines and describes the agents, the life-cycle phases, the activities and roles, setting the introduction to other more specific guides that will incorporate detailed information to help on the project delivery of particular projects. This addresses to construction in general, leaded by the topics that have most influenced the project management, i.e. BIM and IPD.
Some addressed issues worth to be mentioned to highlight some of the major concerns of the nowadays project deliverables.
On its introduction, the document appoints some aspects that are found essential and that need to be meld in order to have a successful project delivery. These are:

- Owner with a defined plan for a facility;
- Production of the design and appropriate decisions by individuals, firms, and companies;
- Contracts with comprehensive and effective definition of roles of the stakeholders and participants;
- Well developed and sufficient construction documentation;
- Organized construction project management and scheduling;
- Installation of the required materials by all individuals and companies.

The construction/facility life-cycle is defined likeness other documents. Yet, for the typical project phases it is explored the main activities and the documents that need to be produced by each agent involved, according with the US regulations. Table 3.3 illustrates one example.

Table 3.3 – Example of Phases, Activities and Produced Documents [86]

Phase	Activities	Documents Produced		
		Owner	A/E	Contractor
Design	Schematic Design	Surveys Geotechnical Date	Schematic Drawings	
			Conceptual	
			Preliminary Project	
			Cost Projections	
	Design Development		Drawings	
			Engineering	
			Outline specifications	
			Revised Cost Projections	

One of the sections (section 7) is turned for project delivery. It is explained and explored the history of the evolution performed on the US until present time and the main principles of Integrated Project Delivery. The document states that:

"Collaboration is a fundamental characteristic of IPD. Stakeholders and participants are integrated into one effort with a common goal, and are encouraged to focus on projects outcomes instead of individual goals. IPD will require changes in attitudes and approaches of members of the design and construction professions and industries. Success is contingent on the following principles:

- *Mutual respect and trust, and commitment to work as a team;*
- *Mutual benefit and reward, and because of early involvement, compensation based on the value added and what's best for the project;*
- *The free exchange of ideas, decisions, and innovation, which are judged on their merits by the team;*
- *Influx of knowledge and expertise in the early formative phases of projects to capitalise on informed decisions;*
- *Project goals that are developed early and agreed upon by the team;*
- *Recognition that intensified planning results in efficiency and savings during execution;*
- *Open, direct, and honest communications among team members in a no-blame culture and the resolution of problems rather than the determination of liability;*
- *Reliance on cutting-edge technologies to maximize functionality and interoperability;*
- *Team structure and leadership appropriate for the project that makes a commitment to the team's goals and values."* [86]

Regarding the design documents (section 9) it is explored the concept of Preliminary Project Descriptions. PPD is a method of describing aspects of the schematic design on a written format. The preparation of the PPD implies thinking through the entire project, decisions and design criteria in broad terms, i.e. main construction elements and their constitution and physical requirements. The effort must lead to the information that suites the production of preliminary cost estimates, time schedules, and initial value analysis studies. It is not common that PPD identifies the materials as they may change during the design stages. Yet, and as referred the constitution of the elements (example, the layers of an exterior wall should be expressed). Depending on the progress of the design and the decision-making process, PPD's may include performance criteria and product descriptions, summarizing therefore many of the information that will be later presented on the BoQ and technical specifications.

The PPD should be organized to describe groups of construction systems, construction elements and components/products in a logical sequence. Depending on the type of project different CICS (in this particular situation the US CICS Uniformat and Masterformat) can be used as guidance, setting the organization, main terms and codes.

This manual constitutes a powerful work tool as it gathers many of the information related with construction projects. It is much geared to the US industry, namely on the processes, legal framework and standards. Nevertheless, the structure and some of the information is applicable to international frameworks. The added-values it's also on the references to other related documents. It works as a project management code with useful information for all agents involved on the construction life-cycle.

3.4.4. COBIM - COMMON BIM REQUIREMENTS 2012

The publication series Common BIM Requirements 2012 is the result of a broad-based development project entitled COBIM [87] that involved several public and private institutions, universities and companies from Finland. The purpose of this project was the awareness of the growing use of BIM in the construction industry and the need of common requirements for modelling. During all phases of a construction project, the involved agents have an increasing need to define more precisely what is being modelled and how the modelling is being performed. These documents are based on previous instructions of owner organizations and the user experiences derived from them, along with the thorough experience the writers of the instructions possess with model-based operations [88].

The publication consists of the following documents that can be downloaded in English on the BuildingSmart Finland website [89]:

- General BIM Requirements;
- Modelling of the Starting Situation;
- Architectural Design;
- MEP Design;
- Structural Design;
- Quality Assurance;
- Quantity Take-off;
- Use of Models for Visualization;
- Use of Models in MEP Analyses;
- Energy Analysis;
- Management of a BIM Project;
- Use of Models in Facility Management;
- Use of Models in Construction;

COBIM documents cover new construction and renovation building projects, as well as the use and facility management. COBIM sets the minimum requirements for modelling and the information content of models included in the modeling requirements. The minimum requirements are intended to be observed in all construction projects wherein the use of these requirements is advantageous. Besides the minimum requirements, additional requirements can be presented. Modelling requirements and content must be presented in all design contracts in a binding and consistent manner [87].

This industry development project is not a factual standard. Yet it is being seen as a good reference for best practices and to ease up the participation on finish construction projects where BIM is mandatory. The document was written with the assumption that all the practitioners and namely the design disciplines work individually and exchange the modelled information whenever it is feasible [88]. The trends point to the integration of project delivery. Notwithstanding, this methodology aims, by setting very specific and strict rules, to overcome the cultural issues related with collaboration.

3.5. CONCLUSIONS

This chapter intended to give an overview on the international standards that are more related with the discussion topic and present the legal context for the Portuguese public works market.

The new version of ISO 21500 and the ongoing revision process of ISO 12006-2 will set the needs for ISO 22263 update. The three documents will establish many of the principles for the sector transformation and will serve as base to the production of other standards construction related and technical documents, like those presented on the previous point.

The Portuguese legal framework is essential for the understanding of a significant part of the developments that will be explained on the following chapter. Also, to enhance the transformations that are being conducted by the Portuguese Government towards the sector improvement and sustainability. The ultimate example is the implementation of electronic procurement on all public contracts.

The Classification Systems topic explores the rise of these systems, explores its importance and future role. The most recent developments are important as they will be embedded on most of the ICT that will be used. The discussion about the proliferation of these systems and the compatibility of CICS tables and construction non-exclusive systems was highlighted has the author finds one of the most sensible topics towards the targets that will be further explored.

The technical documents presented are just few from a group of tools that help all the agents to fit on the construction life cycle requirements. Their publication should be framed with the standards and legal framework, situation which unfortunately does not always happen. One situation that's worth to highlight is the simple use of the term phase or stage for the definition of the parts that constitute the construction life-cycle. The research performed led to the conclusion that new trends point to the adoption of the term phase. Examples of this philosophy are the nomenclature of the ISO 12006 revision, the development of Uniclass 2, or the Table 31 from Omniclass (Phases). Nevertheless, the new version of the Plan of Work or valid standards, continue to use the term stage. This is just a little example of the potential problems of information mismatch.

A final remark, to evidence that the production of this information, regarding its level (standards, legislation, organization systems and technical support document) must involve a significant number of high skilled professionals.

4

PROJECT INNOVATION – EXPERIENCES FROM ProNIC DEVELOPMENT AND TRAINNING AT CROSSRAIL

4.1. CHAPTER OVERVIEW

This chapter is dedicated to professional experiences associated with the discussion topic. Two actions will be explored. The first is related with the continuous work developed by the author and the second reflects a training experience on a foreign company that has taken several innovative steps towards integration of the construction life cycle.

The author has been professionally involved, since 2006, on the ProNIC project. ProNIC started as a Portuguese research and development project with the main goal of establishing national references for technical information regarding AEC design disciplines, documentation templates for project delivery, BoQ template and parameterized work descriptions and routines for the design-related tasks. As it will be described, this initial action had several steps forward and new developments are permanently being performed. The points of this chapter present a general overview on the initiative, its initial objectives, development, the following actions, the implementation and the current situation.

The training experience was performed at Crossrail. This English company is developing one of the largest construction projects in Europe and is very determined on the implementation of new work methodologies to achieve specific design innovation outputs. This example is very interesting because it disrupts the idea that BIM is just for buildings. The introduction of this participation is also essential to focus on essential research topics and to give a real testimony of this company vision towards some of the previously mentioned changes and innovations ambitioned for the sector.

4.2. PRONIC – PROTOCOL FOR CONSTRUCTION INFORMATION STANDARDIZATION

4.2.1. THE NEED AND THE DEVELOPMENT TEAM

4.2.1.1. The needs

The reasons that motivated the development of ProNIC are related with the construction industry characteristics in general and with particular aspects of the Portuguese reality. Most of the global problems were presented, in general lines, on Chapter 2. Given the relevance for the goals of this action and for the overall discussion, the ones more directly related will be deeply explored.

A global view on the sector shows that construction is characterized by its lack of productivity [90]. The industry behaviour on delivering products is very heterogeneous [91], which leads to major concerns regarding the quality assurance of the final product. Other essential factors were referred also by Sir J. Egan on its "*Rethinking Construction Report*" that evidenced the difficulty in accomplishing with timings and budgets [18]. As previously mentioned, the assumption that each produced object is different and that therefore all the processes are singular is rather true [92], neither it would be sufficient to justify, at least in full, the entire situation. The reality is that the construction industry suffers from many low level problems. These have been identified throughout the years.

The most relevant for the discussion are:

- **Tightness between and within construction stages** [93]. In many situations there is no visible connection or result in terms of communication and outputs. This evidence is visible during the design phase with the discrepancy of the different design disciplines. On phases like design, procurement and construction, the work owner receives and sends final documents from one entity to another. The presence, active participation and sharing responsibilities of the different actors it's essential to decrease the tightness;
- **High level of fragmentation.** This situation is closely related with the previous. It is manifested by the inability of the agents to work effectively as a team [94]. Lack of decisions on key actions, absence of common assumptions and communication difficulties are main aspects. Hence, fragmentation is not good in any phase. Yet, it is more relevant on phases like: construction - relations between the main contractor and sub-contractors; and design - different assumptions for the same object by each design discipline [95]. In building construction it is possible to have more than twenty design disciplines. The absence of communication and the common way of gathering the final design documents, promotes a fragmented approach. The establishment of rules for design management and the presence of an effective entity performing this process would bring benefits for the designer and for its outputs.

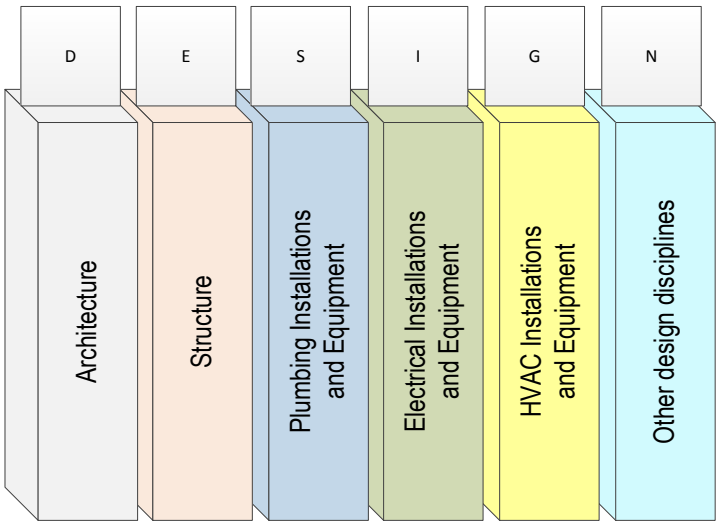


Fig.4.1 – Fragmented approach to the design process – tightness between disciplines [96]

- **Large number of participants.** There are several agents involved on a project through the different phases. It was referred the inability to work as a team on specific processes.

Also, the number of actors, contracts and responsibilities does not contribute to the establishment of an effective team spirit. The key agent should be the work owner. It is he who defines the rules and responsibilities for the project, which must be present on the definition of the contracts and during all the construction life-cycle. Integration of the practitioners should be a major concern in order to maximize the work owner objectives and the ones from the different agents [97].

- **Traditional essence.** The uniqueness of each product (building or other infrastructure) determines a different and traditional approach to each process. Yet, throughout time many evolutions have taken place. Some of them were followed up by the sector, namely those that guaranteed direct economic return, such as reduction of employees or higher dependence of subcontracts. In what concerns other processes, many of them related directly with production and information management, no significant changes were performed. The impacts of these are substantial, yet its extension to the most relevant companies reduced its real importance. It is noteworthy the systematic insertion, by hand, of the same information in different templates to perform outputs.
- **Lack of ICT incorporation** [94]. Many of the previous referred aspects could be minimized or solved with the introduction of Information Technologies. Several examples of tools to expedite some processes could be presented. Yet, this it is not the main objective. More important than the lack of investment is the return or the achievements with it. The results evidence that main investments are performed in applications for specific processes, like calculations or drawings – CAD, rather than wider tools for decision support and management [98]. One important fact that supports some of the referred problems, namely those related with communication is the use of applications that work on a standalone base. The information is stored in each person computer and needs to be sent by regular means such as email or CD. The process of design needs to be sequential rather than simultaneous. The impacts in terms of benefits are limited when compared with the nowadays available solutions and possibilities.
- **Absence of standard language and outputs.** Perhaps one of the most important problems. Different companies understand the same information differently and organize the same output with different formats, presentation and contents [99]. To prevent it, mutual understanding systems should be developed and adopted. This effort helps to guarantee that different designers involved will understand the information in a same way, as well as the work owner, contractor and sub-contractors. Information misunderstandings are very difficult to track as well as their cost on the project.

With the identification of these problems it is not difficult to understand the reasons for miscommunication, differences on assumptions, flaws on outputs and management inefficiencies.

Beyond the referred topics, the weaknesses that have most influenced ProNIC development were related with specifications and references that, as presented on the previous chapter, other countries have somewhat solved. These were the:

- Absence of technical specifications regarding the works execution and materials requirements;
- Difficulty on gathering and disseminating technical information and standards;
- Lack of widespread use content, namely CICS to uniform approaches and understandings, namely for the production of BoQ's and specifications.

4.2.1.2. The Development Team

The project resulted from an application to the Operational Program Knowledge Society, funded by the Portuguese Government that was accepted on December 2005. The structure of the project was comprised by three work owners and a consortium with three institutions to perform the developments. The owners, representing the Government, were the Direcção-Geral dos Edifícios e Monumentos Nacionais (General Direction of national Buildings and Monuments) responsible for the refurbishment of monuments and patrimonial buildings as the main institution, the Instituto Nacional da Habitação (National Housing Institute) responsible for the construction and management of public residential buildings, and the Estradas de Portugal (Roads of Portugal) responsible for construction and management of all road infrastructures.

The developments under funding took two years and were performed by the Instituto da Construção da Faculdade de Engenharia da Universidade do Porto (Construction Institute from the Faculty of Engineering of the University of Porto), the project leading Institution and with management responsibilities, the Laboratório Nacional de Engenharia Civil (National Laboratory of Civil Engineering) and the Instituto de Engenharia de Sistemas e Computadores do Porto (Institute for Systems and Computer Engineering of Porto), that created a consortium designated ProNIC [100]. The consortium gathered fifty people, namely developers (civil engineers), informatics engineers, civil engineers (specialists from many distinct areas), electrical engineers, mechanical engineers and consultants from many other different domains.

4.2.2. MAIN OBJECTIVES

The main objective of ProNIC was the development and establishment of a single and standardized language for construction works. Yet, at this stage the approach would be framed to some types of construction, namely residential building construction and rehabilitation, and construction of roads and highways [101].

This goal, notwithstanding the referred restrains, was in its essence very wide and ambitious. To achieve it, was necessary to "develop within the developments", a plan with gradual steps, to perform verifications and validations.

During this process other goals were defined. These were not directly related with the construction process. Yet, they revealed significant importance in what concerns economic evaluations at distinct levels, maintenance and history record for the study of the construction on use.

The main initial objective was divided into smaller, allowing tasks definition as follows:

- Development of WBS-CW for buildings and roads, adapted to Portuguese construction, with standard work descriptions and definition of organization layers;
- Development of a construction knowledge database with:
  - Technical information about construction works, composed by technical specifications based on the work demands, measurement rules in accordance with national references, applied standards, safety and health risks;
  - Technical information about materials in accordance with manufacturer procedures, production and CE mark demands;
  - Cost scenarios for construction works based on (materials, equipment and resources);
- Software based functionalities for designers to produce standard design documents.

As referred, other relevant aspects were defined during the developments. The main objective of this explanation is to present and detail the initial elements and their singularities. It intends to set a background, introducing the essential elements and their main assumptions.

The main scope was set for the design phase and designers, to produce their projects written documents. Nevertheless, other users can work with it, to get technical information or cost scenarios for tender actions, among other procedures.

4.2.3. THE DEVELOPMENT

4.2.3.1. Overview

The developments, as referred, were divided in several tasks. Those that involved the production of technical contents and specifications took most of the time. One of the relevant tasks was the literature review and the system solution design.

ProNIC is usually classified as a CICS. Yet, it is broader in which regards the level of detail of the information, and narrower in what concerns the facets that includes, i.e. it is mainly a WBS-CW and just for some types of constructions. The deeper level of detail is due to the work description or project description, that links to quantities, measurement criteria and unitary prices, fulfilling the BoQ and the budget estimate. Also, it has technical specifications for works and materials, being all this information managed by a computer application. The majority of the CICS explored on chapter 3 consist of lists and tables with titles, published on a book or in spreadsheets. Therefore, the characterization of ProNIC might not be 100% accurate.

Figure 4.2 intends to identify the main information elements that constitute the ProNIC database.

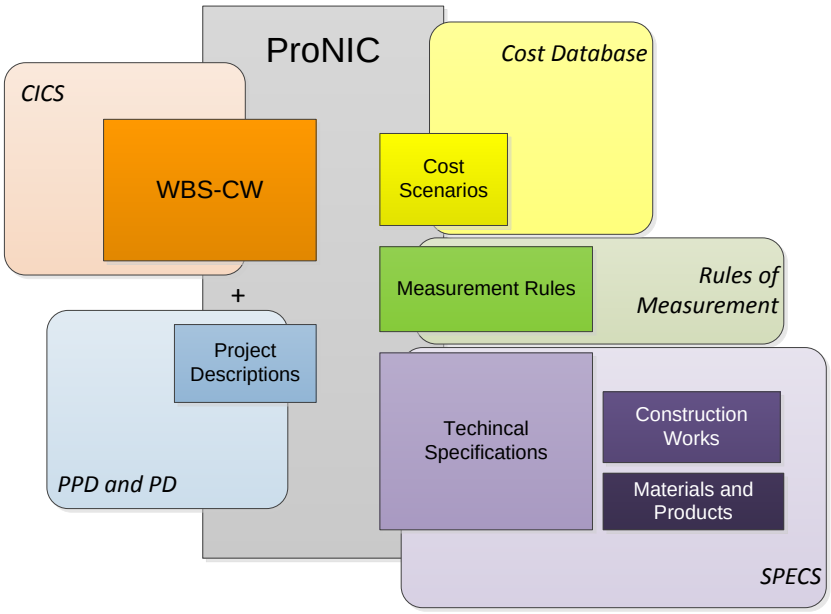


Fig.4.2 – Information Elements within ProNIC

To develop each of these elements it was performed a literature review based on national and international references. The main international references were already explored on chapter 3, so it

worth to highlight the national initiatives. These were scattered by different publications and entities and didn't fit each other. Given the international references, the following initiatives were exploited by ProNIC and were adapted to meet a common approach and strategic and integrated requirements.

Regarding the WBS-CW and specifications, the existent standard documents were used, namely BoQ and specification produced by Estradas de Portugal and the outputs from CIC-NET. The elements from Estradas de Portugal had been revised for the last time in 1998 [102]. The CIC-NET initiative was launched in 1998, with the purpose of creating a new work breakdown structure for building works and a classification and codification system for construction materials, using a modified version of EPIC. The goals encompassed also the definition of the intervenient roles across the construction process. It was sponsored by a group of companies from the AEC industry that gathered for the development, the Instituto da Construção da Faculdade de Engenharia da Universidade do Porto and the Instituto de Engenharia de Sistemas e Computadores do Porto. The outcomes were documents with base concepts, methodologies, work breakdown structure and a computer application with a construction work database. [63]. CIC-NET established most of the main principles for ProNIC development.

Respecting the Measurement rules, Cost scenarios and Specifications, Laboratório Nacional de Engenharia Civil had developments on these areas, mostly for building construction, that originated several publications. The first was released during the 60's. It consisted in procedures for design information organization and definition of templates and rules for design documents [103]. In the beginning of the 70's, it was published a WBS for building works including specifications. The results were published in a five volume book edition [104]. During the 90's and in cooperation with public and private institutions related with the construction sector, it was produced a set of rules for building works measurement (based on the CESMM). These rules were grouped following a breakdown structure by types of work (ex: concrete structure, wood structure, metalwork, woodwork, others) [105]. It is possible to say that this was the most widely accepted and used document. It suffered several updates until nowadays. At the same time, it was published a catalogue with reference costs and resources data sheets for building works. This catalogue was several times updated. The work breakdown structure followed had some differences from the previous defined for the measurement rules as it had an approach more geared to building/construction elements (piles, walls, etc.) [106].

In essence, ProNIC used international references for the definition of the relations and main principles, used national scattered documents that were transformed to meet new philosophies and different requirements, and developed most of the parameterized work descriptions and the material and work specifications, according with the best practices and applied regulations and standards. The following points address to the most relevant information elements, to provide a better understanding of the assumptions, constitution, and extension of each one.

4.2.3.2. Work Breakdown Structure – Construction Works

The ProNIC WBS-CW is a hierarchical division and it is structured according to the type of construction (buildings and road infrastructures). The construction and rehabilitation of buildings uses the same global division as it will be further explored. The upper level is the "Chapter" that corresponds to large groups of construction works, set generically by "arts", such as earthwork, concrete structures, finishing's, water infrastructures, electrical infrastructures or road pavements, to name few. It follows, in general, the basic criteria laid down on the measurement rules from LNEC. For each chapter there is a number from 1 to 99. There are twenty six chapters for building works and ten chapters to road infrastructure works. Both types of construction have a "Miscellaneous" chapter

with the numbers 26 and 10, respectively. They exist to respond to items/works not yet foreseen on the database or that don't fit in any other chapter. Figure 4.3 presents the titles of the chapters.

The following hierarchic levels decompose these groups. To each level there is a numeric code divided by points. At the end, the lower level (corresponding to the work description or BoQ article) is characterized by a brief description and a numeric code, e.g. "*12.1.2.1.2.1.1 – Partition walls; cavity wall with identic clay blocks on both leaves"*.

In which concerns the Buildings WBS-CW, the second level attends to the two types of interventions "general construction works" and "consolidation, rehabilitation and strengthening ". The second option appears only on the chapters where it is applicable. For this, the performed approach consists of rehabilitation techniques framed on the chapters. These techniques can be completely defined by the use of rehabilitation works or by the combination of various works whether specific of rehabilitation, or grouped with works defined on the "general construction works" part, e.g. intervention due to cracking on non-resistant enclosure walls. The set of works are the demolition of the finishes, the reinforcement of the enclosure wall, and application of a new finishing layer. The only work considered on the "consolidation, rehabilitation and strengthening" part is the reinforcement technique. The other two (demolition and finishing) will be performed, in terms of work descriptions, in similar conditions of the ones performed in new buildings. Given this, they are placed on the "general construction works" part.

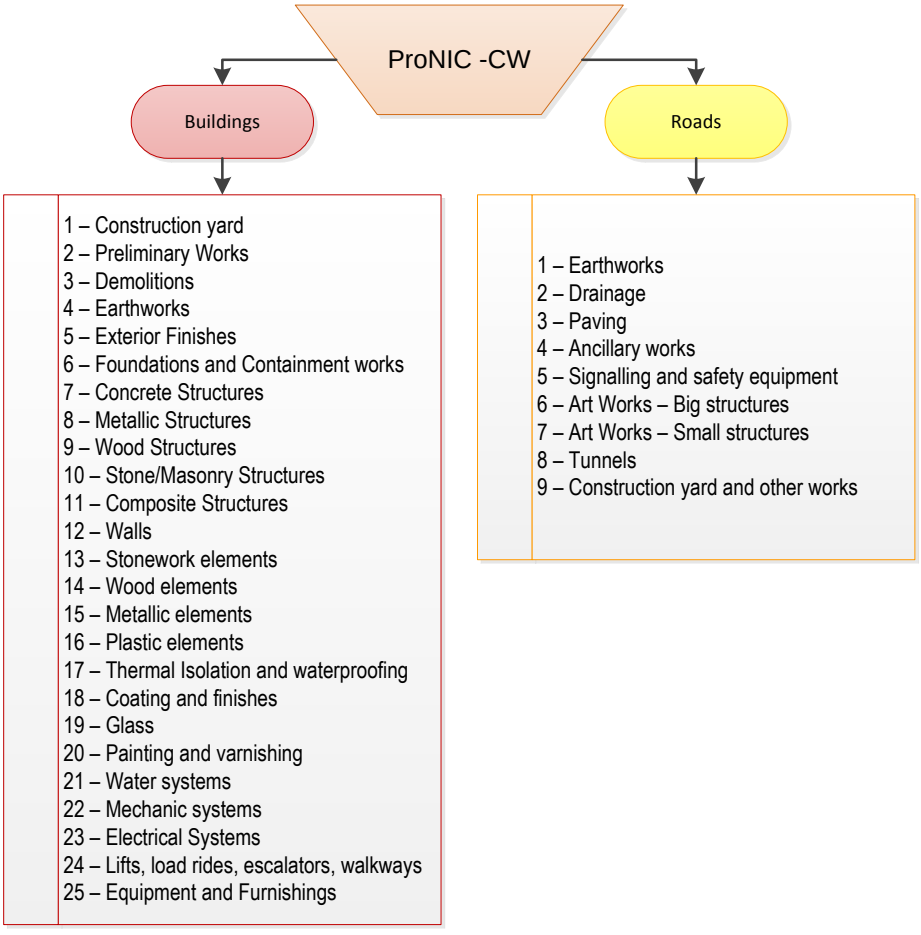


Fig.4.3 – Chapters titles, by type of construction

The following levels establish, according with each chapter a sequence that identifies the type of element, its location, their general characteristics (materials), among other singularities. Figure 4.4 evidences one example. This leads to the final level of the WBS, the article or project description.

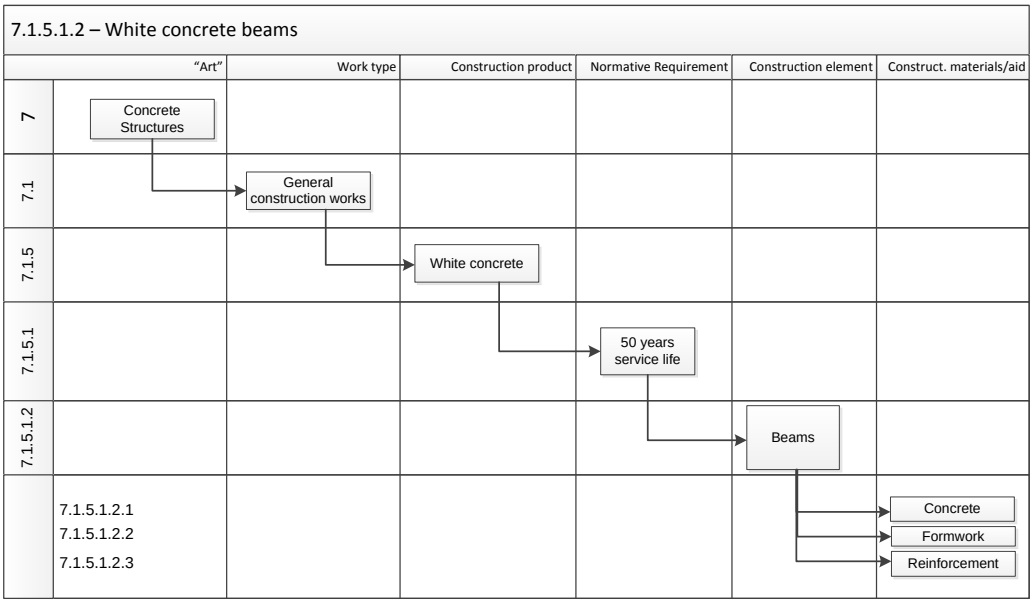


Fig.4.4 – Example of criteria for the WBS-CW levels

4.2.3.3. Project/Work Descriptions

The work descriptions represent the detailed level of the WBS-CW. They are essential elements on the projects and as so, they are also the most important and central aspect of the information system. They allow the production of most of the outputs. The descriptions are composed by standard text and variables or parameters that need to be settled by the design discipline during the design phase. These parameters can be a selection from given options or text inserted by the designer.

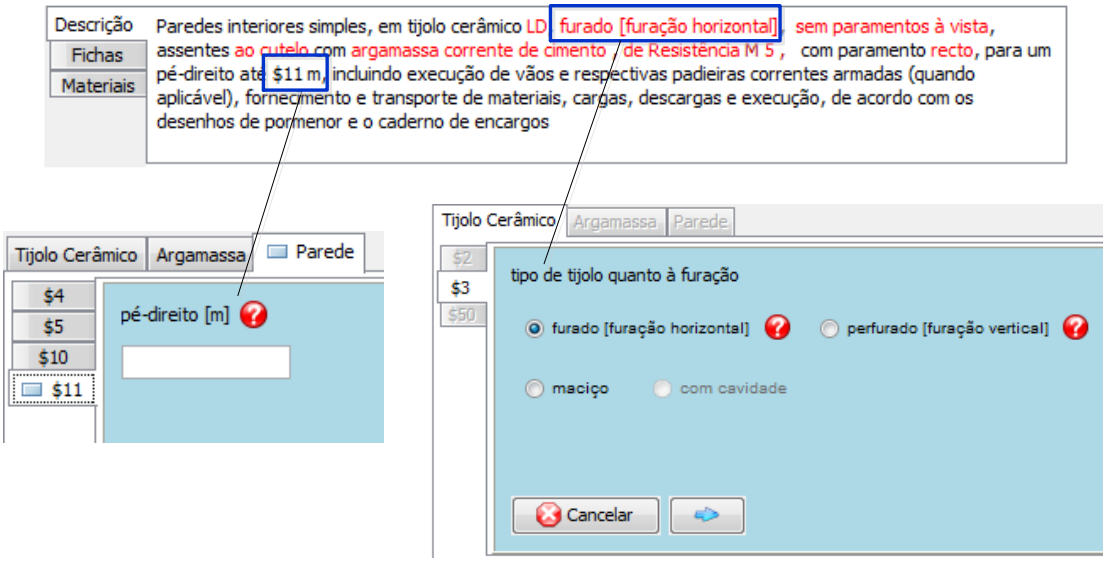


Fig.4.5 – Example of ProNIC work description (standard text and parameters)

The constitution of the work descriptions was envisaged this way given the countless amounts of solutions and their combinations for the works definition. Being the parameterized work description an item of the BoQ, it should be as detailed as possible. The CSI Project Resource Manual, 5th edition [107] indicates two possible and different approaches to the work descriptions:

- through the description itself;
- through the performance and proprieties.

For ProNIC and potentially, given the Portuguese construction process, it was considered a mixed approach. Its work descriptions meet descriptive aspects, like geometry, dimension or aesthetic details and functional behaviour and performance requirements. A possible work description that exemplifies the use of the two approaches is a painting. This work gathers parameters related with descriptive aspects such as, color, texture or layer thickness and functional behaviour like, reaction to fire, UV reaction, wash resistance or cracking absorption. Given this, it is possible to settle groups for the options, according to the type of information to choose/fill. Five main groups were identified, related with the previously referred aspects. These may vary according to the construction work. They support information related with:

- Identification of the element and/or its location on the building;
- Identification of materials;
- Definition of materials characteristics or functional aspects;
- Dimensions;
- Additional task description, distinctive topics, other information that the designer finds useful on the description.

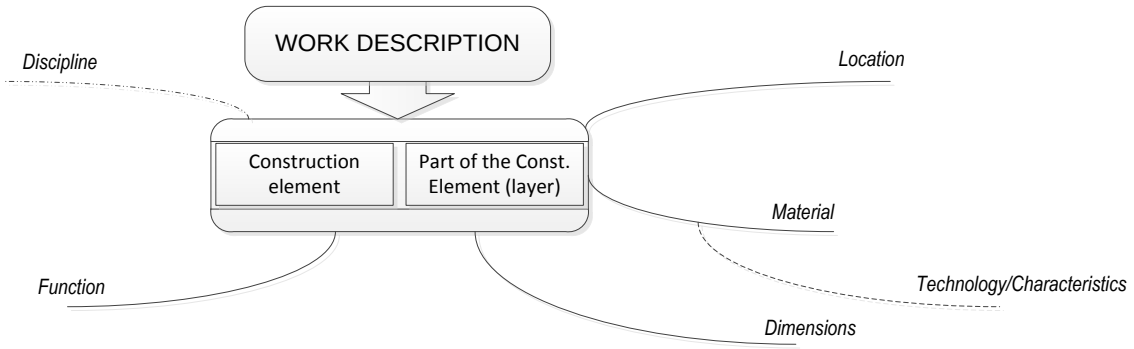


Fig.4.6 – ProNIC work descriptions main information groups

The approach to the project description follows a high level of detail. In many situations, for the description of a construction element it is necessary to use more than one article or project description. One good example is an enclosure wall (construction element), as it will be following described. As referred, all the works are described individually. In some situation there is the possibility of assemble the works giving just one measurement and a unitary price that is applicable to all layers.

The construction element can be described in one work as follows:

Execution of double masonry enclosure wall of hollow brick 300x200x150 mm on the outer wall and 300x200x70 mm on the inner wall, up to 4 m, laid on cement and sand 1:5 mortar, with polystyrene isolation 6 cm thick in the cavity, exterior and interior rendering 1:1:5 (cement, lime and sand) with 2 cm thick, 3 layers of white colored external painting with plastic ink, washable up to 1000 times, UV resistant according with standard, application of red color ceramic tile on the inner surface with 150x150 mm, weight 1,3 kg/m2, non-slipping surface and sealant filled joints with 2 mm.

Nevertheless, the element description on ProNIC would be more or less like referred on table 4.1.

This division (in layers) is necessary due to the number of options in each work. Nevertheless, it is essential for the maintenance phase, as the materials durability might be different from layer to layer. From a construction life cycle point of view, this is the philosophy that assures the information individualization, maximizing its reuse.

ProNIC produced thousands of work descriptions. The amount of different works is wider as each work description has a very considerable number of parameters and filling options.

Notwithstanding, there are works that were not foreseen. For these situations, there is the possibility of add new works on the WBS-CW. This addition can be performed on the work description level or for the entire framework (upper levels of the structure).

Table.4.1 – ProNIC work descriptions example

Code	Work description	measure. crit
12.1.1.1.2.1.1	*Double masonry wall of hollow bricks, laid on cement and sand 1:5 mortar, up to 4 m*	*m2*
	- *inner wall leaf 300x200x150 mm*	*m2*
	- *outer wall leaf 300x200x70 mm*	
17.1.1.1.5	*Application of polystyrene isolation 6 cm thick in the cavity*	*m2*
18.1.2.1.1	*Application of interior rendering with 1:1:5 (cement, lime and sand) and 2 cm thick*	*m2*
18.1.1.1.2	*Application of exterior rendering with 1:1:5 (cement, lime and sand) and 2 cm thick*	*m2*
20.1.3.2.1.1	*Application of 3 layers of white colored external painting, plastic ink, washable up to 1000 times, UV resistant according with standard*	*m2*
18.1.2.4.1	*Application of red color ceramic tile on the inner surface with 150x150 mm, weight 1,3 kg/m2, non-slipping surface and sealant filled joints with 2 mm*	*m2*

4.2.3.4. Technical Specifications

Technical specifications are written documents that instruct the design disciplines. They are composed by general and singular project related information. The general information is related with the standards and with the best practices to perform the work, or to deliver a determined material. The particular specifications differ from one design to another. This work is always performed by the designers on every project and usually it is settled from zero. The other specifications can and should be organized according to the type of construction and the works to be performed.

ProNIC developed general specifications that include the standard information and best practices requirements for each work and material. This information is linked to the project descriptions or to higher levels of the hierarchy, being "called" to the project when the work is parameterized. This information can be engendered by the designer whenever he wants. The outcome is a pdf document with all the information organized by files according with the works and the generic materials

Each type of file, i.e. construction work (FET) or generic material (FMAT) has different information requirements. There is a common structure (template) for each type as shown on Figure 4.7.

FET – Construction works files	***FMAT – Construction materials files***
- Construction work identification - Materials - Preliminary works - Work execution - Work inspection and acceptance - Tests - Technical and standard references - Measurement criteria/rules - Associated risks (security, health) - Other provisions - Maintenance	- Material identification - Application domain - Material composition - Properties and characteristics - Application - Technical and standard references - Quality marks and certifications - Manufacturing process - Packaging, storage and conservation - Associated risks - Tests - Other provisions

Fig.4.7 – FET and FMAT titles structure

At the end of the design phase the document is automatically produced, gathering the information from the parameterized articles by that specific designer or its team.

4.2.3.5. Cost Scenarios

As referred, each work is composed by standard text and parameters to be fulfilled. These, may or may not influence the cost. The combination of possibilities leads, on each work, to a considerable amount of cost scenarios or unitary prices. These, represent a reference value that does not have the ambition of being exact. Instead, it aims to be as close as possible to suit a design estimate. These cost scenarios are based on materials, equipment and labour [108].

The possibility of having retrofit information of the work descriptions used in the works makes possible the achievement of new cost scenarios. Yet, the analysis of the price and its decomposition on

the referred bases is always a work that needs to be constantly performed for the database update. Example of this information is presented on point 4.7.4.

4.2.4. THE OUTCOMES

The project was concluded by 2008, and at the end the result was an application with a standardized database of technical contents that allowed designers from different disciplines to perform their BoQ and Budget Estimates, getting automatically the specifications for the works and materials foreseen on the BoQ. All the work is produced within the application and using the system functionalities. In order to have quantities there is the possibility of performing them on the application or to use a spreadsheet template to import them to the program measurement sheets and to the BoQ (global values). The same situation is possible for the unitary prices in case of not using the defined scenarios from the database. All the documents can be exported to spreadsheets or to pdf format. The project can be exported into a file and it can be added to other project. One example of this situation is the request from the design coordinator to add on a single project all the contributions from the different disciplines, e.g. House A = House A (structures) + House A (architecture) + House A (electricity) + …. The application has the possibility of working online, running through the internet or in a standalone base. This last was the used version for the previous actions description.

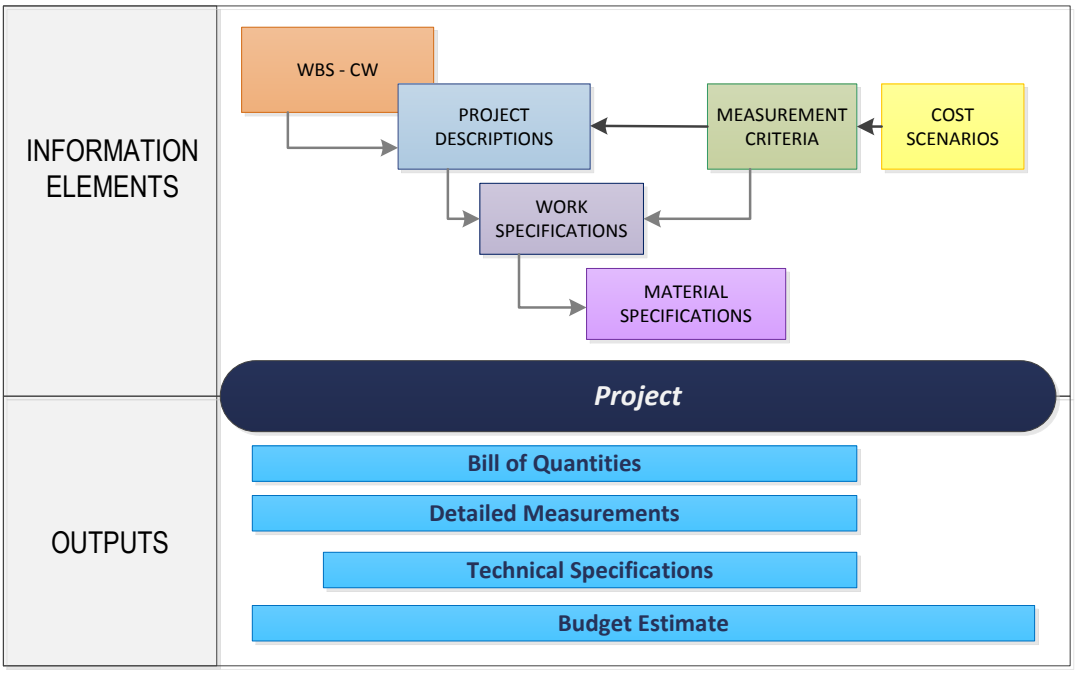


Fig.4.8 – Main information elements and outputs

In resume, all the actions that lead to the project specification during the design stage can be summarized on information requirements that need to be settled, selected or inserted on ProNIC. ProNIC's most important inputs are:

- Project definition (designation, selection of the construction entity type, other parameters – data about the project);
- Establishment of the design discipline;

- Articles specification (BoQ items) – selection (on the WBS-CW or from previous projects), parameterization and price definition;
- Insertion of quantities or upload of detailed measurement sheets (by discipline).

ProNIC's deliverables are automatically generated using standard information and designer inputs. The most important outputs include:

- Clear definition of project related information;
- Standardized BoQ (entire project, by discipline, chapter);
- Budget estimate (entire project, by discipline, chapter);
- Template for the production of detailed measurements (by discipline);
- Standardized measurement sheets (by discipline);
- Technical Specifications (entire project, by discipline, chapter).

4.2.5. CHANGES ON THE LEGAL FRAMEWORK

The publication of the CCP allowed the clarification of many aspects related with the construction, as referred on chapter 3. The publication of this diploma matched on time with ProNIC conclusion. ProNIC results were delivered to the promoters and given the contents of the new legal framework not foreseen objectives and a wide field of activity could be explored using the project outputs. This point explores the main aspects from the legislation where ProNIC as it was delivered or with slight developments could help the fulfilment of the prescriptions.

The Portaria n.º 701-H/2008 settled the rules for the design phase. Among the provisions, there was the definition of the design disciplines and the structure of folders for project delivery. As referred, ProNIC had the possibility of working on a standalone base or online (could base). The most beneficial scenario was through the use of collaborative working. The possibility of settling a common project structure with the definition of the construction entity and its characterization, the design disciplines and its users, as well as the folders structure for project delivery was studied. The documents produced by ProNIC would be automatically uploaded to the specific folders and other documents could be attached. At the end of the design phase, it would become possible to create a single file with all the information.

The CCP defined the use of electronic procurement for all actions under its framework. Several electronic procurement platforms were created to give answer to this need. There are great differences between public procedures for goods and public works. Among all the differences, it worth's to highlight the amount of information and its size or weight. The way traditional projects were delivered and the upload of this information to the platforms raised many questions. For the ProNIC developers by having the project delivered as referred on the previous point it would become simpler the upload of the process, namely via web service or integration.

The CCP created an instrument geared to the monitoring of the construction activity, the Observatório das Obras Públicas. This instrument could benefit from the information given by standard BoQ, namely reference values for the construction works cost, design disciplines relevance depending of the type of construction, chapter values and references for investment values by square meter and by type of construction, among others [109].

These are few examples of improvements that were discussed in 2008/2009, after the delivery of ProNIC and after the study of the new legal framework. Many of these hypotheses were implemented and other just structured. The two following points will address to them from different perspectives.

The first addresses to the developments performed by the consortium between 2008 and 2009. The second will explore the developments performed framed with the implementation on a real situation.

4.2.6. NEW DEVELOPMENTS

4.2.6.1. Construction Complexes and Construction Entities

A construction project can have multiple dimensions in terms of the objects to be built. Construction works can involve a single object, multiple objects or in infrastructures situations, parts of the object. Each can be set as the project, being composed by one construction entity or several (construction complex). One example is a school can assume a single building entity or a set of buildings performing a complex. Yet, the intervention an intervention to be performed on the two should be organized differently. According with the standards, a construction entity can exist alone or as an independent division of a construction complex. This division can be set assuming different purposes, such as physical division, roles/constitution, construction organization, operation (of the complex), maintenance, cost division, etc. The following examples explore possible divisions:

- for a road infrastructure, the separation of sections – bridge 1, landfill 1, tunnel, landfill 2, etc., or;
- for a set of buildings the separation between entities – building A, building B, access road, playground, etc.

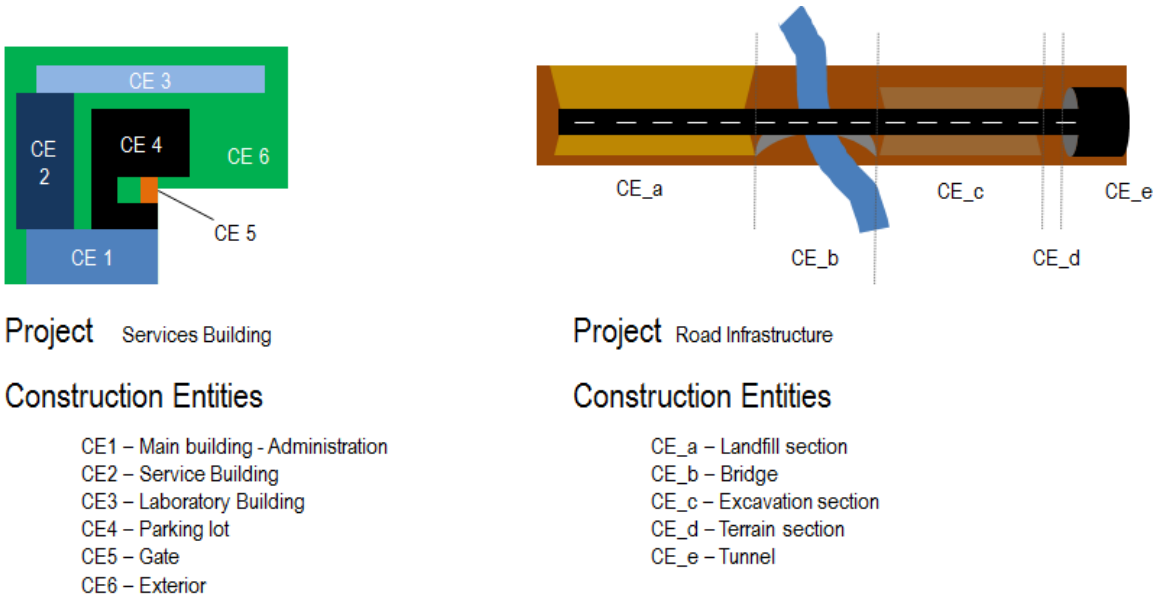


Fig.4.9 – Construction complexes and division in entities [94]

Before beginning a project in ProNIC it is necessary to define the project title and its constitution, from the construction entities point of view. These entities should be established in a way that serves all the construction life cycle phases. For each construction entity it is possible to select which design disciplines are allowed to develop work, e.g. landscape architecture has only authorization to work on the construction entity "Landfill". This definition can be established alone by the owner or its representative (project manager) or together with the design team.

4.2.6.2. Project Folder Structure

As referred, the publication of Portaria n.º 701-H/2008, provided the structure for project organisation and the set of mandatory documents for each discipline and construction type. To help the designers accomplishing this prescription, ProNIC developed a functionality that allows the definition of models for design organization that is, folders organization for different types of projects and within for different types of disciplines and documents.

It is also possible to set the organization for all the construction life cycle. In fact, each construction phase might constitute the first level of the structure. Figure 4.10 presents a generic design discipline organization model for buildings works (design phase).

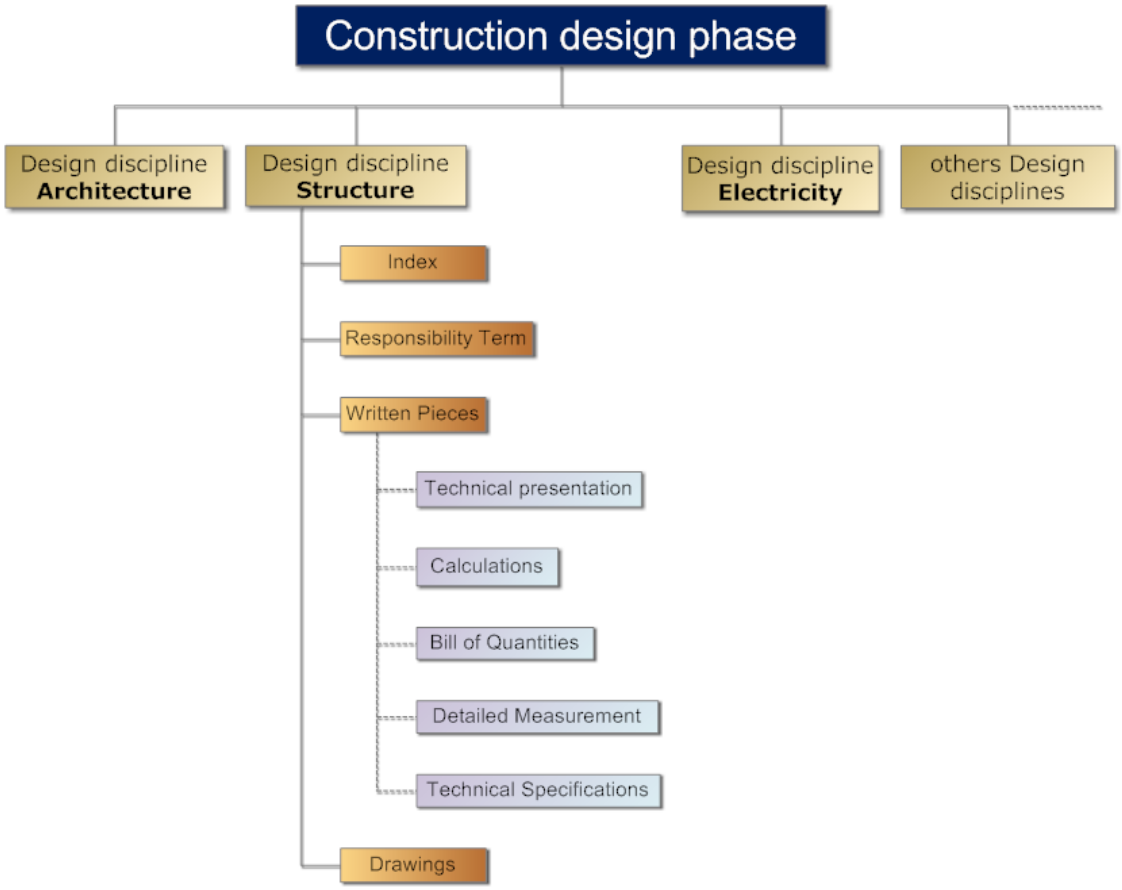


Fig.4.10 – Design discipline organization model for buildings works

4.2.6.3. Collaborative Environment – Profiles and Permissions System

As presented on the beginning of this chapter, one of the most preeminent problems identified is the fragmentation of the design process. This situation is more serious in this phase, as all the outputs will constrain the following phases and developments. Technology allows nowadays for people involved on the same project to be scattered all over the world producing their design discipline documents. However the exchange of these documents via email or other tools does not provide the compatibility between works that are being produced simultaneously. Thus, the use of online tools in which the work is in fact performed becomes very useful to supersede the identified difficulties. As referred,

ProNIC was developed to work online or in a standalone base. The described processes and functionalities followed the second possibility. The publication of Portaria n.º 701-H/2008 created a mandatory folder structure for design delivery. It became clear that a single structure common to all the disciplines involved on the project would be useful. Also, to improve the production of the BoQ it would be helpful to have a collaborative and functional environment for its production and control. To make it possible it was developed a permissions system that identifies the project phases, types of agents/roles, design disciplines, levels of functionalities. The following image presents some of the defined permissions. Through this it becomes easy to manage the design phase, as it is possible to identify who should prescribe what [110]. This environment allows also the minimization of work duplications. Two examples that can be addressed as they easily can arise on design documents are the production of final drawings and the water taps. Often all the disciplines prescribe the production of the final drawings with values that address to the global production and not just their discipline. This work should be prescribed one time by the design coordinator. The other regarding the water taps, is the duplication because of the absence or incoordination between disciplines. This work stands on the border of the Architects decisions and it is the final object of the water supply system. Just one should prescribe it, but often they come duplicated. On this collaborative environment the water tap work, as others, is a single work description with a specific code. Its double use is signaled before the second insertion, informing the user that other discipline or his discipline, has already used that work, and in which construction entities it was used [111].

Profile/Role		Permissions
	Designer	Production of its/their discipline(s) BoQ, introduction of quantities, unitary prices, attachment of external documents, i.e., drawings, particular specifications, project memory, etc.
	Design discipline coordination	All the previously mentioned functionalities, and: Design discipline completion (digital signature of the documents)
	Surveyor	Production of the measurement template Measurement sheets introduction, introduction of prices.
	Design Manager	All the designer functionalities, and: Design process overview, control of mistakes, work validation and design process completion (digital signature of all documents and production of the global BoQ and Budget Estimate).
	Work owner	If decided, the design process follow up. Introduction of documents prior project developement and after design completion to launch the tender action.

Fig.4.11 - Example of system profiles and permissions

4.2.6.4. Indicators

The industry notes a general absence of reference values regarding different levels of the construction. Most of the statistics produced are geared for the sector performance and specifically the housing market. ProNIC integrated the reference values or unitary prices of construction works developed by LNEC. Nevertheless, these values did not cover all the possible works from the built environment. Through the use of ProNIC, namely using online work mode, it becomes possible to have retrofit of the values used on the different works and across distinct projects. These values can address to budget estimates and to winning bid. With them, and performing statistical treatment it becomes possible to set reference values for the works according to the options, the construction type, the work relevance on the project global value, region where the work is performed, among others [112]. It is possible also to perform high level indicators for groups of works, chapters, disciplines, construction entities, values by square meter, just to name few.

The following images present two distinct situations that can be treated from information platform retrofitting.

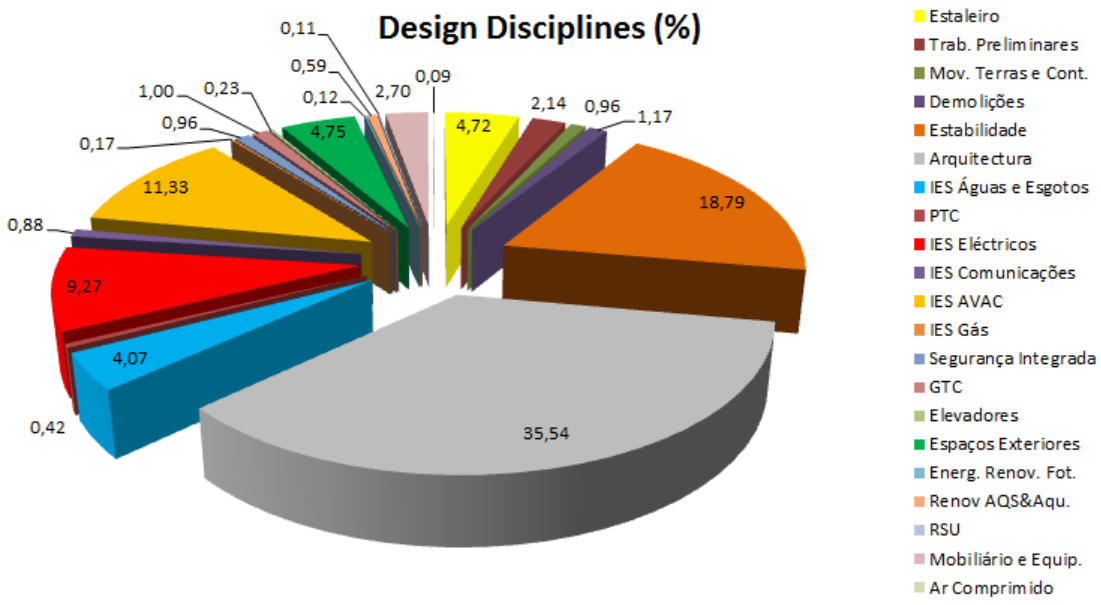


Fig.4.12. Example of information gathered from different (same construction type) projects – design disciplines relevance (%)

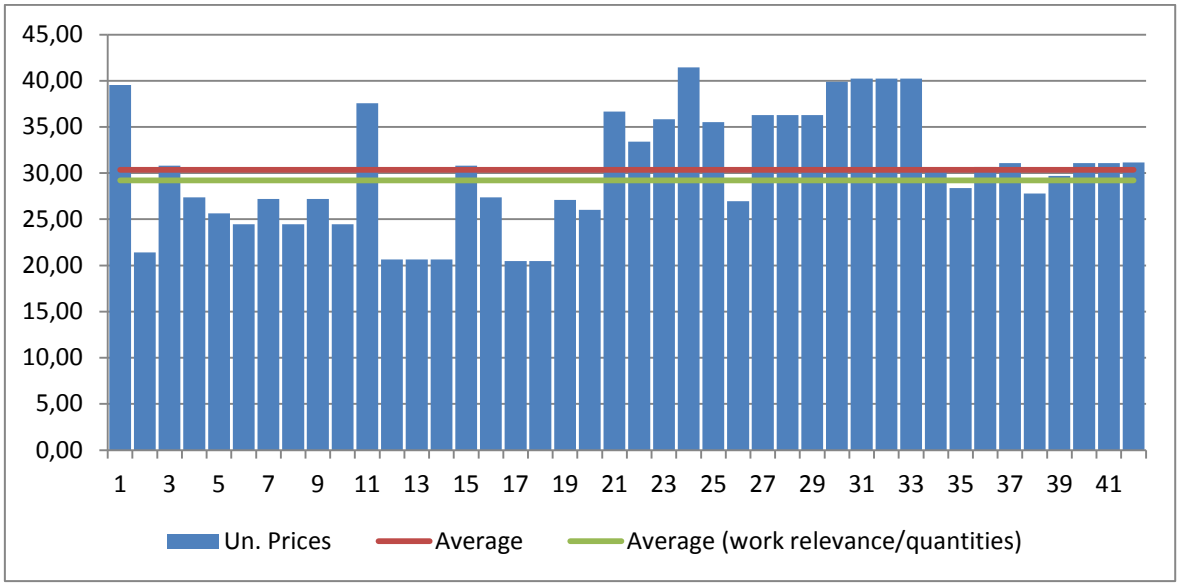


Fig.4.13 – Example of information gathered for a work and initial statistical treatment

The sample is composed by forty two situations. The maximum value registered was 41.43 €/m^2, the minimum 20.46 €/m^2, leading to an average price of 30.36 €/m^2. The average price considering the impact of the work quantities leaded to a value of 29.20 €/m^2. The global amount of work executed was 115451.27 m^2.

4.2.7. Real case Application

During the 2009, Parque Escolar, EPE that is the Portuguese Government entity (Ministry of Education) responsible for planning, managing and developing of the secondary schools refurbishment program, decided to apply the ProNIC on the 3rd stage of its program. This stage comprehended one hundred schools and a total investment of approximately 1100 million euro.

ProNIC team together with Parque Escolar, performed some tests to verify the applicability of the methodology. Given the type of constructions and the contracts requirements, few adaptations had to take place. This implementation motivated:

- The development of new works adapted to school needs, namely HVAC and security systems;
- The improvement of the project conceptual structure to support the logic of construction complex constituted by one or more construction entities and selection of design disciplines;
- The improvement of the governance model for the implementation of a cloud based collaborative working environment, namely requirements for specific access rules (given by username, according to specific design, work and type of user/role on the process (designer, coordinator));
- The need to train more than five hundred users on the application in a short period of time;
- The experience of building the project design phase and its documents in a collaborative platform, with the possibility of live coordination between the different design disciplines.

Most of the implementation, training and work development were performed in a period of one year.

The initial scope was the implementation of the application on the design phase and to be used by the design teams and owner project coordinators.

As the work started to be developed on more than half of the projects it were identified several functionalities to support the owner design coordination activity, namely the production of reports and mechanisms for data insertion.

As previously referred, CCP mandated the adoption of e-procurement. This provision constituted a difficulty for the public entities, as they became responsible for the information upload. Has it was studied, the communication between ProNIC and the electronic procurement platforms could streamline this process saving time that had not been foreseen by none of the parts involved on the project, namely design teams and work owner. Thus, and given the use of a single electronic procurement platform by Parque Escolar, it was designed and implemented a mechanism that allowed the automatic upload of the entire project. This will be further explained.

Given the information on the platform it was simple to extend functionalities to the construction phase, namely for the execution control and invoicing and to additional works and contracts. The focus was the end of the process and the possibility of produce an "As built" BoQ. At present time ongoing developments are being performed for this specific phase [109]. They will be explored on the next point.

After most of the processes have entered in the construction phase it was performed a survey with the intention of identifying the benefits of the applications and the user satisfaction. The process was ambitious and it was performed in a narrow timeline. Nevertheless, most of the users saw great benefits and it was satisfied by the use of the platform. The lessons learned from part to part allowed many improvements and the identification of opportunities.

The work is now being performed mostly by supervision teams and contractors for construction management and using the new functionalities.

In brief, the application of ProNIC to this public works program led to a large experience of work with the application in a very demanding scenario and with great needs. It was necessary to assure the correct operation of all functionalities and to educate a large amount of professionals in the functionalities and application technical aspects. High level of training actions was performed to frame the professionals on the legal framework requirements, i.e. identified needs that did not came from ProNIC, but through ProNIC because of the legal diplomas. This was an extra difficulty for the process.

The program involved the construction of one hundred school facilities (construction projects), each with more or less twenty five design disciplines. The number of companies involved achieved to six hundred, only on the design phase. Plus one hundred during the work phase (supervisors and contractors).

The works achieved, as mentioned, to an investment of nearly 1100 million euros. The universe of users is approximately one thousand and five hundred. More than eight hundred hours of training took place.

The following point explores in more detail the developments performed under Parque Escolar contract.

4.2.8. EXTENSION TO OTHER LIFE-CYCLE PHASES

4.2.8.1. Procurement phase

The operation of ProNIC in these projects rapidly evidenced the advantages of the collaborative environment established and the opportunities and functionalities for further life cycle phases. From the main contract for support and training, additional contracts were performed to develop most of the construction phase functionalities.

According to the legal framework and the public competition procedure, after design completion, the project should be sent for tender action. All the information needs to be uploaded to the electronic procurement platform and from there all the competitors can have access to the information and place their bids and questions or doubts. There are two stages during procurement, where contractors can place questions regarding the project interpretation. These have specific requirements. At the end, the contractors place their final bid and the owner will perform the evaluation of the proposals according to a pre-established criteria.

As mentioned, there were identified problems regarding the upload of the information. An integration scenario was envisaged and several possibilities were explored. The option was not to follow complete integration of processes. The communication was established to send all documents from ProNIC to the electronic procurement platform in each stage. The owner accesses to the platform to see the contractor's doubts and performs the adaptations on ProNIC.

To perform this communication it was necessary to:

- Improve the validation procedure, through digital signature of the documents, for each design discipline as confirmation of "work ended – discipline completion";
- Similar procedure for the design coordinator, stating that the project is ready to be launched into competition – design completion;
- Create work owner functionality to see which projects are ready to be launched and to build the tender notice;
- Improvement of the validation process requirements performed by the work owner to put the tender notice on a "ready to send" state;
- Communication mechanism to send all the information to the electronic procurement platform and positive or negative feed-back;

The process was implemented as all the communications for this stage can be resumed on Figure 4.14.

At the end all the proposal can be imported to ProNIC to perform numeric comparisons. Yet, this functionality was not explored on this context. Several case studies were performed regarding its potentials [113] [114] [115].

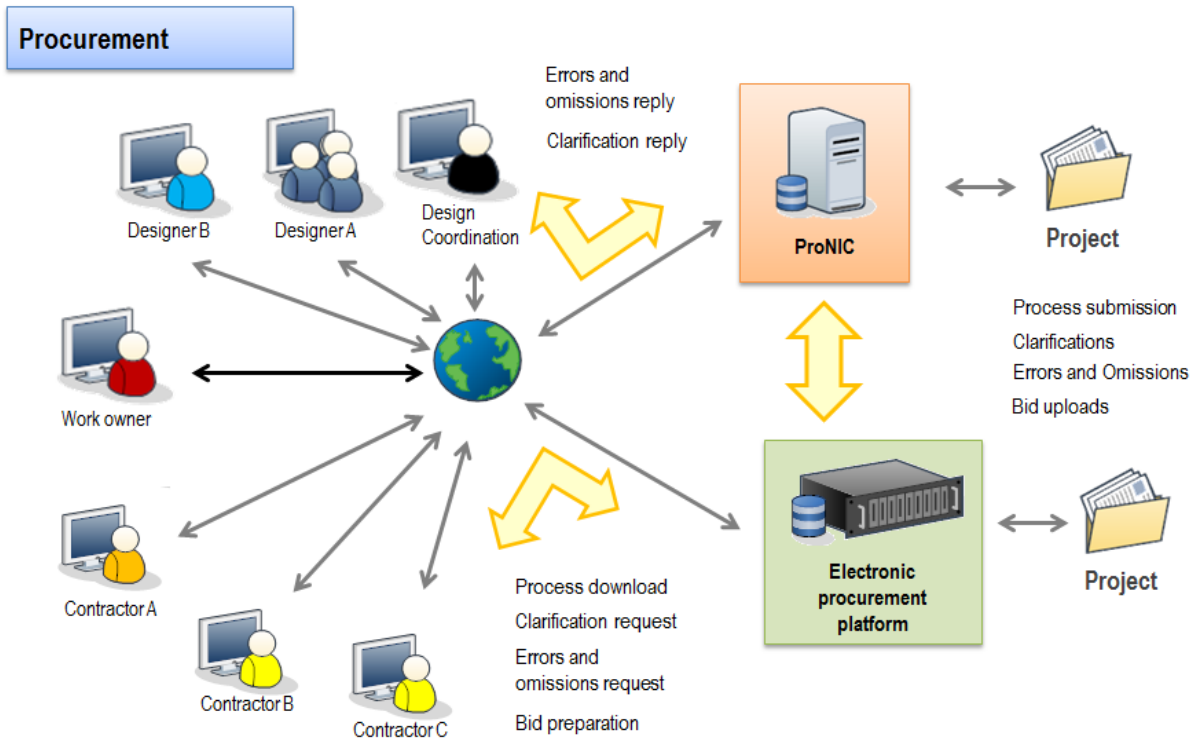


Fig.4.14 – Information exchange during procurement phase between users and applications

4.2.8.2. Construction phase

CCP sets the production of monthly measurement reports for the effective control of the works performed and to support the payments to the contractor. This process is performed by the contractor with the supervision participation. This document is sent to the owner that must accept it to authorize the emission of the invoice. One other document that should be produced is the "current account", which sets a balance between the works performed and those missing. It is also monthly based. To streamline this process, that is usually made using spreadsheets, the information is produced on a template with the referred format and with specific rules for its fulfilment. The supervision team performs the template download and gives it to the contractor that places the executed work quantities. Then both verify the document and if they agree they perform an upload to ProNIC and finish the process by performing each a digital signature. Then the owner can accept or send the document backwards for revision. If it is accepted the process is terminated and it becomes possible to produce the following template that will incorporate all the previous uploaded information. This process continues until the end of the work and it is followed by the production of the "current account" document.

CCP frames the possibility of performing additional works or contract changes. In resume these can be performed due to suppression of works, new works (not foreseen) or errors on the measurement that will need to be corrected (over or under measurement). Additional contracts need to be performed. To produce them it is possible to open the project on ProNIC during the construction phase, setting an additional contract. Then, it is possible to perform changes according with the CCP prescriptions. Most of these processes are not under competition, so the contract is performed with the same contractor without tender action. The works to be supressed are deduced on the initial contract and the new works or extra quantities will be measured on an additional monthly measurement report, for the additional contract. The process runs as it was previously referred. Figure 4.15 resumes these actions.

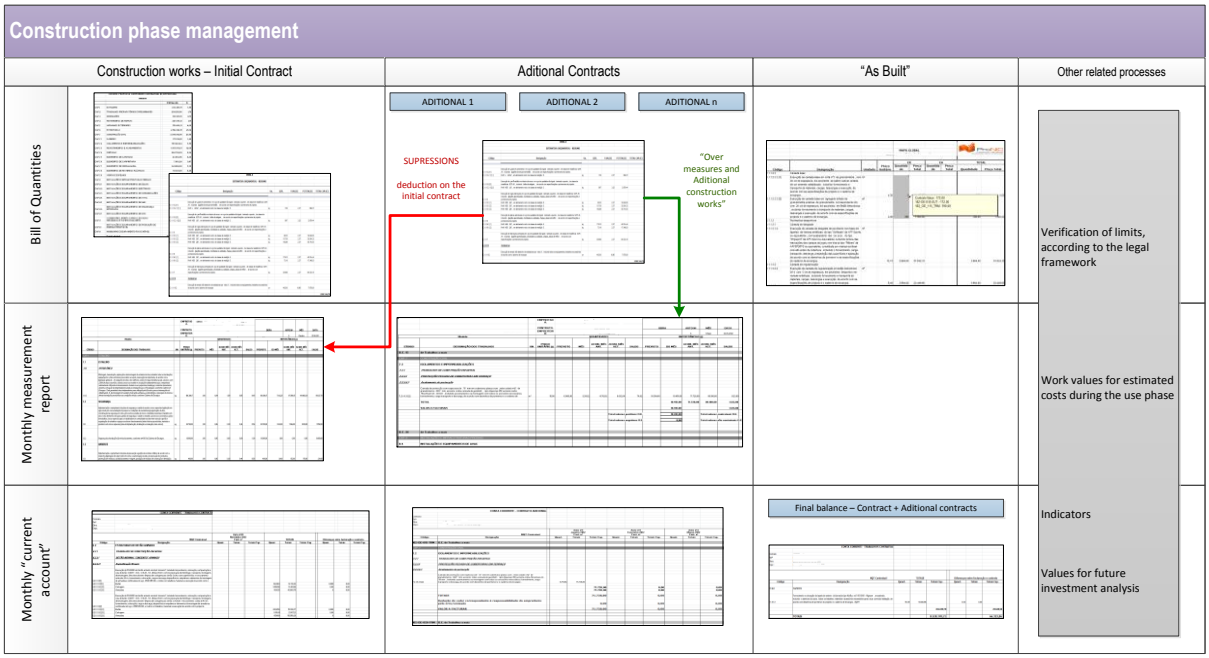


Fig.4.15 – Example of information gathered for a work and initial statistical treatment

CCP also frames the limits in terms of values for these additional contracts. The most recent development is a report that automatically gives the contract condition regarding the accomplishment of the limits.

At the end of construction and with the integration of the functionalities that set all the possible changes on the BoQ it can be produced an "As Built" BoQ that presents all the work developed, its quantities and cost.

Regarding the construction phase, it is being explored the communication with owners ERP for financial control based on the technical information that supports the invoices and payments. The following image resumes the possible actions [116] [117] [118] [119].

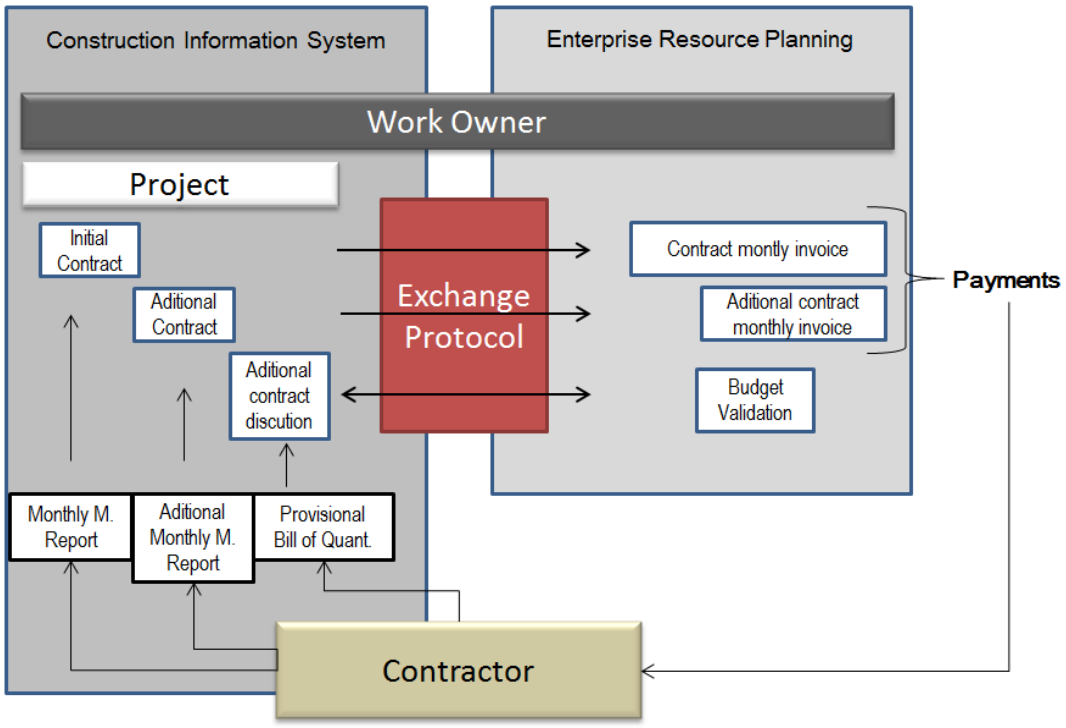


Fig.4.16 – Processes during construction stage, where communication between ERP and CIS was found essential

4.2.9. REMARKS

ProNIC is nowadays more than a CICS or a R&D project or an application. It is a methodology to support from an integrated and collaborative point of view a construction project from the design phase until completion. Its roots and main focus continue to be the technical information that supports the written parts of the design. Despite all the potential and functionalities, this technical information is the added value and the main element, as it is the base for all the actions, the support of all the functionalities and the differentiating point from other tools. The ability to fit to more agents, types of constructions and works, is possible and it is being explored, followed by the WBS-CW revision to support new types of construction. Regarding the CICS part, the developments led to new tables, namely (and given the references from chapter 3) agents, roles, phases, elements, systems and materials (the last three within WBS-CW).

It is worth to highlight the work that is being performed regarding the preliminary stages of the design phase, namely the possibility of skipping the introduction of measurements and quantities in a determined stage and the possibility of calling articles for the project without its full parameterization. Some of these topics are related with the proposal explored on point 5.5.

The author's involvement in this project has been mainly on the production of the technical contents and the definition of the system solution design. During the implementation on Parque Escolar, among the referred tasks, it performed a significant part of the training actions and managed the IC team on the users support actions.

Given the presented, ProNIC is a tool geared for Information and its integration across the construction life cycle. Notwithstanding, its environment contributes for the integration of the agents

involved on each phase and the integration of processes with the transparency for all users. The following figures help resuming the functionalities and outputs.

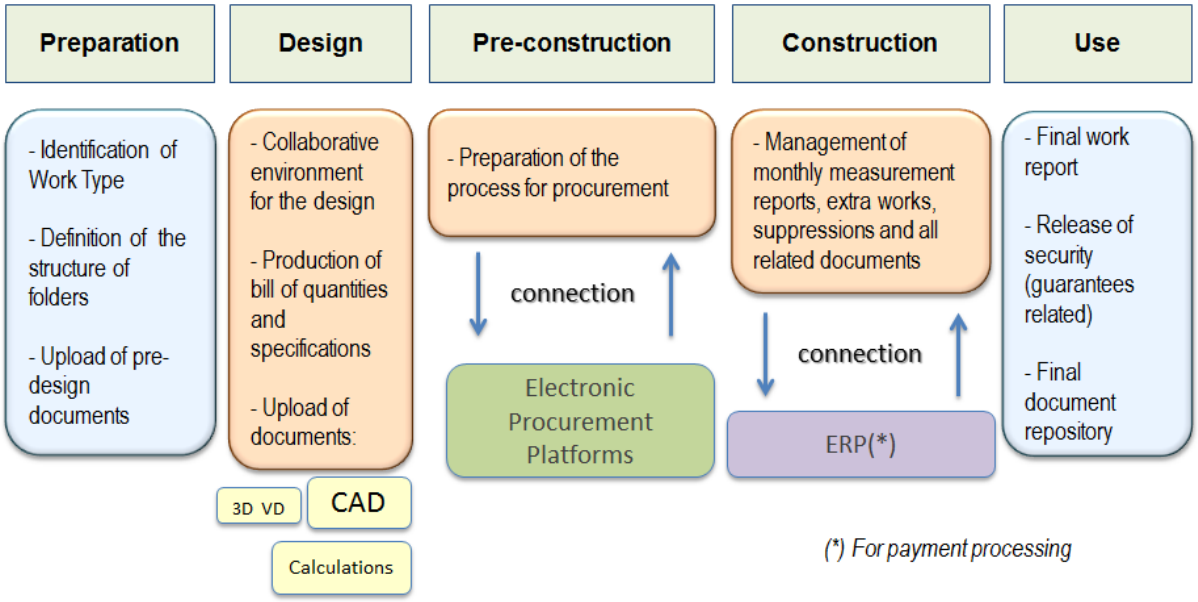


Fig.4.17 – Construction life cycle functionalities and information exchange with other tools

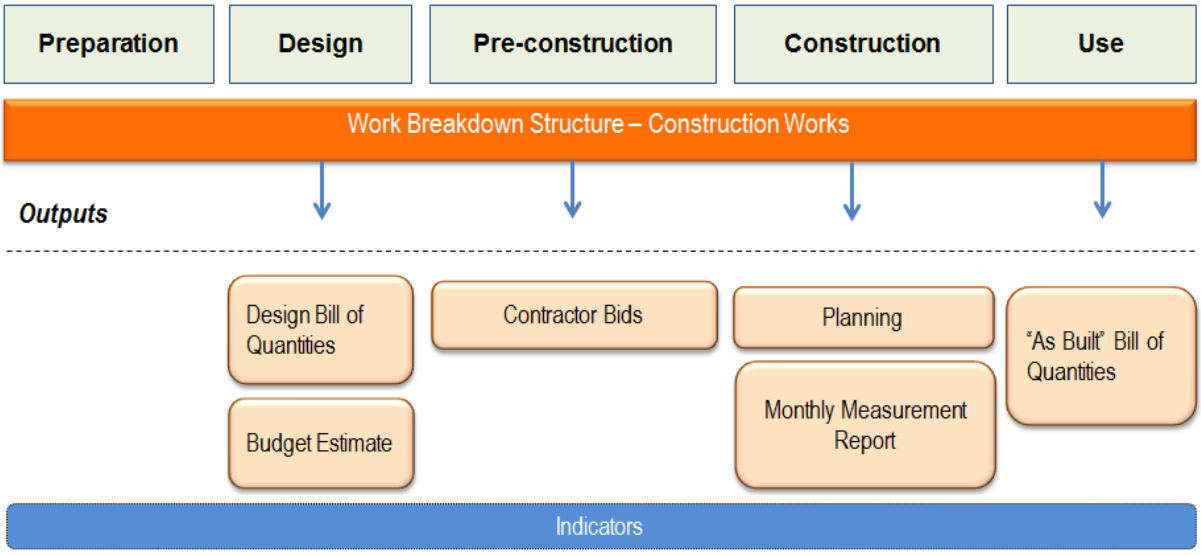


Fig.4.18 – Construction life cycle main outputs related with the WBS-CW

The ambition is the dissemination of this tool on the Portuguese construction industry and the continuous improvement in terms of information and functionalities. There are positive signs from the Government towards this action [120] that are supported by previous opinions from the Court of Auditors [121].

4.3. DESIGN INNOVATION – FINDINGS FROM TRAINING AT CROSSRAIL

4.3.1. THE COMPANY AND THE MISSION

Crossrail, Ltd is a company that was established in 2001 with the purpose of developing new urban railway lines across London.

It started as fifty/fifty joint venture company between Transport for London and the Department for Transport. In 5th December 2008, it became a fully owned subsidiary of Transport for London. Crossrail represents a real commitment to the development of new services to tackle the lack of capacity and congestion on the existing London rail network.

The main civil engineering construction works for Crossrail are planned to be completed in 2017. Fit-out of stations and testing will continue afterwards. It is expected that Crossrail services will commence on the central section by late 2018, followed by a phased introduction over several months of services along the rest of the Crossrail route.

In terms of numbers, Crossrail is nowadays Europe's largest construction project. The works started in May 2009 and nowadays there are ten thousand people working across over forty construction sites. The Crossrail route will run over 100 km from Maidenhead and Heathrow in the west, through new tunnels under central London to Shenfield and Abbey Wood in the east. There will be thirty eight Crossrail stations including nine new stations at Paddington, Bond Street, Tottenham Court Road, Farringdon, Liverpool Street, Whitechapel, Canary Wharf, Custom House and Woolwich. The total funding envelope available to deliver Crossrail is 14.8 billion pounds.

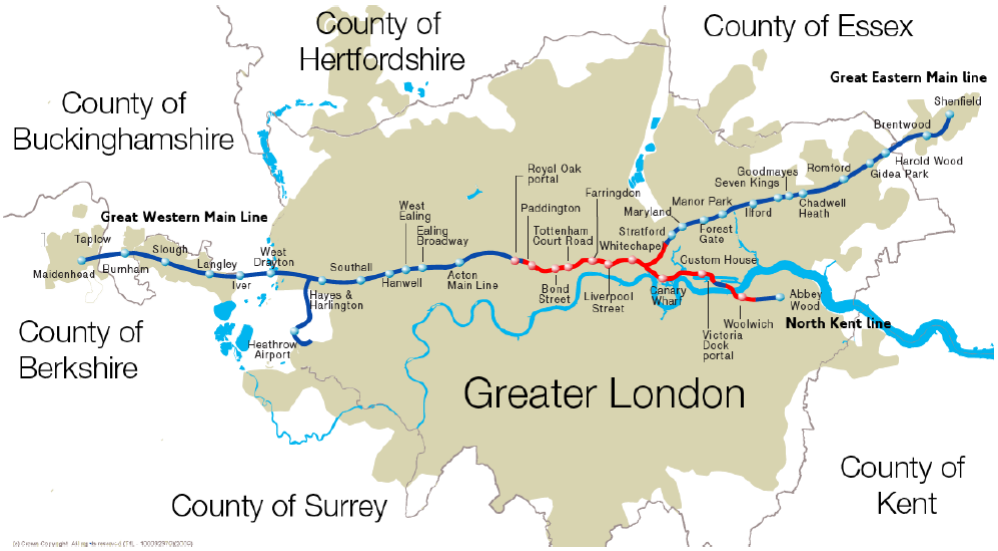


Fig.4.19 – Overview on the Crossrail project [122]

The expected timeline and future milestones are the following:

- 2014 - In early 2014, Crossrail's final tunnelling machine will be launched from Pudding Mill Lane in East London. The contract for Crossrail's new high-capacity rolling stock will be awarded in 2014. By the end of 2014, the vast majority of Crossrail's twenty six miles of tunnelling will be completed and the major civil engineering works will be

complete. In late 2014, Transport for London are due to confirm who has been awarded the Crossrail operating concession from 2015;

- 2015-2017 - Major fit-out of stations and tunnels continues as does the major upgrade of the existing rail network for Crossrail services by Network Rail;
- 2017 - The first new Crossrail rolling stock will start to replace existing suburban trains between Liverpool Street and Shenfield;
- 2018 - In late 2018, the first Crossrail services will start through the central London tunnelled section;
- 2019 - In late 2019, the full Crossrail service will be operating from Heathrow and Maidenhead to Abbey Wood and Shenfield [123].

4.3.2. DESIGN INNOVATION - INFORMATION INTEGRATION USING BIM

Driving industry standards for design innovation on major infrastructure projects has been this company aim since the first surveying work that was undertaken in the mid-nineties. The detailed design work for the project using collaborative 3D environment was a core contractual requirement across all the design contracts.

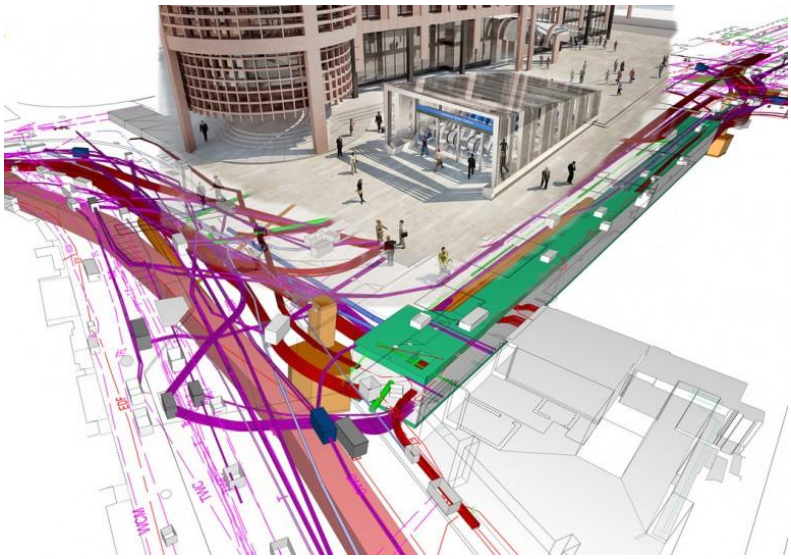


Fig.4.20 – 3D visualization of part of Crossrail project [123]

For Crossrail, BIM is the process of generating, building and managing data through the life of the project by using model-based technologies linked to a database of project information. BIM incorporates data – physical, environmental, commercial – on every element designed. A BIM environment has not been created on this scale for a European transportation infrastructure project before and, by doing it, the efforts and focus are on exploiting the opportunities that BIM can bring not only for the delivery of the railway, but perhaps more importantly in driving forwards design innovation within the construction industry. One of the other fundamental key focus is the long-term cost savings that can be produced through the use of the BIM model (following Crossrail requirements), namely by providing accurate information that can be handed over to the operators of the railway for managing assets on the post-completion phases.

The Crossrail project involves nowadays twenty five design contracts, thirty main works contracts and sixty logistics main works contracts that have a large number of interlinked interfaces within the complex and sensitive urban environment of London. All this information is standardized and it is stored within a centralized information model. There are some main aspects of this design innovation strategy that worth to be highlighted:

- All of the design to-date follows a coordinated and consistent set of 3D rules and processes. In order to successfully manage all of this design data, it was adopted a central software model for all 2 and 3D design files using BIM;
- CAD files are created, approved and integrated within the centralized information model;
- The 3D design information model is hosted by the company and it is provided to the construction contractors. There is the hypothesis of moving across to the operators and maintainers of the railway;
- The previously referred topics allow a significant reduction of information loss between contracts and project phases, reducing project risk by giving greater visibility into design and construction processes, and leveraging technology to make delivery more efficient and economical as well as less disruptive;
- The integration of all the design models into one centralized set of linked databases allows the creation of detailed still and moving visualizations of specific elements of the project – ability to bring to life elements of the project years before the actually beginning of the construction work. This also allows to be significantly more effective during the design and construction stages – it enables the spatial relationships of all the component elements to be defined and this ensures that there are no clashes between say, the mechanical engineers duct work and the structural engineers concrete or steelwork;
- Engineers can visualize many of the complex utilities in and around the stations in 3D. This ensures that anyone working in the vicinity of the proposed stations is readily aware of the intricate and complicated weave of pipes and cable under the streets that need to be avoided or protected;
- When each work package is completed, the CAD models are updated and re-integrated to the central database. It is possible to link this to other centralized databases, ensuring the ability to visualize existing component elements alongside other related data such as Crossrail asset information, specifications, operating manuals, etc.

It is expected that the implementation of these innovations will lead, among others to the following key benefits:

- **Reduction of risks** from greater visibility into design and construction interfaces and activity;
- **Improved safety** through increased construction awareness from easy review of complex details or processes on site;
- **Reduced errors** from using a trusted "single source of truth" approach to data management, for example ensuring only the most appropriate version of models, drawings and documentation is used;
- **Improved collaboration** through linked data sets and integrated 3D models that create a "virtual" project before the physical project is constructed, allowing design and construction refinement;
- **Reduced information loss** between project phases, ensuring we capture and hand over full asset information into the operations and maintenance phases;

- **Improved project delivery** leveraging technology advances including data interoperability and mobility.

4.3.3. TRAINING ACADEMY

It has already been referred that the success of the changes depends on a knowledgeable and engaged workforce. To achieve this desired condition it is necessary to structure and perform training and development opportunities to help and motivate the employees, as well as the service providers. Crossrail developed a training academy that provides both formal and informal training and development opportunities designed to help employees grow in their jobs and careers. This academia intends to give opportunities to:

- Attend training sessions designed to help the practitioners to improve skills further in their current role;
- Be involved in projects to build experience and preparation for the next role on the global project;
- Gain further qualifications in areas that help to improve their specialist technical ability;
- Apply for professional development;
- Receive coaching and feedback through formal and informal mentoring relationships;
- Participate in continuing development opportunities.

4.3.4. TRAINING SESSION

In order to improve the understanding on Crossrail's innovative design endeavour, the author participated in a training session in London at Bentley's headquarters, where it is based the Crossrail academia. The session was initially geared to contractors, but due to the attendance of practitioners that play other roles on the construction process, the scope became broader. This occurred on the 4th September 2013. The session's agenda was based on an introduction to the learning academy and awareness sessions focused on:

- Document Management;
- Management and Control of Design Information;
- Assets Information Provision;
- BIM in Delivery Working Group.

Before the end there was a breakout session with training pods and questions and answers. The following points address to the contents from the session that are considered more relevant for the discussion.

4.3.4.1. Introduction to the academia

Before the beginning it was delivered through all the participants a glossary with the session main terms, in order to improve the correct understanding of all the attendants. This was divided in two parts with terms that address in general to CAD issues and to Asset issues. Regarding the first it was interesting to find that the four terms were:

- ProjectWise, a EDMS used by Crossrail;
- BS1192:2007, a standard already mentioned;
- Uniclass, a CICS also already mentioned;

- RIR, that means Register & Issue Record.

This first session had the intention of showing the importance of the academia within Crossrail universe, within the UK BIM strategy and to enlighten about some of the strategic decisions that were taken.
The academia, like previously referred, is important to train and motivate all the practitioners involved on Crossrail project. For this entity, the main issues regarding the implementation of BIM are related with:

- the amount of people (fragmented industry);
- their different understandings (absence of standardized terms) and;
- the differences on the way the work is performed (common practices and software).

Given Crossrail's project dimension and ambition on innovative design, the solutions to these issues were identified at the very beginning. One that the author finds essential is related with the software. In this situation, the company is not just the work owner it is also the software provider. All the people involved on Crossrail global project need to use a set of software that is supplied and supported by the work owner. This eliminates the ambiguity and compatibility problems between different versions of the same software and discrepancies between different software with the same purpose. Information integration and peoples training becomes simpler because, in essence, the tools are the same. One other identified aspect is related with the design phase, where there are many disciplines that potentially work with different approaches. Often, the design phase is an outsource operation regulated by a contract. On most of the situations, Crossrail hired professionals to integrate its structure and to form design teams. This situation also tends to eliminate different understandings and helps the settlement of common working methodologies within and across design projects. Contractors are hired, yet their involvement comes quite after the beginning of the construction, as they need to perform the training and at the same time make contact with the final part of the design phase and take place on their part of the project.

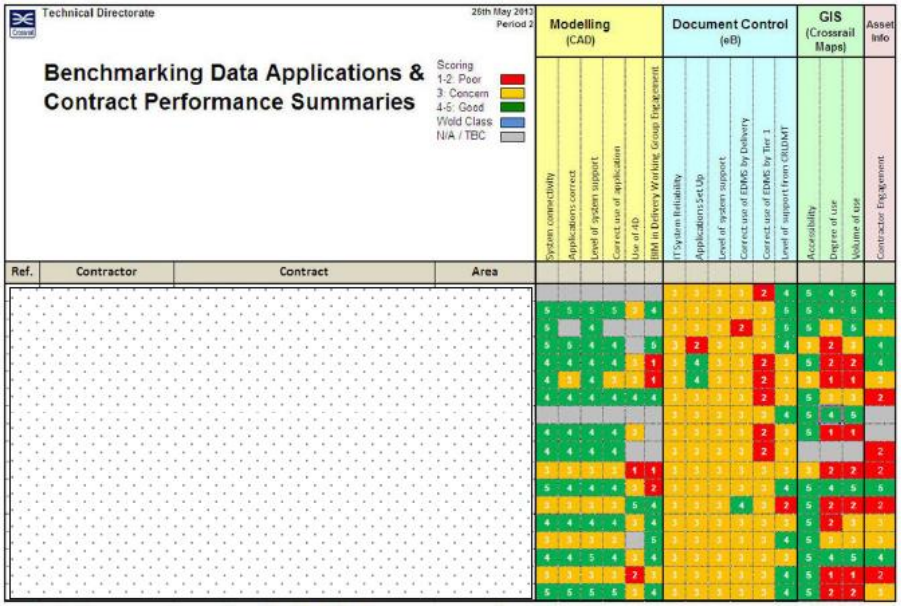


Fig.4.21 – Example of results from contractors evaluation, annex 2

The training is thus focused on the functionalities of those specific tools, on their technical details and on the finest practices to attain the best project delivery. All the training that is performed with contractors is submitted to a periodical benchmark for the contractor performance evaluation and its commitment to the targets/goals.

In this first part it is also highlighted the importance of the adoption of these methodologies, given the UK Government commitment towards BIM implementation and it was explained the meaning of the term for the company. The term can be defined by the topics:

- Connection of Data (Documentation, 3D Models and Mapping);
- Creation of virtual assets, not just physical ones…
- A set of processes that began some years ago...
- Integration of data for design, construction & operation life-cycles;
- Collaborative management of all types of data;
- "Single source of truth".

4.3.4.2. Document Management

This session was geared to the procedures for information management and document control.

All the information that is produced on Crossrail projects is managed and stored on a Bentley software named eB. eB is a cloud based Electronic Document Management System. All the practitioners that work in or for Crossrail have access through a User Name and Password that sets specific permissions according to the project, type of institution and the professional role or task. This access is given by a central contract site administrator that manages all the permissions to access to the software.

All the documents need to be approved before becoming available. One example is the validation of documents during the construction stage. This approval needs to be performed by two professionals, one responsible for document control from the contractor side, and the Crossrail document controller. The documents have lifecycle states due to their approval process during creation, and for their versioning. There are four life-cycle states for the documents that are:

- Not Approved – Draft (red);
- Approved – Current (green);
- Approved – Current (new revision - yellow);
- Approved – Historic (old version - grey).

All the documents follow a standard nomenclature that underlies several classification principles. This nomenclature might seem unnecessary for a designer of a determined discipline, yet all the practitioners need to be tuned that all the work they are producing will be stored for the following phases, and that their project is only a functional part of the Crossrail's global project. Therefore, the nomenclature of the documents considers the contract, the originator, the discipline, the document class, the location and the document number.

The process may seem complicated and time consuming, yet if all interveners follow the same principles and if work in a disciplined way the process works straight and without struggle.

4.3.4.3. Management and Control of Design Information

The main principle of the Data Strategy is:

"To create an integrated design, facilitating multidisciplinary collaboration throughout the life of the Project, becoming the base for an asset management system."

Given this, the system solution design needs to attend to the Customer requirements (Transport for London), the potential number of users, the industry standards, the workflows, the data legacy, the security issues, as well as the multiplicity of office locations and worksites. These business requirements combined with the option of using Bentley products led to the use of two core applications that are ProjectWise and MicroStation.

These applications need to have few customizations to meet the specific needs, given the type of constructions and the dimension of the global project.

BS 1192 [82], as referred, is the standard that establishes the methodology for managing the production, distribution and quality of construction information. Each contractor has its own set of good practices but consistency was necessary in order to fit everything and work together seamlessly. To help accomplishing it, the BS 1192 processes were implemented in ProjectWise. Specific procedures were also developed to integrate railways technical issues and CAD standards (many of them are now part of PAS 1192-2) [83].

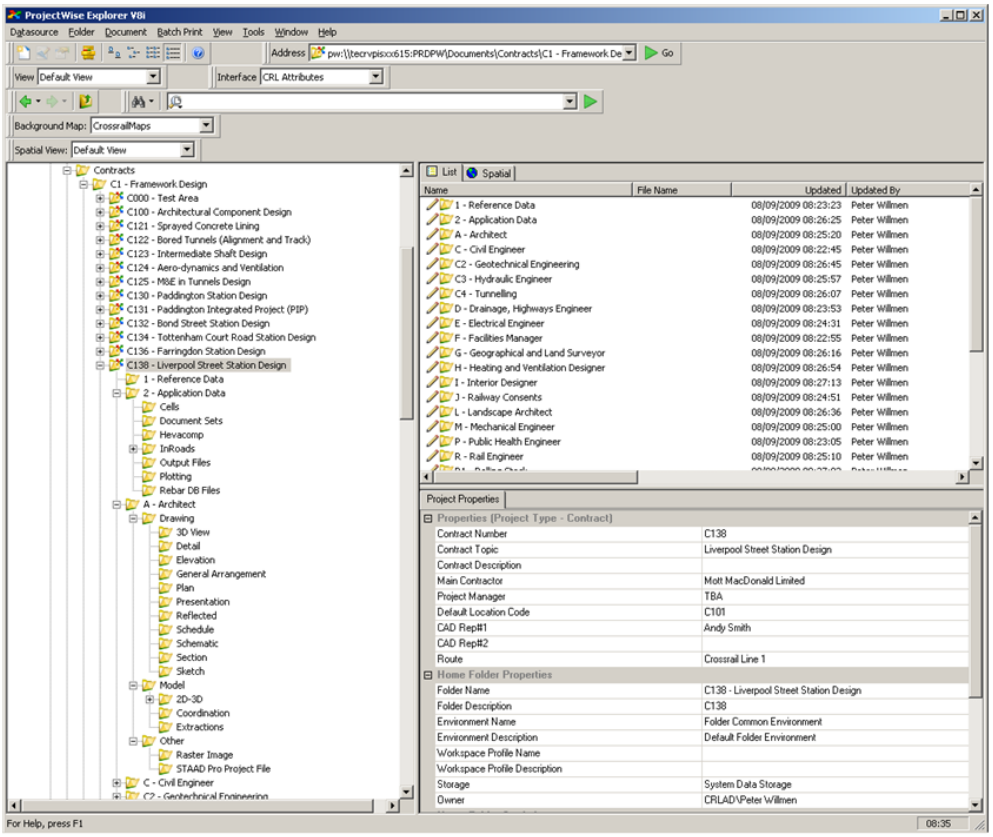


Fig.4.22 – ProjectWise Folder Structure

One of Crossrail's BIM mainstreams is that, its adoption for the information management from concept to grave implies sharing information with the right people at the right time, and ensuring that information is structured the same way by all interested parties. This requires a unified approach to

classification. It is also important that the classification is unified so that, at each phase of the life cycle of any construction project, information can be developed following logical principles. The current UK CICS is the already mentioned Uniclass. This system is considered a good framework but it is not well aligned for mapping from one table to another. Given this, Crossrail has been performing some changes and has set some proposals for Uniclass unification and improvement; development of Uniclass 2 [67].

The main desktop applications working in collaboration that allow the information workflow through the construction life-cycle phases are therefore the ProjectWise, the eB and MicroStation.

4.3.4.4. Asset Information Provision

The presentation started with the definition and application of the term and the key principles of the asset management, namely the necessary differences between the traditional asset information timeline and the approach performed by Crossrail.

The term is in general used to represent:

- A physical thing that delivers rail services e.g. train control;
- A physical thing that provides supporting services e.g. compressed air;
- Any grouping of the above.

The asset record should go down to the level of the object that is expected to be maintained, e.g. water pump and not pump motor bearing.

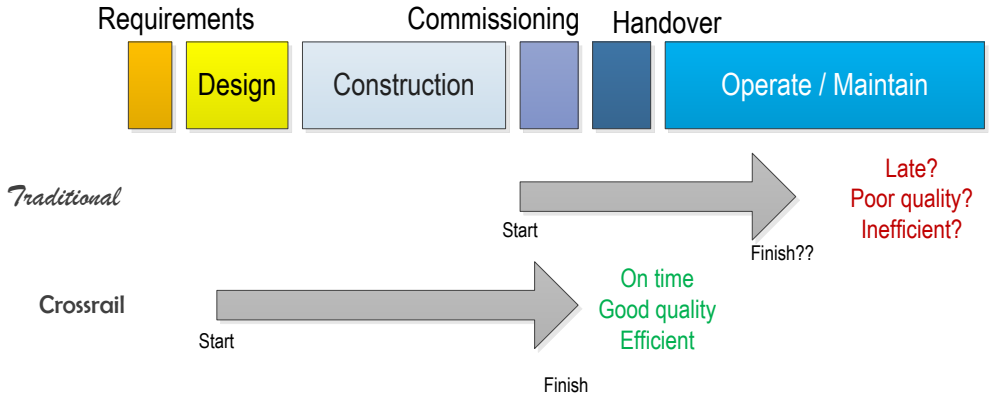


Fig.4.23 – Traditional VS Crossrail asset information timeline

The eB application has a specific module that works as AIMS, allowing the link between documents and assets. All the assets, in order to be maintained need to be defined and tagged. The information regarding these assets comes from the previous phases. So, like evidenced on Fig.5.6, the assets definition is performed on the design phase envisaging their operation and maintenance. Each asset will have information fields to support the Tag, the Equipment and the serial number.

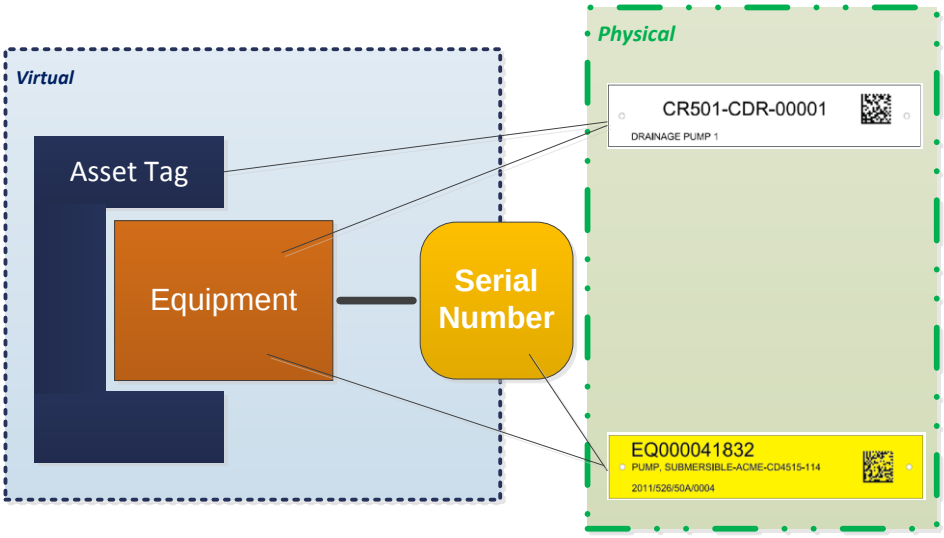


Fig.4.24 – Asset Representation – Asset Tag Label and Equipment/Serial Label

The Tag will have information about the asset location, its classification and its function (what is the asset designed to perform). This information is standardized and it is ruled by the Asset Data Dictionary. This element defines the types of assets that have interest, the relations between classification and function, among others. The asset classification is performed in accordance with Table L from Uniclass (Construction Products). Nevertheless, and as it was already mentioned on this and on previous chapters, the specificities of a railway infrastructure are different from the buildings. Due to that, additional classes were added to Table L. In respect with the locations, these need to obey to the Crossrail location system.

The specific equipment and serial number are defined during construction and the information needs to be placed by the contractor in accordance with the asset information pack. All the assets will be identified with an Asset Identification Standard, see Fig.5.6.

4.3.4.5. BIM in Delivery Working Group - BIDWG

All the effort that is being performed by all the practitioners must be driven to the implementation of best practices and to perform innovation. Working on this project shouldn't be faced as "Business as usual". On the contrary, this involvement and effort should be targeted for the "Exploitation and adoption of technologies", namely with the following objectives:

- Establish discipline specific modelling based on industry recognised open standards;
- Ensure that these standards are consistent with those required by the end user;
- Influence contractual requirements for BIM to support Delivery;
- Identify software limitations to ensure information integrity and quality;
- Understand how to align modelling standards to assets, schedule and cost.

BIDWG encourages new thinking and the identification of opportunities for increased efficiency and automation to improve project delivery, involving all the practitioners of the construction supply chain. These were challenged to participate in task groups that develop initial ideas into a business plan for approval, identify key metrics and conduct field trials to demonstrate and measure value. The task groups that currently are working are geared to Modelling, Mobility and As built data collection.

Once again the emphasis is on a collaborative approach engaging not just Crossrail technical and delivery teams but also tier one contractors, designers and delivery partners.

4.3.5. REMARKS

The training session, the questions and answers and some discussions during two days with Crossrail and Bentley personal allowed some interesting understandings.

This endeavour aims the full integration of the life-cycle, in which BIM is a lot more about information management that what often people think. Usually, when people talk about BIM what comes to the mind is 3D elements and applications like Revit, Archicad or Microstation, just to name few. The major concern in Crossrail is using BIM to integrate people, project stages and information, where the 3D plays an important role but it is highly dependent on the information reliability. The correct definition and classification of all the parameters, the definition of work procedures, workflows and common work practices is the hardest and yet, not hidden face of this project implementation. As mentioned backward, this level of commitment was possible due to the overcome of some issues that are reachable only by few work owners. This project dimension allows the owner to settle the applications that will be used, train all the involved agents and demand from their service providers. On most of the projects each agent uses their own applications and interoperability problems start to come in. In addition is the usual problems brought by the common fragmentation of processes. And one that is found the most important that is the enlightenment of the work owner on the project that will be performed.

4.4. CONCLUSIONS

The two presented experiences were detailed in different levels and do not report all the work that has been developed by the author. It was found interesting to detail only the general lines of the activities and explore further the topics directly related with the discussion topic. Highlights of ProNIC were presented to establish connection with the following chapter.

The testimony of these two experiences has the intention of evidencing the main concerns regarding the issues under discussion and showing the actions that are taking place at national and international level, exploring their potential impacts.

Peter Vale, Information Manager at Crossrail, shared its state of mind regarding the power of the information that will be delivered at the end of the project: “This change of mind is demanding for all the practitioners and it may involve substantial expenses that usually were not foreseen. Nevertheless, how much will we be able to save just by knowing what is happening with each asset instantly, and have all this information available and ready to be used since the day one?”

5

INTEGRATED DESIGN & DELIVERY SOLUTIONS – DISCUSSION AND SPECIFIC PROPOSALS

5.1. CHAPTER OVERVIEW

This chapter has the main purpose of framing the technical research, strategies and experiences with the CIB reflections, namely the strategic research roadmap for Integrated Design & Delivery Solutions [5]. A general overview of this document is performed, enhancing the most relevant aspects for the research subject. Specific attention is given to the major aspects related with IDDS, as well as to the main requirements and elected topics. These will be discussed from an international and national point of view, exploring the potential actions that can push them forward. From the discussion and future trends, specific proposals that fit the topics and the integrated construction organization goals are presented and explored.

5.2. IDDS ROADMAP

The development of a specific roadmap for IDDS came from the awareness of the changes described on chapter two and from the importance and impacts they have on the industry. Many research centres around the world have been investigating particular aspects that are relevant for the industry on a regional context. These particular aspects are essential. Nevertheless, it urges to settle a limit from which the research might have broad impacts. One of the evidenced examples from the past was the individual development of CICS. On this global context, the collaboration issues are placed on the scientific development in the same way they are placed on a project, i.e. it matters exploring what is being developed, and follow, at least until a given level, the same general lines and information that is provided and validated by many organisations. Thus, CIB aims to stimulate the worldwide needed research to support this innovation, and the execution of this research such that its collective outcomes lead to maximum benefits.

The Integrated Design and Delivery Solutions (IDDS) priority research theme takes a higher-level view of the changes and then focuses down on a prioritised set of research targets. These targets have been investigated, re-focussed and validated over a large period of time and by many entities and organisations worldwide.

5.2.1. THE TERM

Integrated Design and Delivery Solutions (IDDS) represents a vision of a revitalised sector based on the smart adoption of new processes, developing a workforce with enhanced skills and supported by information and knowledge technologies, leading to an accomplishment where people with traditional and new skills practice more collaborative and communicative processes, supported by pervasive, but nearly transparent, knowledge and information based technology [5]. Thus:

"Integrated Design and Delivery Solutions use collaborative work processes and enhanced skills, with integrated data, information, and knowledge management to minimize structural and process inefficiencies and to enhance the value delivered during design, build, and operation, and across projects." [124]

This vision is supported by new processes, methodologies and philosophies that should constitute research areas. Figure 5.1 resumes the called "*three imperatives*" towards IDDS, and the main topics that leverage it.

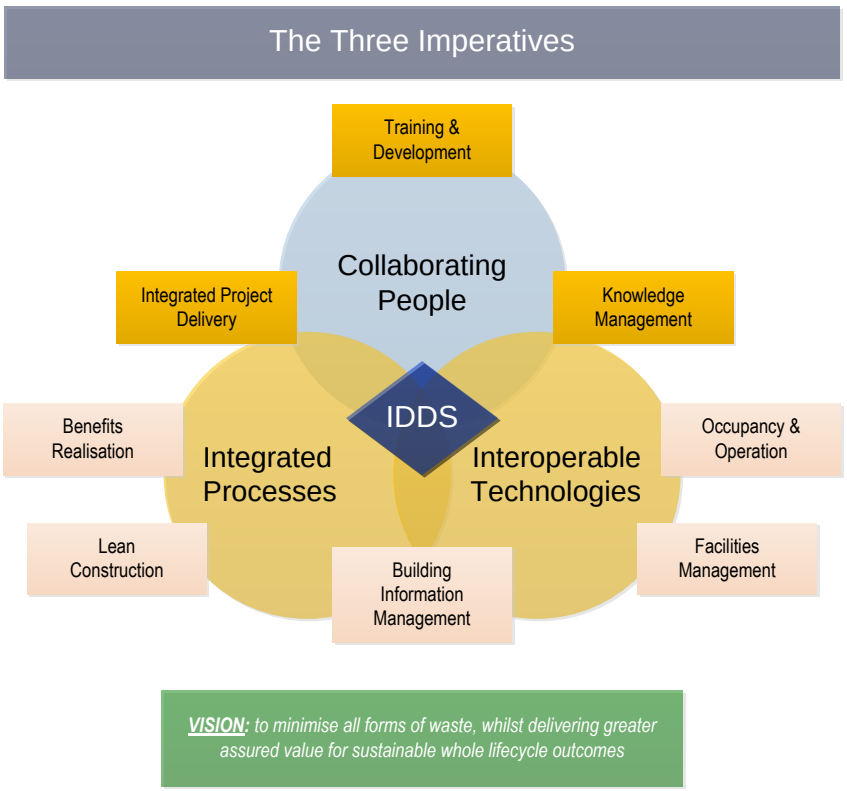


Fig.5.1 – The imperatives for IDDS vision and major concepts/research areas, Based on [5]

Given its importance, relevance and what was previously described on chapters 3 and 4, a brief overview on the understanding of BIM is presented. This aims to provide a resume of this concept, and the different visions in discussion.

5.2.2. BIM – BUILDING INFORMATION MODELLING

BIM is one of the most recent acronyms in the AEC world.

The origins of BIM date from the end of the 70's, meaning the data modeling of construction products [125]. The term was used on the beginning of the century by an Autodesk architect, Phil Berstein, and it was spread out by Jerry Laiserin as the designation for virtual design [126]. Various groups around the word are using the acronym at the same time, but with different meanings. BIM as already fallen into the same use, abuse and misuse that CAD, CADD [127] and CADFM did. At best, these acronyms provided a rough guide to what was being discussed; at worst they led to endless debate on whether the "*D*" stood for design, drafting or drawing, a debate which produced nothing of practical relevance. The same interpretation problems are placed for BIM. The individual letters conjuncture images. "*B*", Building; for some it means an envelope and everything within it, for others it represents a wide view of a building and its surroundings, infrastructures and landscape (built environment). The word is somewhat restrictive as it does not consider a broad range of policies, strategic decisions, life cycle considerations, among others. "*I*", Information, is quite straightforward if taken at face value, and is probably the most important word represented in the acronym. The "*M*" is interpreted in two quite different ways; model/modelling or management [59] [128].

Given this, the term should be interpreted from a broad scope as an innovative methodological approach in construction, based on information management and virtual design. Otherwise BIM should be like beauty; is in the eye of the beholder. More than discuss the acronym and its meaning, it matters to understand its ingredients that can be considered the following:

- 2D/3D graphic databases;
- object libraries embedded on software platform;
- common procedures and workflows to foster collaboration;
- 3D parametric objects;
- classification standards.

The scope of BIM can be thus explored from a narrow perspective where a designer uses a 3D software to perform its discipline drawings, without any concerns regarding the information organization of its elements, neither the compatibility with other disciplines (it is possible to discuss if this should be considered BIM) to the example of Crossrail presented on the previous chapter.

In today's world information is king [59]. Like referred, construction is one of the heaviest information producing industry sectors [96]. Never have there been so many parties contributing information to the built, used and recycled product.

BIM represents the realisation that information cannot be produced in silos, whose contents rarely pay attention to their neighbour. BIM is a force for co-operation and teamwork. The important and far more powerful idea is that the current interest in BIM provides the potential for a more positive and beneficial way of creating the information asset required for producing, managing and using the building stock [59] [129].

5.2.3. THE TARGETS

As referred, in order to improve the industry, there is the need to set smaller objectives that can be checked towards the global completion. The performed research led to four main targets with groups of objectives. These targets where set to be accomplished at near, mid and long-term. Figure 5.2 reproduces these targets and objectives.

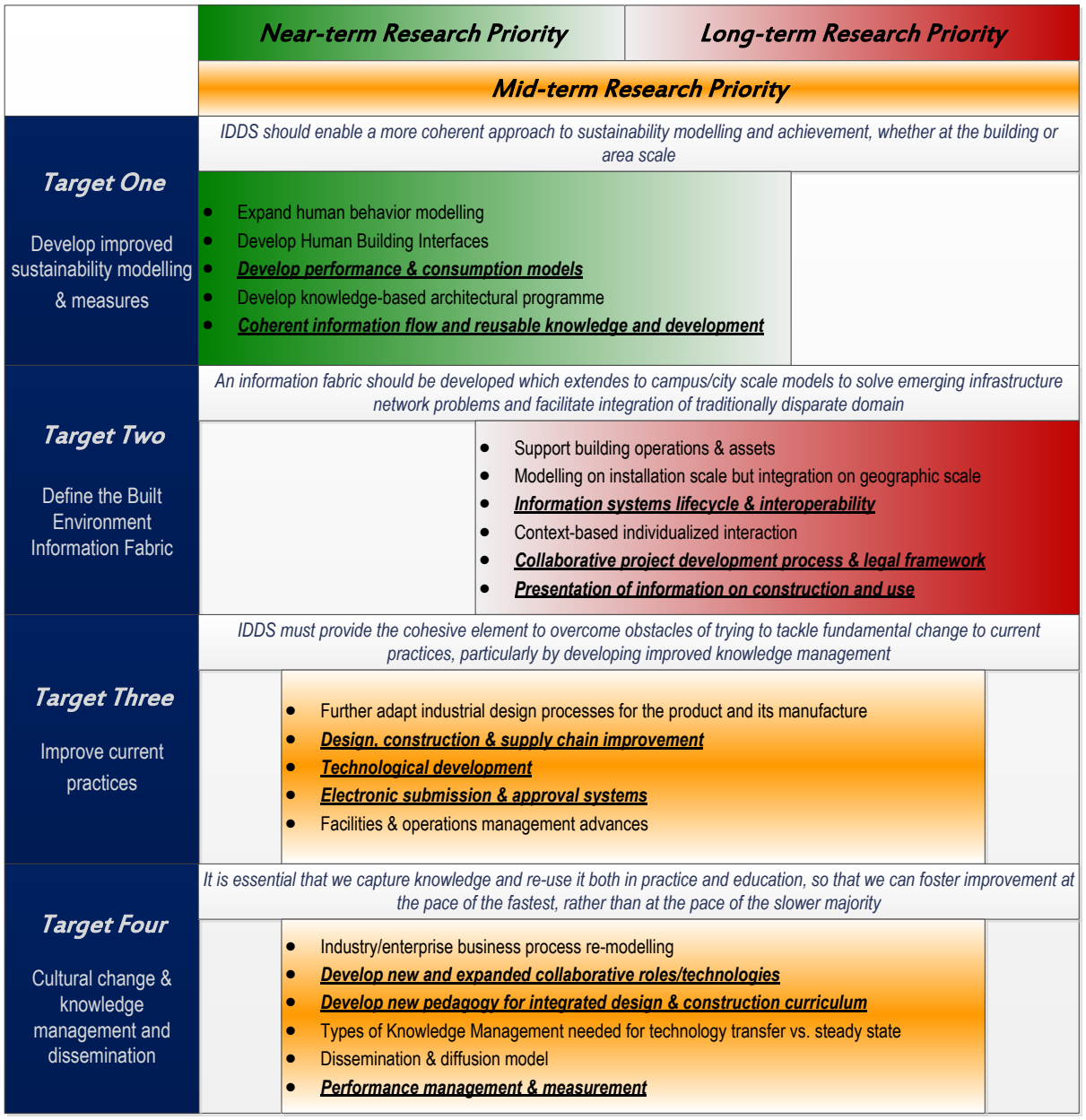


Fig.5.2 – IDDS general targets and topics under discussion [5]

The targets one and two are geared for the IDDS value delivery improvement in the real world. Targets three and four are concentrated on assisting in the changes which are already being performed in several countries around the globe. They will be discussed further from a national perspective and framed with the strategic guidelines.

5.3. DISCUSSION TOPICS

The research agenda towards IDDS sets, as referred, the four targets and main objectives. From these, a group was identified has being more framed with this document scope. They will be explored and discussed based on the IDDS research agenda, on the strategic EU documents and necessarily from a global construction sector point of view, pushing to the national needs. This reflection as the intention of launching the discussion, giving a knowledge overview and the author's opinion about specific situations:

- Target One – topic 3 – "*Develop performance & consumption models*"
  The research agenda points, on this topic, for the development of models that, at near-term, could improve construction reducing by 20% its defects, defining methodologies that may contribute to the efficiency, and forms to reduce the waste, in terms of cost, quality, time and rework. This topic frames essentially on the strategies for Sustainable Growth, namely "An industrial policy for the globalization era".
  Seeing it as a near-term accomplishment, the implementation of systems like ProNIC would foster the efficiency, namely in terms of works cost monitoring and terminating many of the rework situations. In what regards Portuguese AEC industry, the tool is ready to be disseminated. From a global point of view, it is demanded that professionals follow the standards and technical documents. As it was proved, there are many good manuals of practice and guidelines that could help improving some of the common practices. Many of these can be adapted to other realities or can be used as inspiration for the development of new ones. Training actions to recycle apprehended skills and to continuous professional development should be fostered, supported by the referred publications. In what concerns specifically the contactors, the adoption of Lean thinking will help on overcoming some of the wastage. For both situations the short-term actions should be framed with a long-term strategy, where life cycle analysis for construction materials and entities will play a leading role.

- Target One – topic 5 – "*Coherent information flow and reusable knowledge development*"
  The research agenda highlights the need for coherent approaches on sustainability. The wide range of tools and techniques, and namely those addressed to the sustainability analysis, are geared for individual aspects and lack on global and integrated approaches. This leads to sub-optimal decisions during the design phase and fosters the misunderstandings. This topic is as basic as essential. It frames nearly all the strategies according with the information that is intended to be matched. The proposal presented on point 5.4 explores the potential problems and impacts that urge from the wide range of tools and systems available to perform the same or similar processes. From a global point of view, the use of ICT helps overcoming these problems, namely those geared for the analysis of sustainability. Common referential should be developed and embedded on the different systems so they can achieve to similar outputs. If this does not happen, the sustainability analysis will become vague and subjective, i.e. meaningless, what, according to the roadmaps, is considered unacceptable.

- Target Two – topic 3 – "*Information systems life cycle & interoperability*"
  It is foreseen an evolutionary scenario, where the outputs from the design and construction are updated and operated during the use phase. The systems need to produce, store, receive and process information from different origins and have correct interpretations. Standards and agreements will be required to support the very basic underlying structures of the information fabric. This includes aspects which in today's database research would include: ensuring adequate privacy of sensitive data and access controls for users dealing with the data; ensuring that adequate provenance is recorded for all data and its estimated reliability within the models, among others. The digital agenda for Europe frames most of the developments within this topic. It is a long term achievement that will require new understandings and skills. Therefore, training will be essential. Regarding ICT, that is the main scope of this topic, it will be essential the development of wide systems that can fit all the needs across the construction life cycle (what may seem difficult) or the development of several systems that together cover all the phases and agents needs, through the definition of a chain of processes and exchanges that enables their integration, communication and information flow [130]. The last system should be capable of manage all the construction entity/complex and receive information from sensors or equipment that are operating within the construction. Important note worth's to be presented regarding the systems requirements, in terms of upgrade and reconfiguration across the construction life cycle [131]. Strategies for this trend must be envisaged, using all the available tools and setting targets for new developments and steps for the accomplishment. Point 5.5 explores one possible example of this information exchange/interoperability.

- Target Two – topic 5 – "*Collaborative project development process & legal framework*"
  Perhaps one of the most important topics listed. The term collaboration has been quoted over and over along this work to define working with effective communication i.e., as a real team. In essence, it is possible to have all the technology, all the guidelines and do not get to the expected results, due to the absence of collaborative work. Regarding this, it is found essential the inclusive growth targets, namely regarding training, new skills and work mentality. This should be fostered between agents working on the same phase of the construction life cycle (example given for the design phase and its fragmentation), but also across different phases. This will help realize why things are carried out in a determined way. Related with this is the construction legal framework that should be adapted to this kind of work and methodologies. The developments should be performed envisaging changes on the legal framework, namely on situations related with document delivery and traditional working requirements. One example in the Portuguese legal framework is the data compilation that needs to be delivered to the owner at the end of the construction. If there is a collaborative project development, the produced information is stored in a single place across the phases prior to completion, being ready to be used. A situation that can be placed is if it fits the needs of the following phases. The requirements become the definition of the information that is demanded, rather than the delivery of information that cannot be identified. This purpose is the main achievement of the previous and following topics. The legal framework must embed the outputs to provide easiness instead of create obstacles. The rationalization of services and the adoption high level administration for construction projects would help on the achievement of this topic. The complexity of the legislation can be, as referred, a factor of

intricacy. Nevertheless, the different understandings of the same legal diploma and the processes to comply with the prescriptions open way to heterogeneous approaches. The proposal presented on point 5.6 explores this theme.

- Target Two – topic 6 – "*Presentation of information in construction and use*"
  This topic picks up on the legal framework demands referred previously. The research strategy points to the investigation on protocols to turn a model into a base of information and knowledge, for users. Accepting that a BIM will be the repository of significant quantities of information onto a building and across its lifetime, it will be necessary to find methods to repurpose this information for the myriad of users. Each one will have very different information needs, framed by their action/role or facility use context. As well as the previous, this long-term topic as a wide scope. The experience referred on chapter 4, namely the point 4.3.4.4., reveals the importance of this subject. The sense that all the information is produced to fit the needs of further agents is essential. The presentation of information in construction and use, underlies the need for correct information production and management during the design phase. This is incorporated on the mid-term targets that it will be following explored. In essence, the information produced during construction should be created and stored in a way that it would be useful for the operation phase and for the development of all the maintenance methodologies.

- Target Three – topic 2 – "*Design, construction & supply chain improvem*ent"
  One of the identified construction basic needs. The research agenda addresses one of the longest texts to this topic. It worth to highlight:
  "For early design phases work could be undertaken on reusable object libraries containing the attributes and information for objects that are typically being required by BIM tools at the stage when architects do not typically make these decisions".
  "move towards code compliance checking could be refined to enable early designs".
  "encapsulating notions of level-of-detail at various phases of a design, adopted across disciplines to ensure appropriate and complete information flows".
  "approaches to providing code compliance advice at early stages, further work on simulation and optimization approaches for early design phases should be investigated".
  "decisions at early design phases have the greatest effect on building performance, it could be beneficial to ensure that simulation systems could be accessed at these stages".
  "greater collaboration and coordination across all professionals".
  "In inspecting information flows there would also seem to be potentials for the elimination of duplicate design processes" [124].
  These are just few of the parts addressing to this topic. Chapter 4 presented few actions that contribute to this achievement. These requirements fall within the "*Industrial policy for the globalization era*", namely on the "*new industrial innovation policy*" and "*promoting industrial modernization*".

- Target Three – topic 3 – "*Technological Development*"
  This topic is closely related with what was referred on target two, topic 3. Yet, this is a mid-term target. Its accomplishment will help the achievement of the referred. In what respects this topic, the research agenda states the need of an understanding of the impacts that technology will have on the construction life cycle, as well as the new emerging areas that will appear. The construction industry is one of the industries that less invests

on technology [132] [133]. Notwithstanding, its agents are used to use mobile phones, and nowadays take advanced advantage of the smart phones potential. This opposite posture creates a contradiction within the industry that is urgent to solve. The implementation of ERP's on the construction companies constituted a first step to this status change [134]. The lessons learned from this process should be embedded to support the implementation of new technologies, as BIM and the use of "*apps*" on mobile devices (smart phones and tablets). In terms of framework, all the topics fit this demand because it is assumed as a main priority.

- Target Three – topic 4 – "*Electronic submission & approval systems*"
  The agenda envisages the accomplishment of incorporating electronic submission and approval systems in all countries. For all planning and approval processes the nominated public agencies should be able to deliver computable specifications of the regulations and local consent conditions. This would allow local checking and certification of designs prior to formal submittal to authorities. All the public agencies should accept digital models for their approval and consenting processes and ensure consistency and traceability through electronic process management for the delivered models. Investigation on emerging approaches to supply chain improvement, in particular, the expansion of electronic provision and tendering. It is envisaged that this could expand to include suppliers who publish IFC models of components and assemblies available online, or linking through to national product libraries for BIM.
  Regarding these goals, Portugal is giving strong steps towards accomplishment. Regarding e-procurement, and as mentioned on chapter 3, Portugal became the first European country that implemented this new form of tendering. Regarding the automatic code compliance check, several works have been developed [135] [115]. The topic should continue to be discussed and must be considered on the innovation agenda for the industry. The evolution to green procurement procedures constitutes the next step. The development of a common material platform with standardized information is an ongoing process, sponsored by APCMC. The actual project is setting the general lines and the system solution design. Notwithstanding the main objectives of the work, it is being performed in order to communicate with other applications, namely 3D virtual design tools, ProNIC, ERP's or electronic procurement platforms. This project will be further referred on point 5.5.2. Improved effort must be concentrated on these actions to accelerate and enrich what is already in operation, and to continue the development and discussion of the other mentioned aspects. These developments fit in the smart growth and sustainable growth priorities, namely the topics "*A vibrant digital single market*" from the "*Digital agenda for Europe*" and "*Improving framework conditions for industry*" and "*Strengthening the single market*" from "*An industrial policy for the globalization era*".

- Target Four – topic 2 – "*Develop new and expanded collaborative roles/technologies*"
  The research roadmap envisages a scenario in which all the information on a project is consistent, up-to-date, and available to all participants. This involves research into new models to define what information must, should or could be exchanged, when and between whom. Specification and tracking of information at this level, will lead to the establishment of new models of liability and responsibility within projects.

This management overcomes the construction processes. The highest level of project management will be a role played by the owner or other delegate entity, that will need to set the information needs in each phase, provide, control and manage the tools, the accesses and the way the processes are performed, delivering at the end of construction the project information package ready to be managed. This entity could go further and assure, by contract, the facility management. This highly technological and technic role will need to have improved skills on project management and ICT.
This type of processes will tend to leave behind applications that work on a standalone base.

- Target Four – topic 3 – "*Develop new pedagogy for integrated design & construction curriculum*"
  Regarding this topic the research agenda states:
  "It is essential that A/E/C industries capture knowledge and re-use it both in practice and education, so that we can improve at the pace of the leading edge participants, rather than at the pace of the slower majority. Improving knowledge management and dissemination should be seen as a short to mid-term goal of IDDS."
  It worth's to highlight the need for the development of new pedagogies for integrated design. A powerful approach towards this, is to identify ways to integrate education and training more closely to facilitate rapid sector learning.
  This target is related with the inclusive growth priority. Essential aspects to perform this development, is the need to gather the previous experiences on the implementation of wide programmes. This situation is placed mainly for the professionals. The implementation experience from ERP's, the lessons learn from Crossrail academia, and the training experience during ProNIC implementation on Parque Escolar, are few examples that should be used as base for the development of new curriculum and/or continuous professional development. In terms of teaching future professionals it is necessary for them to understand all ground considerations that lead to the requirements. With this assumption it becomes essential the explanation of the methodologies and tools based on case studies.
  Important note from the research agenda that worth's to be transcribed, regarding the mindsets barriers:
  "However, this will stress some current educationalists who are not used to such rapid change and approaches to smooth the uptake change will need to be incorporated into the rollout strategy. To ensure that there are sufficient projects to be utilised in this learning style there will need to be developments for data harvesting for project, programme, portfolio and sector performance learning and improvement."

- Target Four – topic 6 – "*Performance management & measurement*"
  The built environment performance management improvement requires an establishment of an economic rationale for performance management and benefits that flows from such management. To accomplish it, is necessary the documentation of case studies and the creation of common project metrics to measure consistency of outcomes. This will help ensure that comparisons are made on related projects under the same basis. This may lead to the development of tools to provide support through dashboards and KPIs that can't be gamed.

> The Portuguese commitment for the sustainable competitiveness of the AEC industry identifies one of the ProNIC benefits by its the possibility of performing performance measurement in construction by direct comparison of the same work performed in different projects/construction entities from the same or different types. The indicators can be produced from the contract level until the work level, passing by the design disciplines, WBS-CW chapters, groups of works, or each level of the WBS-CW. The use of standard classifications and classifications with mapping conditions streamlines this possibility. These developments are essential for the sector competitiveness. Thus, it should be framed on the sustainable growth demand, namely within the "*Promotion of industrial modernization*".

A first discussion of the topics was performed. Each one should lead to a deepen reflection, setting common and structured actions towards IDDS. Given the ambition of the present work, few specific proposals (three) related with the topics, will be introduced and explored in general lines.

5.4. PROPOSAL 1 - MAPPING BETWEEN TWO INFORMATION CLASSIFICATION SYSTEMS

5.4.1. INTRODUCTION

There are several ICS geared for exclusive application on the AEC industry, CICS. There are others with broader scope that address to many activities being construction just one of them. Often, there are no mapping relations between them. As previously referred, ISO 12006-2 establishes the general lines for CICS framework, with the aim of enhance mapping possibilities. Yet, the level of correlation is only possible on the higher levels (table titles or facets) and it is not always followed. The scenario is worse if the comparison is performed between exclusive and non-exclusive systems. The use of ICS's should contribute to the organization and streamlining of processes, leading to gains on information coherency and efficiency. The following case study presents a real situation where there is an absence of mapping between classifications for the definition of the construction types or construction entities, according with ISO 12006-2. It is explored the process of classification in each system and their inherent flaws and misinterpretations, as well as the problems that may arise from this individual classification. To overcome the situation it is presented a prototype for the establishment of the mapping and the methodology to perform the classification.

5.4.2. CASE STUDY – GENERAL EXPLANATION

Construction projects produce objects (entities or complexes) that can be translated through their shape and function. Each result has a specific purpose or role to play on the built environment. It is common sense that, if people need healthcare they go to a hospital or if they need to travel by airplane they go to an airport. Yet, this empirical classification that all persons use needs to have an objective classification reference with multiple purposes. Some of them are related with the construction phase, others with built environment classification or asset management. The present case study will focus on two classification systems, one with exclusive use on construction and other non-exclusive. Both are geared for the classification of construction entities from different points of view. The CPV is a classification focused on services and products exchange or procurement, e.g. "45247210-5 – Dam construction work". The CC is used for statistical purposes, based on the object use, e.g. "21521 - Hydro-electricity dams and similar water-retaining constructions".

CPV, as referred, is not exclusive for the construction sector. It is used on public procurement actions, on the tender notice/procurement procedure, to identify the object of the contract. The work owner or the tenderer when has the intention of launching a tender notice needs to fill the classification field on the form, set by the EU and Portuguese legal framework (see chapter 3). CC is construction exclusive and it is used by EUROSTAT to produce statistics. Annually, the construction companies need to complete a questionnaire about their activity. One of the topics is related with their activity (monetary values of the performed works) that needs to be classified according with this referential. In brief, the same object will need to be classified by two different stakeholders (work owner and contractor) involved on the same construction project. This classification is performed in different phases of the construction life-cycle (procurement and construction).

The referred situation (different moments and different intervenient) is itself enhancer of misinterpretations. Additionally, there is the possibility of this classification being placed by professionals that don't have technical competence for a proper analysis of the object (secretaries, administrators or persons from the owner procurement unit or accounting officers from the construction company), may lead to considerable differences that endanger the desired information coherency and the ability of performing accurate analysis of the sector activity. Thus, the work developed has the main aim of propose a prototype for the mapping of the two systems. As it will be further described, the process of performing the classification through CPV has other problems that this methodology intends to suppress. The methodology working assumption assumes that the classification is performed by the work owner on the beginning of the project, on the preliminary design phases, where all the information about what it is intended to be built should be set.

5.4.3. MAPPING PROPOSAL

5.4.3.1. Methodology

The mapping was set between CC-PT and CPV. It was used the CC-PT because it is a wider classification and once the translation to CC is easy. The first task developed was the translation to English of the CC-PT non-existent terms. To perform it and in order to find the best terms it was used the detailed information and explanatory notes provided on the Eurostat web site [56]. The following task was to mark on the two classifications the different levels using colours. Figure 5.3 presents the colours set for each classification and level. To set the correlation, the "45200000 – Works for complete or part construction and civil engineering work" CPV codes and descriptions (in English and Portuguese) applicable to each item of the CC-PT were placed on the same line and in different columns. The result is the matrix presented in Annex 3. Some situations have direct correlation and unique correspondence, e.g.: "CC-PT 24112 – Stadium; CPV 45212224-2 – Stadium construction work".

CC-PT	
Code	Term
1	Section
11	Division
111	Group
1110	Class
11101	Subclass

CPV	
Code	Term
45000000-7	Division
45200000-9	Group
45210000-2	Class
45211000-9	Category
45211300-2	Subcategory
45211340-4	
45211341-1	

Fig.5.3 – Colours used for level and classification differentiation

There are other situations in which to one CC-PT there are several correspondent CPV codes. The opposite situation was also confirmed. Figure 5.4 shows an example of the first situation described. In many cases there is some ambiguity on the mapping i.e., for one determinate term there might be other possibilities that are not translated on the classification.

CC-PT	
Code	Term
12611	Cinemas and theaters (concert halls, opera houses)

CPV	
Code	Term
45212322-9	Theatre construction work
45212150-2	Cinema construction work

Fig.5.4 – Example of several CPV codes (two) with correspondence to one code of CC-PT

The exercise allowed identifying situations that are not compatible or that don't fit on the other classification. On the matrix, the situations where it was not possible to find a CPV code for the CC-PT were marked with black. Many CPV codes didn't have correspondence with the CC-PT. This fact is due to the level of detail, as in many situations CPV describes operations with lower (more detailed) level than the construction type. Figure 5.5 presents some of those situations.

CPV	
Code	Term
45211370-3	Construction works for saunas
45212500-1	Kitchen or restaurant conversion
45215141-7	Operating theatre construction work
45215142-4	Intensive-care unit construction work
45215143-1	Diagnostic screening room construction work
45215144-8	Screening rooms construction work
45248400-1	Landing stages construction work

Fig.5.5 – Examples of CPV codes without correlation with CC-PT

The correlation was established looking into the terms in English and, in case of doubt, to the Portuguese translation. It was possible to verify that the classifications follow different breakdown principles. This leads to situations where the correspondence between the levels is practically identic and others where it is completely different. From the analysis performed, the correlation should, at the moment, be performed between the defined codes. Deep study on the proposal needs to be performed to identify the situations where the correlation can be applied on the upper levels.

5.4.3.2. Implementation

The objective of the presented proposal is to streamline the characterization of the construction project in terms of its type, contributing for the elimination of ambiguity. Through the implementation of this mapping it becomes possible the characterization of the object to be built, its classification according to its function and therefore the information related with its construction contract. This

characterization should occur during the preliminary design stages and should be performed by the work owner or its representative. The characterization should be performed by a professional with skills in terms of construction and the classification should be supported by tools that set automatically the correlations and define them on the documents. As it will be further explored, the starting point should be the CC-PT and not the CPV.

5.4.4. REMARKS

This proposal is a first approach on the mapping between the two systems. Despite their differences in terms of scope and organization, it was possible to set most of the items and find some situations of unique correspondence. The identified situations of non-compatibility occurred on the higher levels and generally, due to differences on the organization philosophy, as lower levels found match.

The implementation could be performed through the use of the matrix (see Annex 3) as it streamlines the construction entity search, by function. CC-PT is more organized and intuitive than CPV. CC-PT classifies the construction and not the works that are performed on object. This correlation fits construction in general, yet its application is more geared to new construction, once CPV has with less detail other operations, such as demolition, maintenance or repair. Ideally, the mapping between the systems should be integrated on tools that support the construction activity, such as e-procurement platforms, CDE's or EDMS. For this scenario it will be necessary to validate the proposal with further analysis and explore some of the potential problematic situations that are placed by CPV.

The CPV review process is a major concern, as there is no formal neither informal maintenance process based on changes request, there is no release policy established and the revision process is less systematic than in others systems [75]. For a mandatory system this situation is considered inadequate and insufficient. Other situations are related with the process of placing the codes. It lacks the tools to support the CPV. As previously mentioned, the person that will place the classification on the tender notice might not be fully qualified to do it and the condition is even worse because of the code search methodology (by hand or through key words) and freedom of choice that exists on this action. Tools to support its functioning or the CPV integration in e-procurement environments is vital to minimize the ambiguities. The recommendations regarding the current CPV and for the future CPV, placed on the "*Final Report - Review of the functioning of the CPV codes/system*" [75] should be taken into consideration to achieve the target of "*Coherent information flow and reusable knowledge development*".

5.5. PROPOSAL 2 - INTEGRATING INFORMATION AND MODELLING TOOLS

5.5.1. INTRODUCTION

The integration of processes throughout the construction life cycle is one of the main achievements foreseen for construction. Its accomplishment is dependent of the fulfilment of small changes that were considered on the targets presented on the previous chapters. The Crossrail example is one of the few, where some parts of this integration have been implemented and tested. Notwithstanding, the already mentioned project context, the created environment may be difficult to replicate to other situations. Yet, the lessons learned are fundamental, and from the information and project dimension points of view, this endeavour is extremely important for the intended sector improvement, and namely to the UK Government construction strategy.

Focusing on the priorities of the "*development of knowledge-based architectural programme*", "*development of new and expanded collaborative technologies*" and "*information systems lifecycle & interoperability*" at a national level, this proposal intends to explore the potential benefits from a possible integration or permanent communication during the design phase, between ProNIC and 3D virtual modelling tools. This proposal follows a similar approach performed recently, during the development of the SIGABIM project, where the author has participated [137]. The survey was performed using the 3D virtual modelling tool ArchiCAD, version fifteen and ProNIC-WBS, performing an integrated workflow, mainly from the contractor point of view and to its needs during the construction phase. The context, development and results can be found on the scientific paper "*Framework for the coordinated application of two different integrated project delivery platforms*" [138].

5.5.2. DEVELOPMENT

The starting point for this proposal comes from the finding that ProNIC is a tool mainly geared to the production of standardized written information, lacking in terms of visualisation, and that 3D virtual modelling tools are essentially driven for objects visualisation and drawings, lacking or leaving to the designer decision, the insertion of the information related with the construction elements. In resume, the first tool is geared for Information and the second to Modelling. The integration or communication towards information exchange between them, establishes the essential ingredients of BIM, as previously mentioned on point 5.2.2.

In order to define the communication needs and information exchange, it is necessary to understand how the design phase is carried (action of the elements from the design team) and which information can or should be interpreted by each tool.

For this integration scenario it will be considered that the processes address to the design without evidencing any discipline. In addition, it will be considered a situation of collaborative work, i.e. parallel work processes by different people from the design team that may belong to the same or to different disciplines.

The objective is to have at final of the design phase, documents with integrated information, namely drawings and written documents, like BoQ and detailed measurements, as well as mechanisms that automatically transpose the information from one tool to other. The general lines of the process will be described, taking the experience of the performed survey. Further studies and surveys will need to be performed for different situations, namely distinct work descriptions and construction elements.

The use of collaborative work sets the first requirement. This is related with the identification and role definition of all the involved agents. For this, it is suggested the use of the mechanism referred on point 4.2.6.3, regarding the identification of the agent's roles. This access system should be common for both tools. Through it, the authorisation for work development on both tools would be the same and the information exchange will be performed according to it.

The project definition in terms of construction complexes/construction entities should also be performed. Further research on this situation needs to be performed, in order to better define in which tool the process is performed. To simplify the methodology at this moment, this example will focus on the project situations that involve a single construction entity.

On the initial stages of the design phase there is the identification of shapes and some materials, without entering in high levels of detail. To define these initial shapes and the main construction elements, the objects of the 3D virtual modelling tools can be used and parameterized, e.g., piles –

concrete; walls - masonry. Other possibility is the use of object libraries. These usually have more detailed levels of information regarding the solution characteristics, as they are being produced more frequently by the product manufacturers, e.g., type of walls finishing solution using tiles.

The link between the drawings and the written elements is performed by the construction elements and its layers that, as seen on chapter 4, point 4.2.3.3 should match with the articles or work descriptions from ProNIC WBS-CW. This situation sets immediately a condition. The level of detail used on the 3D model should be equivalent to the work descriptions, i.e., the individual identification of all the layers that constitute the element. Figure 5.6 evidences the situation. The identification of the suspended ceiling in one single layer designated as "Plasterboard" is not inadequate for the early stages of the design, as an initial identification and design is being performed [139]. Nevertheless at the end of the design phase it would be inadequate to include on this layer the insulation and the empty space as the first constitutes an individualized work. Problems start to occur not only with the material characterisation, but mainly with the dimensions, as it will be further explained. For the selected element, the ProNIC work descriptions would be those presented on table 5.1:

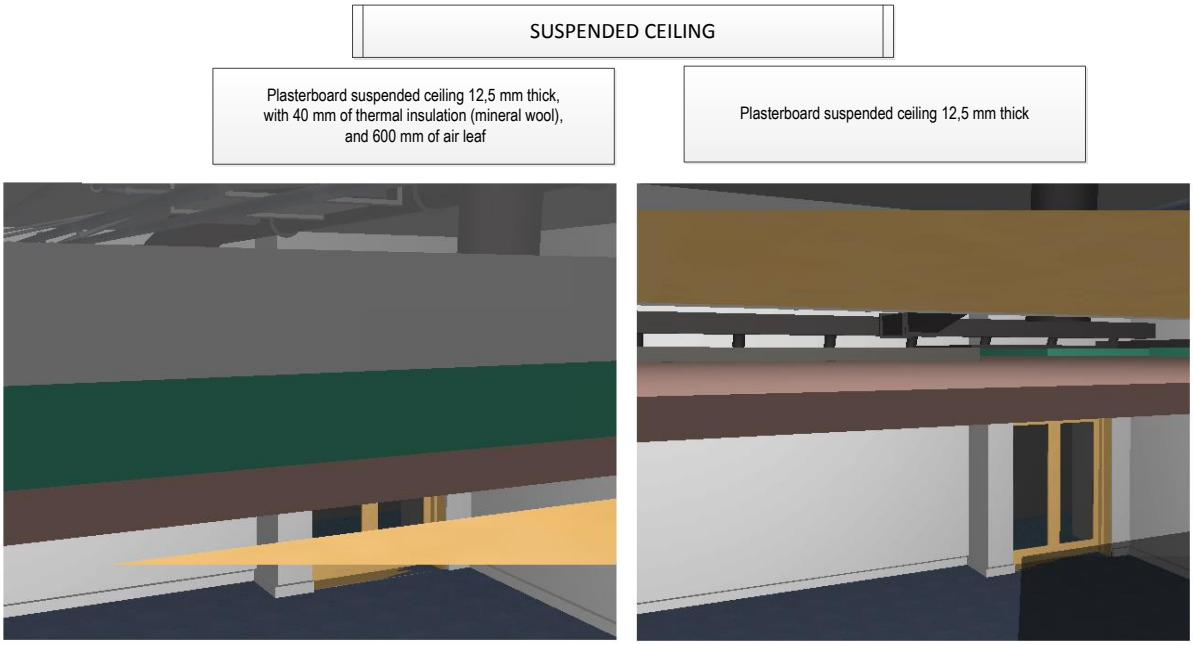


Fig.5.6 – Different level of detail for construction element characterization

Table 5.1 – ProNIC work descriptions for interior suspended ceiling layers

Code	Work Description	Unit
17.1.1.3.3	Thermal insultation on interior suspended ceilings, constituted by mineral wool plaids	
17.1.1.3.3.1	with 40 mm thick	m²
18.1.4.5.1	Interior suspended ceiling, constituted by plasterboards, supporting structure made of steel and air leaf with 600 mm	
18.1.4.5.1.1	with 12,5 mm thick	m²

Ideally, and to streamline the work, it should be used an object library, Figure 5.7. This should have information about the codes for the different work descriptions. This is framed with a research project, currently under development, referred on the previous chapter and where the author is involved. If not, this work should be performed manually through the identification of the ProNIC work code and insertion on the 3D virtual modelling tools.

Fig.5.7 – Example of material/object definition with BIM library for download [140]

Often and like mentioned, the use of these libraries is not useful on the initial stages of the design. Yet, between the element definition and the complete characterization of the material it is possible to have a general indication of the material/element/solution. This is the balance point for the element 3D drawing and the general work description, i.e., just standard text without parameters definition or only the definition of few. This process, performed on the 3D virtual modelling tools would identify the work that should be automatically called for the project in ProNIC.

Given the detailed information of the work description, the more specified is the information on the 3D virtual modelling tools, the more accurate and completed will be the information set on ProNIC. Following the groups of parameters that are usually required on ProNIC, it becomes simpler to identify those that can better be defined by the 3D tool. Figure 5.8 presents these parameters, based on the image from chapter 4, point 4.2.3.3.

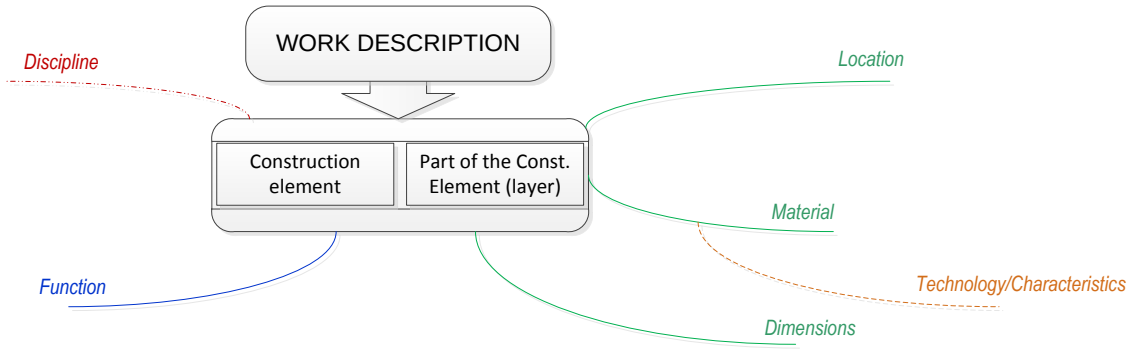


Fig.5.8 – Parameters defined by the 3D modelling tool (green)

The material identification and some general characteristics might also be part of the 3D model. The acquired experience from the referred approach [138] indicates that most of the information requirements set by ProNIC (and therefore by the standards) related with the materials characteristics don't fit on fields of the actual versions of the 3D virtual modelling tools. On the early phases of design this is not problematic for the design development.

Yet, for delivering the final design documents, it will be necessary to define these characteristics on ProNIC, by complementing manually the absent options on the work descriptions parameters. To improve the organisation and to speed up this process, in situations of similar layers/works they should be somehow differentiated, Figure 5.9.

Fig.5.9 – Differentiation of solutions through specific identification

Thus and ideally, during the design the information is created on the 3D virtual modelling tools that sets or calls automatically the works to be placed on ProNIC. The work quantities are also passed to ProNIC to get the global quantities and the detailed measurement sheets. In a near future the author finds that the information to be passed will be only the final quantities as all the other information can be consulted on the 3D virtual modelling tools. Other possibility is to pass a document with the measurement tables produced by this tool to be archived on the project folder structure. The designer will have then to fulfil the parameters that were not specified. The following figure evidences a general scheme of the processes and the information flow.

As referred, the intention was showing the general lines of the integration between ProNIC and 3D virtual modelling tools during the design phase. This constituted an initial approach as many issues need to be further explored, namely the identification, customisation and differentiation of the information fields to be exchanged from one tool to another.

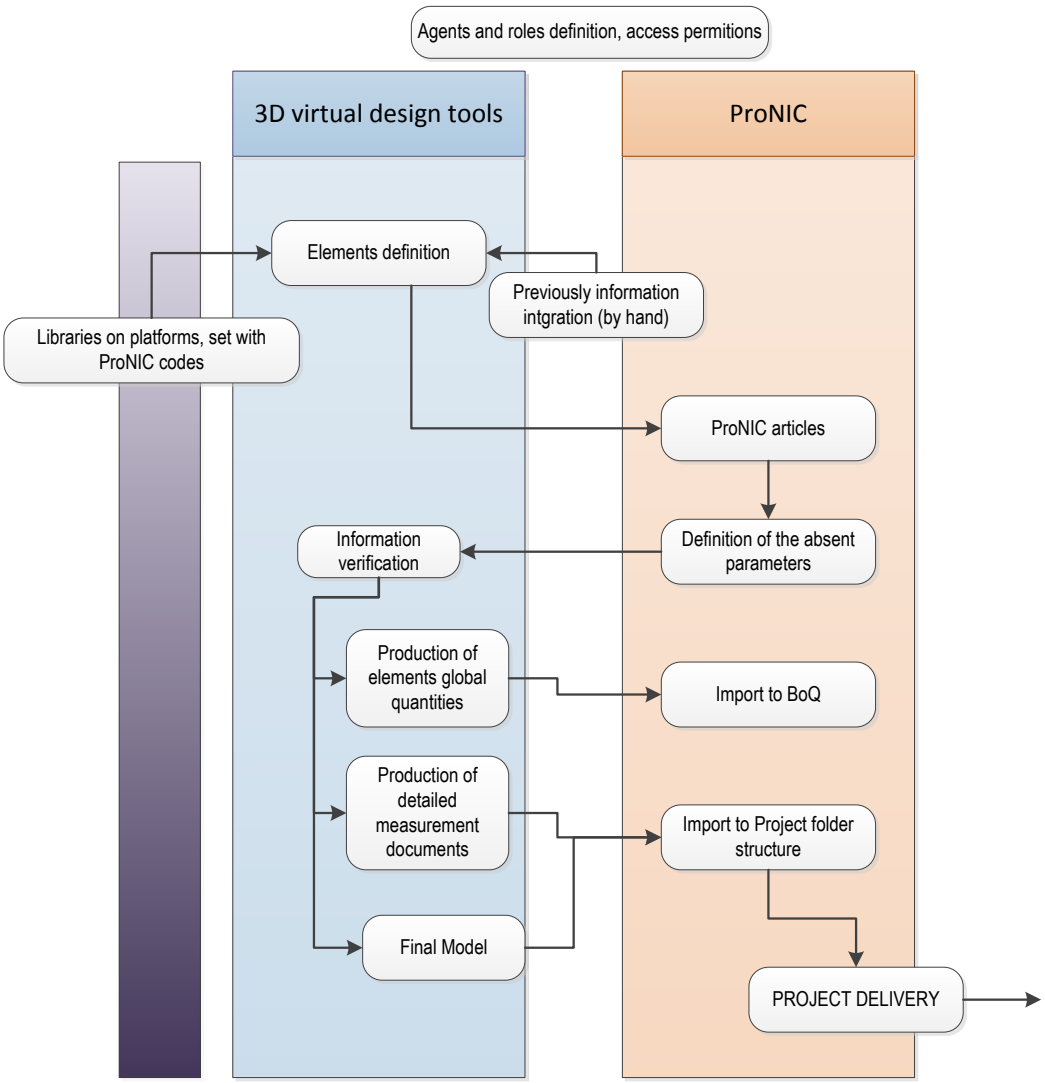


Fig.5.10 – Schematic design of the information integration needs

5.5.3. REMARKS

This proposal intends to streamline the design process by integrating the information that it will lead to the outputs. One of the design phase main challenges has been the compatibility between written and drawn parts. With ProNIC it was possible to integrate the written parts, namely BoQ and Specifications. There is the need to introduce measurements and/or global quantities, as seen. With the integration or communication between these fundamental tools for the design phase it becomes obvious the advantages on the working process and the contribution for design quality. The use of common language, like IFC [141] might be the key to set this communication. As referred, further survey needs to be performed to identify all the requirements. This proposal as intention of giving a general overview and perform a proof of concept regarding the benefits on this working method.

5.6. PROPOSAL 3 - SHARED SERVICES – A PROPOSAL FOR THE IMPLEMENTATION OF THE CONCEPT IN CONSTRUCTION

5.6.1. INTRODUCTION

This proposal has its roots on the perception of the paradigm shift that is underway in some economic sectors and how these changes can be framed or applied in construction. As previously referred, some changes are foreseen and demanded for the AEC industry. The activity restrictions due to the economy's health or expansion on the emerging countries, among other factors, are setting the foundations for the sector reorganization. These trends are notorious.

The construction works have always unique characteristics. However, they are result of phases, steps and processes that have many common points and that usually respect the same principles. Given this, the proposal explores the advantages on the adoption of a shared services structure for construction, with capability to take over the management of the common processes, assuring an uniform approach to the construction process and to their management, working in addition as a strategic decision support institution for public investment and a regulatory authority in what regards the production and adoption of standards and specifications.

5.6.2. SHARED SERVICES

5.6.2.1. Definition

The term shared services is often associated with cost reduction [142]. This relationship is mainly due to its roots. In essence, the implementation of the concept frequently leads to cost savings. Nevertheless, the logic nowadays intends to be more comprehensive and aims substantially broad impacts. The literature states that the term was introduced during the 80's of the twentieth century, by a group of companies with large budgets and with multiple business units. They began to structure possible ways to reduce their administrative costs [143]. Since then, the term has evolved and it has been transformed into a more complete and flexible approach, aiming the optimization of resources and management improvements [144]. According to several authors, this approach has been adopted by many public sector institutions, governments and private companies [145] [146][147]. Several definitions can be used as they suit more the sectors characteristics or the organizations type. Nevertheless, the following were considered the wider and at the same time more adapted to the subject in discussion:

"The term Shared Services is applied to a new form of collaborative work, in which a subset of roles or functions from a business organization is run by a specialized business unit with an independent management structure and designed to promote efficiency, added-value, cost reduction, improved quality of the services provided and transparency.

Shared Services are based on the assumption that the transactions processing and strategic decision support are performed/supplied by separate units/entities. The specific and professional added-value processes are maintained within the different entities while the operational and repetitive processes become responsibility of the shared services unit" [147] [148].

or

"Shared Services can be envisaged as a strategy that aims the optimization of human resources, capital, time and other corporate resources, bringing together on a new business unit, (semi-autonomous) Shared Services Centre, designed to promote efficiency, create added-value, cost reduction and provide services with levels of excellence throughout the organization." [149]

The designation that is more related with the intended scope and that fits better the understanding is:

The framework for Shared Services requires high standardization of processes, procedures and working methodologies. This standardization should also contribute to overcome the existing level of dysfunctions between information systems." [150]

From the referred, it is possible to conclude that the implementation of the shared services logic, in a given context, will tend to bounce a new strategic thrust to several services, based on technology and information systems, increasing the level of efficiency and at the same time productivity gains through the rationalization of costs and resources.

The materialization of the concept requires among other things, a radical reshaping of the organizations involved. The recognition by all parts of the need for change as well as the inherent commitment of organizations constitutes key factors towards successful implementation [151].

5.6.2.2. Concept application – Case Studies

There are many situations where the shared services logic was successfully implemented. This point will explore two situations from the Portuguese public administration that were found more interesting as they are in some way linked to the topic in discussion. The changes resulted from public administration restructuring programs, such as PRACE and PREMAC, as well as a new understanding on public management [152]. This way, the use of shared services in public administration aimed the services quality improvement, the increase of the data reliability, the processes standardization based on best practices, the elimination or segregation of duplicated, parallel and overlapping functions, the relocation of resources to relationship/treatment activities with citizens and companies, i.e., higher quality, faster response and cost reduction [153].

SPMS – Serviços Partilhados do Ministério da Saúde, E.P.E. (Ministery of Health Shared Services Unit)

The SPMS was made official in March 2010 by the Decreto-Lei n.º 19/2010, of March 22, amended by the Decreto-Lei n.º 108/2011. From the text of the first legal document stands out one of the goals for the establishment of the entity:

"*The Government, the institutions and the NHS services no longer have the responsibility to provide services that by their nature and strategic relevance, can and should be assured by a single supplier to all the entities from the health system. This will allow them to focus on the pursuit of its nuclear activities, such as providing health care to citizens"* [154].

SPMS mission is, within the healthcare field, to provide services such as procurement and logistics, financial management, human resources and information and communication systems, among other complementary and subsidiaries activities.

It is possible to highlight the following assignments:

- Cooperation with the health services on innovation and management changes;
- Promote knowledge sharing to strengthen the reorganization of the health sector;

- Work as the health sector procurement and purchase central for goods and services, with large scale contracts that can be negotiated and dialogued with suppliers from a different point of view, achieving to improved economic benefits;
- Contribution to the Operative Unit of the Ministry of Health to promote modernization and innovation in the operational procedures of Hospitals and Health Centers, by proper integration of information and communication technologies, in perfect coordination with national and regional policies. [155];

Since its establishment major achievements that worth mentioning are the public procurement health catalog, the Health User Portal that has a clinical summary of all the NHS users and the Health Data Platform.

eSPap – Entidade de Serviços Partilhados da Administração Pública (Public Administration Shared Services Unit)

This unit, that has the legal form of a special regime public institute, was made official in 2012 by the Decreto-Lei n.º 117-A/2012, of June 14. It was created from the merge of several entities such as the Institute of Informatics of the Ministry of Finance, the Public Administration Resource Management and the National Public Procurement Agency.

From its mission and responsibilities it worth's highlight the commitment on the development and provision of shared services and public administration human resource management, as well as structure, manage and evaluate the national procurement system and the management of the Government vehicles fleet. It is also its mission to provide planning, design and support actions on the formulation of strategic policies in the area of information and communication technologies (ICT) within the Ministry of Finance and the evaluation of the computer technology initiatives of its services and agencies [156].

5.6.3. Shared Services on Construction Industry

5.6.3.1. Guideline

In order to have a clear view on the improvements and possible benefits of the implementation of a shared services logic in construction and particularly on the construction operations undertaken by the Government and its institutions (public works) it is interesting to perceive the evolution of the Government organization until nowadays regarding this area. Until 1974, the MOP was the ministry that controlled most of the public entities that could play the role of work owner. Since then, many of these entities were passed to other ministries according with the construction entities they promote/manage. Nowadays, these public work owners that depend of the Government are spread by ministries like Health (hospitals and other health facilities), Justice (courts, prisons), Education (schools, universities), Environment and Territory (residential buildings). Most of the entities that promote infrastructure works (railways, roads) continue on the MOP dependency (nowadays integrated on the Economy Ministry). This organization lead to a situation in which each of this entities develops and produces technical documents (better or worse) to support their works and with individual interpretations of the legal framework and required procedures. Previously there were common general lines developed by MOP that serve most of the entities [155]. Low level documents for specific issues were individually produced. This finding reinforces Carlos Carapeto affirmation that states:

"The silos management culture that prevails in public administration and that is reflected in the organizational structure of its ministries and agencies is highly expensive by the repetition of the respective internal services" [157].

The observed demands for the construction sector will require from the public administration to follow the changes, as the Governments are one of the most important promoters of construction works. The experience referred on chapter five fits on the changes that need to take place in these institutions. Thus, public entities must be technically prepared and skilled to define the objects to be built, organize the processes according to the regulatory and technological requirements, manage the processes of the construction supply chain and have the knowledge and ability to establish the requirements for those processes. This situation does not reflect in exclusive the Portuguese reality and it has application on others.

5.6.3.2. The application of the concept - goals

Portugal, as mentioned on chapter 3, performed an update on the legal framework regarding the AEC industry. Alongside with this effort, it has been implementing national regulations and standards. In general, the results of these developments are procedures, control methodologies and recommendations to be followed.

Subsequent to the production of legislation, the compliance with these procedures should be undertaken by all entities, namely by those that play the role of promoter's or public works owner. Many of these procedures, as already mentioned, involve structuring and the operationalization of methods and support tools. These developments are often supported by these entities. From another perspective, the appropriateness of these methods to the requirements depends on the motivation and technical capacity of those entities, as well as the volume of work and the relationship they have with its service providers, including construction companies, designers, consulting and auditing companies. Given the above, it is not difficult to find entities with similar profiles working individually on different solutions, tailored to their needs and yet, to meet the same requirements. Many of the reasons that led to the implementation of shared services logic fall into these requirements, as well as on the basic principles and concerns for the sector restructuring.

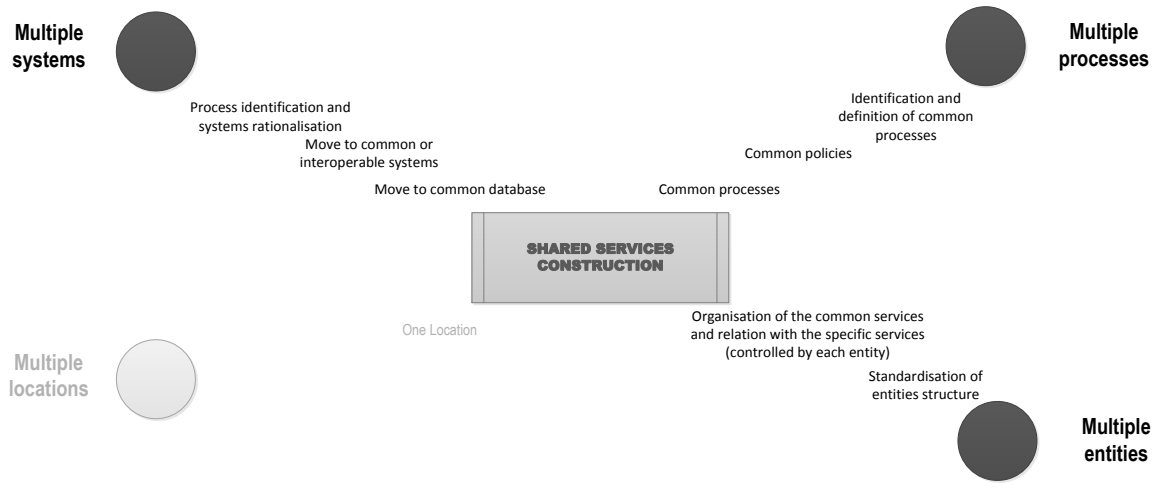


Fig.5.11 – Actions towards the implementation of shared services (based on [158] and adapted to construction)

In Brief, the proposed Public Works Shared Services Unit - PWSSU tends to respond to the challenges of processes modernization, approach to construction life cycle integration and communication requirements, i.e. collaborative work. From these it stands out:

- The quality and organization of the construction projects across all phases;
- The rules and procedures for financial control;
- Requirements in terms of information provision throughout the construction process (those mentioned on chapter three, OJEU, contract report, audit procedures, final report of the work, values for statistical treatment.);
- Requirements in terms of market opening and equal competition conditions.

5.6.3.3. General Lines for Implementation

This proposal envisages the creation of a unit that is independent of the organizational structure of the entities with which it interacts. Given the proximity with other existing instruments and entities, namely InCI, this unit could be fitted into the MOP organic. The PWSSU could be structured by the following departments:

- Customer management and technical support;
- Information systems;
- Development and Research

Some of their possible main activities will be further envisaged.

All procurement procedures need to be published on the Portuguese Republic Electronic Journal and, depending on the value and type of procedure, on OJEU. They are also published online on the Base portal [45]. This instrument later produces the statistical data for analysis by the Observatório das Obras Públicas and indicators for INE. The centralization of this information and development of tools and methods that could enable greater assertiveness in communicating this data constitutes the starting point for this unit.

A public construction process, apart from its specificities, must answer to the CCP provisions. As mentioned, many of the provisions require a systematic approach that could be developed and defined jointly by all entities, being applied in a single way (construction phases, procurement/tendering, project management, completion, warranty periods), using the same methods, understandings and systems. Nevertheless, each public owner would be responsible for the specific technical issues related with the processes, function and characteristics of the object to be built (construction entity/complex) [159].

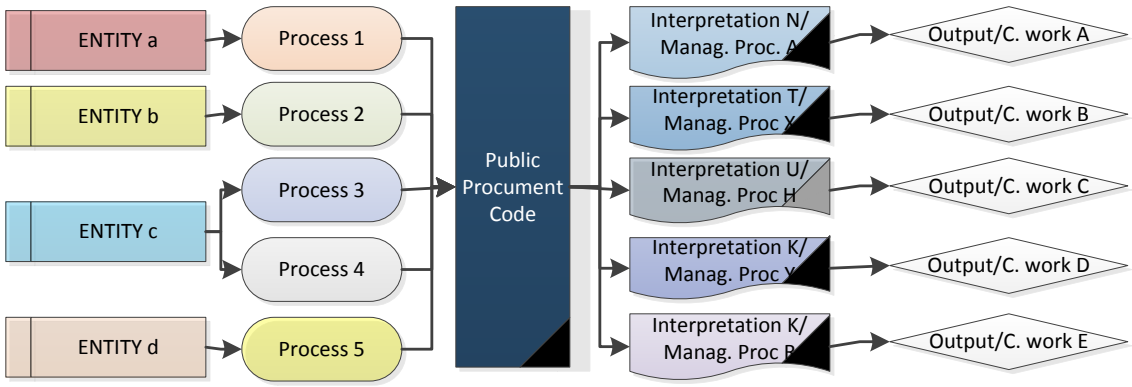


Fig.5.12 – Present situation regarding the processes and legal framework interpretation

By performing this approach, at the end of the construction process it would be possible to obtain comparable information to be explored at the entity level (internal indicators) or on higher level (comparison of different types of work according to the same basic principles).

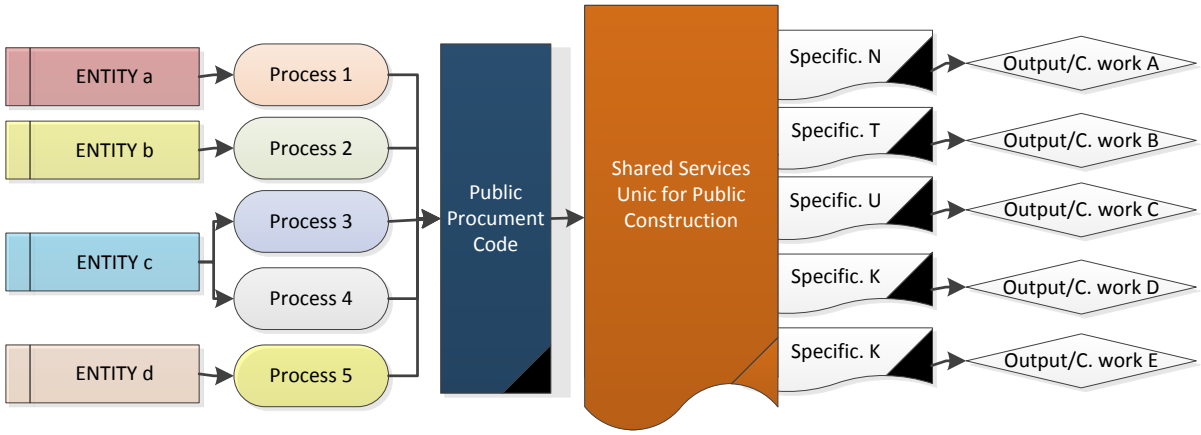


Fig.5.13 – Shared service unit role on the process (common interpretation and management process apart construction type specificities)

This service intervention may be extended to the operation phase, in particular the development and management of tools to support maintenance management, operations systematization and management of the use.

From other perspective, the production of technical and legal documentation and could be centralized by this unit ensuring the participation and contribution of the entities that may be involved in the subject.

In general lines, the following topics constitute an initial reflection on the PWSSU possible department's attributions:

- Customer management and technical support:
  - Technical support to all the users and helpdesk;
  - Organize and coordinate the initial phase of the contract, definition of the initial information and processes according with the chosen procedure;
  - Develop training actions and manuals for all types of users.

  - Work as interlocutor between the different entities that use services provided by the unit;
  - Information articulation with InCI and INE;

- Information systems:
  - Provide, ensure maintenance and support of all applications, as well as communication and storage infrastructure;
  - Ensure the safety of all applications and infrastructures;
  - Ensure the data communication and data exchange capacity;
  - Development of new applications and improvement of the existent;
  - Manage the systems solution design toward full interoperability.

- Development and Research:
  - Manage the information that is gathered producing reports on the construction activity;
  - Develop indicators to be communicated to InCI and INE;
  - Enhance cooperation, knowledge share, information and development of consultancy activities related with the subject;
  - Develop and promote the use of standards, methodologies and requirements to assure collaboration and interoperability of the information and information exchange;
  - Identification, promotion and development of revisions to the existent legal and technical documents and production of new ones;
  - Work with users on the identification of change needs, development of new processes and solutions;
  - Perform proactive analysis of the implemented systems and improvement opportunities.

5.6.3.4. Remarks/Discussion

The implementation of PWSSU intends to leverage the standardization of processes enabling the public work owner entities (central and local) to improve, standardize and streamline their working methods, participate on the development of new procedures, as well as regulatory documents and standards, contributing to a more efficient and competitive sector. It also seeks to eliminate reworks, wrong data introduction and information misinterpretation, which impacts are impossible to quantify.

The Governments must behave as agents raising the level of the construction. The service providers work and compete on a global market and are adapted or tend to be adapted to the best practices and requirements from different realities.

Furthermore, the sector rebound will only be effective if it is grounded in the previously mentioned trends and if takes into account some of the concerns that have been being expressed in particular by the Portuguese Account Court [121].

This initiative will always be ambitious. The adjustment should be gradual and closely monitored, allowing a change on the routines and past practices, an awareness of the responsibilities and labour relations, as well as training and consolidation of new processes.

The experience of implementation in other sectors will always be useful for a better understanding of the threats and opportunities and to the chaining and planning operationalization of the new assumptions.

5.7. CONCLUSIONS

This chapter explored topics that, within the IDDS strategy, were more focused with the discussion scope. These topics were framed with the strategies and with the requirements. Some general proposals and ongoing works were evidenced. Most of the referred topics should be discussed from a national point of view and with the involvement of the Government entities, the Universities and Research Centers as well as the associations and companies (owners, design, supervision and construction) involved on construction life cycle. Notwithstanding, the creation of specific reflection groups, the dynamic and representatives of the construction related clusters, namely cluster Habitat [160] and PTPC [161] constitute key places for the discussion, structuring, decision and funding of these actions.

In what regards the presented proposals, they intend to materialize effective actions that can contribute to the IDDS targets, and mainly to the construction organization improvement and integration. They have distinct levels of complexity and tend to fit different needs. As referred, the given examples are respectively geared to information, technology and management. Their objectives and possible development framework, according to the topics previously presented should be the following:

- Mapping between two information classification systems, contribution to the near-term priority topic "*Coherent information flow and reusable knowledge and development*";
- Integrating Information and Modelling Tools, contribution to the mid-term priority "*Design, construction & supply chain improvement*";
- Public Works Shared Services Unit, contribution for the long-term priority aiming the "*Collaborative project development process & legal framework*".

These are just few ideas and ongoing/potential research to improve the construction sector performance. On the following chapter a general overview and possible future trends will be resumed.

6
FINAL REMARKS

It is undeniable the importance of the AEC industry for the global market, for the single economies and for the welfare of populations. Thus, its role for the strategic growth cannot be individualized from others and, as so, the sector presence and its priorities must be embedded in the wide targets. From other perspective, all the strategic priorities must forecast specific goals and funding opportunities to support the achievements through the use of an operational and competitive sector.

It becomes evident that construction failed to perform, in time, most of its demanded upgrades and reorganization. Nevertheless, the forewords of Sir Jonh Egan on the Wolstenholme Report [162] express in the best way the general opinion and the state of mind of many practitioners:

"In Rethinking Construction we wrote that 'continuous and sustained improvement is achievable if we focus all our efforts on delivering the value that our customers need, and if we are prepared to challenge the waste and poor quality arising from our existing structures and working practices'. Since 1998 we could have had a revolution and what we've achieved so far is a bit of improvement. People are now measuring performance, and it is heartening to look at the demonstration projects to see that some very good work has been done. The opportunity remains just as large today, with the added incentives of harder economic times and major environmental pressures. So I congratulate the team on a thorough review and on pointing out the next steps on the way to radical improvement – every crisis is an opportunity."

Given this statement, it urges to find the best ways for the sector to contribute to global improvements and at the same time raise its bar.

This work had the intention of performing an information systematization and reflection, exploring the improvements that can be performed based on:

- the integration of information;
- introduction of new technologies;
- new forms of relation between agents and management procedures.

The interlacement of all this vectors found a common assumption on the concept Integrated Construction Organization and a wider strategy, that is the IDDS – Integrated Design and Delivery Solutions.

From the state of art it worth's mentioning the development of the ISO Standards. They constitute the general lines for global themes and, by doing it, the commissions should have representation of all the practitioners and the discussion should be more effective. New ways of financing this effort are essential due to this situation.

On a global world, the information and namely the good information will become a precious resource. The development of individual CICS, as presented, is a good example of the uniformity effort that must be performed. The publication of the revised ISO 12006-2, of Uniclass 2 and the developments of Omniclass need to be followed. Each country must find ways to set common structures until certain levels and from then, introduce the national specificities. Commitment to standardization and to mapping processes between systems is therefore essential towards information coherency that will support a significant part of the requirements for the technological development/implementation.

Regarding the legal framework, continuous development must be performed to improve the prescriptions, to introduce new trends and to eliminate mismatches and colliding/counter requirements.

The IDDS research roadmap settled the baseline for a crossed discussion over the identified topics and European strategies. The topics were discussed from an introductory point of view and further discussion should be performed and poured into national guidelines for the sector. The Commitment for the construction sustainability [25] needs to be further developed, namely on the points 4, 5 and 7. Detailed actions must urge from the debate over essential factors. Figure 6.1 resumes the key factors for the discussion beginning:

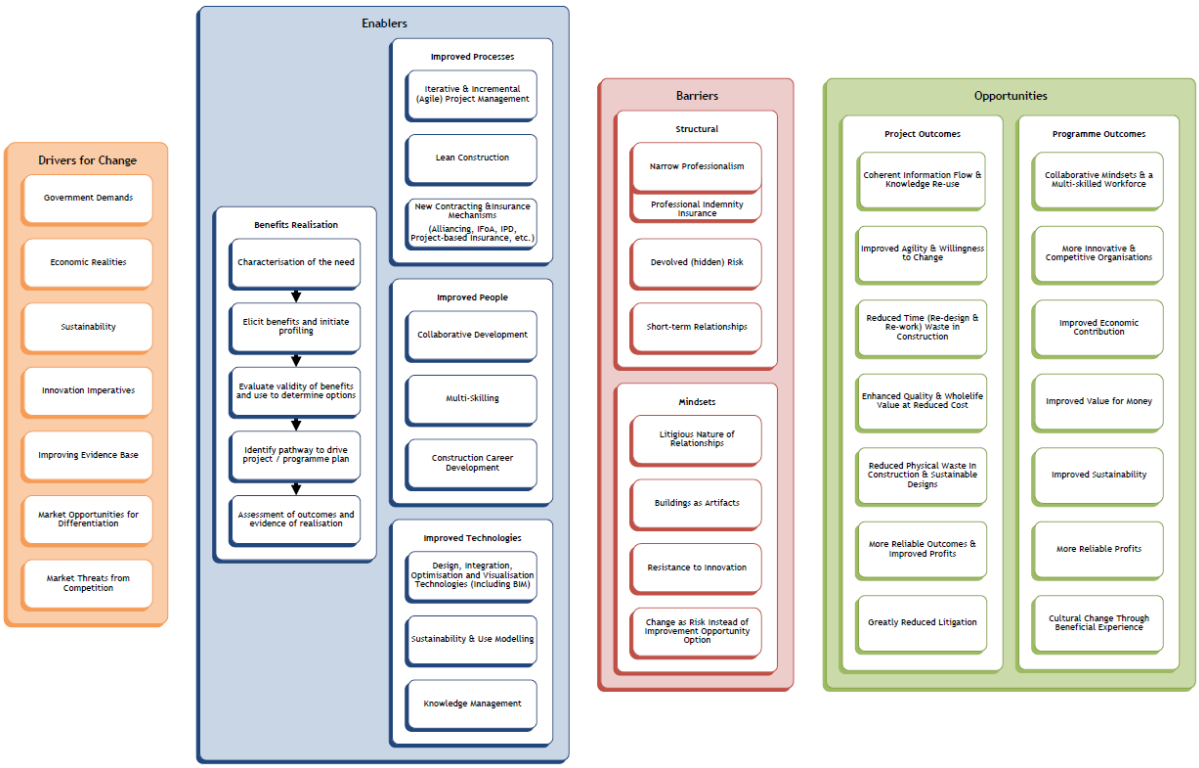


Fig.6.1 – Drivers, Enablers, Barriers and Opportunities [5], Annex 4

The ideal spaces for this debate, strategic development and for the support of these actions are the technological platforms and clusters, notwithstanding the creation of specific task groups. From a national point of view, PTPC [161] and Cluster Habitat [160] constitute privileged spaces for these forums. The Governments should identify its role on these structures and support directly or through other types of funding their activity.

Many good examples are undergoing. They should be encouraged and fostered, as they are framed with the strategic priorities. Their outcomes constitute important lessons learned that need to be disseminated. Chapter 4 presented two different level initiatives that can contribute for the industry modernization and at the same time, through the improved outputs, to the welfare of the populations.

One of the main terms related with the discussion topic is BIM. The different understandings of BIM from a specific software platform to a methodology for information management through project life cycle were previously explored.

Within this span of outlook a subsidiary notion is being developed; BEM. BEM is as elusive as BIM in the way the terminology is applied. At one end of the spectrum BEM can be used to mean an individual building product incorporating its entire manufacturer's specification information. Geometry may or may not be part of the package at this level. More useful applications of BEM do certainly include geometry as well as possible relationship descriptions. BEM has a connotation as part of a larger BIM. The idea has validity in the sense that the practical world, consists of several pools of information linked together by the best means available from the software platforms used [59].

This idea helps on the ProNIC definition that was placed on chapter 4. After all the discussion it would be possible to say the ProNIC is BIM, as it constitutes one of the main and essential ingredients of BIM, that is information. Nevertheless, the wide understanding sees BIM as 3D model. The idea of BEM is interesting fitting similarly on ProNIC, mostly due to the absence of geometry. Yet, ProNIC functionalities are wider. The author's opinion is that the most consensual understanding that should be set regarding ProNIC is that, it should be identified as an Integrated Design and Project Delivery tool. Its main roots are based on standard information from CICS and specifications, functional and collaborative environment functionalities and common processes for construction projects life cycle, being complementary to other tools, like those evidenced on chapter 4 and point 5.5.

Regarding the presented proposals, they address mainly to each specific topic (management, information and technology) and have the intention of giving general lines on actions that can contribute for the identified achievements.

REFERENCES

[1] European Commission. *Strategy for the sustainable competitiveness of the construction sector and its Enterprises, COM (2012) 433 final*. European Commission, Brussels, 2012.

[2] HM Government. *Construction 2025 Industrial Strategy: government and industry in partnership*. Crown, London, 2013.

[3] ECPT. *A vision for a sustainable and competitive construction sector by 2030 - Challenging and Changing Europe's Built Environment*. ECTP - European Construction Technology Platform, www.ectp.org, 2005.

[4] Souza, W. *Estudo sobre custos da não qualidade na construção*. Master Thesis in Production Engineering, Santa Catarina Federal University, Brazil, 2001.

[5] Owen, R., Amor, R., Dickinson, J., Prins, M., Kiviniemi, A. *Research Roadmap Report Integrated Design & Delivery Solutions (IDDS)*. CIB International Council for Research and Innovation in Building and Construction – Publication 370, Rotterdam, March 2013.

[6] *70th Euroconstruct Conference* – Budapest, Hungary, December 2010

[7] Global Construction Perspectives and Oxford Economics. *Global Construction 2020 - A global forecast for the construction industry over the next decade to 2020*, Global Construction Perspectives and Oxford Economics, London, 2011.

[8] Jeune Afrique, *Quand les Villes font leur Révolution*, Maghreb & Moyen-Orient, special n.º 4, 2013.

[9] Robinson, G., Commonwealth Ministers Reference Book, 2011.

[10] Instituto Nacional de Estatística, I.P. Estatísticas da Construção e Habitação 2012, Instituto Nacional de Estatística, I.P, Lisboa, 2013.

[11] EUROSTAT. (http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home). October 2013.

[12] Gabinete de Estratégia e Estudos Ministério da Economia, da Inovação e do Desenvolvimento e Gabinete de Planeamento, Estratégia, Avaliação e Relações Internacionais Ministério das Finanças, *Boletim Mensal de Economia Portuguesa N.º 08*, Lisbon, Portugal, August 2011.

[13] AECOPS. (http://prewww.aecops.pt/pls/daecops3/get_doc?id=33606796). October 2013.

[14] PorDATA – Evolução do PIB Português. (http://www.pordata.pt/Portugal/PIB+e+rendimentos-2412). October 2013.

[15] Análise de conjuntura FEPICOP (http://www.fepicop.pt). July 2013.

[16] Accenture Construction Report (http://www.accenture.com/us-en/Pages/insight-achieving-high-performance-construction-industry.aspx). November 2013.

[17] Rezgui, Y., *Review of information and the state of the art of knowledge management practices in the construction industry*, The Knowledge Engineering Review, Vol. 16:3, 2001, 241–254.

[18] Egan J.. *Rethinking construction*. London: Department of the Environment, Transport and the Regions,1998.

[19] Ortiz, O., *Sustainability in the construction industry: A review of recent developments based on LCA*, Construction and Building Materials, 23, 28-39, (2009).

[20] Rezgui Y, Zarli A., *Paving the way to the vision of digital construction: a strategic roadmap*. ASCE J Construct. Eng. Manage., June 2006.

[21] European Commission. *A strategy for smart, sustainable and inclusive growth COM(2010) 2020 final*, European Commission, Brussels, 2010.

[22] European Commission. *A Digital Agenda for Europe, COM (2010) 245 final/2*. European Commission, Brussels, 2010.

[23] European Commission. *Europe digital challenge*, Comission Contribution to the European Council, October 24 and 25th, 2013.

[24] European Commission. *An Integrated Industrial Policy for the Globalisation Era Putting Competitiveness and Sustainability at Centre Stage, COM (2010) 614 final*. European Commission, Brussels, 2010.

[25] Governo de Portugal e Confederação Portuguesa da Construção e do Imobiliário. *Compromisso para a Competitividade Sustentabilidade do Setor da Construção e Imobiliário*, Lisbon, March, 2013.

[26] International Organization for Standardization. *ISO 12006-2:2001 Building construction -- Organization of information about construction works - Part 2: Framework for classification of information*, International Organization for Standardization, Oslo, 2001.

[27] International Organization for Standardization. *ISO/TR 14177:1994 - Classification of information in the construction industry, International Organization for Standardization*. Oslo, 1994.

[28] Classification – Mr. Kjell Ivar Bakkmoen (http://www.standard.no/Global/externalSites/iso-tc59/IndustryISO_Session_2012-10-15_Classification_Bakkmoen.pdf). June 2013.

[29] Ekholm, A. *ISO 12006-2 and IFC – Prerequisites for coordination of standards for classification and interoperability*. Journal of Information Technology in Construction (ITcon) Vol. 10, 2005, pg. 275-289.

[30] Ekholm, A. and Häggström, L., *Building classification for BIM – reconsidering the framework*, CIB 2011-W78-W102 – Computer Knowledge Building International Conference, October 26-28th 2011,Sophia Antipolis.

[31] Zandhuis, A., Stellingwerf, R. I*SO 21500 Guidance on project management – A pocket guide*, Van Haren Publishing, The Netherlands, 2013.

[32] International Organization for Standardization. *ISO 21500:2012 Guidance on project management*, International Organization for Standardization, Oslo, 2012.

[33] International Organization for Standardization. *ISO 22263:2008 Organization of information about construction works - Framework management of project*, International Organization for Standardization, Oslo, 2008.

[34] Diário da República, Série I-A — N.º 51 – 2sd March 1999, Ministério do Equipamento, do Planeamento e da Administração do Território, *Decreto-Lei n.º 59/1999*.

[35] Diário da República, Série I-A — N.º 197 – 25th August 2001, Ministério da Saúde, *Decreto-Lei n.º 233/2001*.

[36] Diário da República, 1.ª série — N.º 20 – 29th January 2008, Ministério dos das Obras Públicas, Transportes e Comunicações, *Decreto-Lei n.º 18/2008*.

[37] Official Journal of the European Union. *Directive 2004/18/EC of the European Parliament and of the Council*, 31 March 2004.

[38] Official Journal of the European Union. *Directive 2004/17/EC of the European Parliament and of the Council*, 31 March 2004.

[39] Diário da República, 1ª série – N.º 145 – 29th July 2008, Ministério da Obras Públicas, Transportes e Comunicações, *Portaria n.º 701-H/2008*.

[40] Sousa, H., Moreira J., Mêda, P. *ProNIC® and the Public Works with the new Code of Public Procurement*. GESCON 2008 – International Forum on Construction Management, December 11-12nd 2008, FEUP, Porto.

[41] Diário da República, 1ª série – N.º 145 – 29th July 2008, Ministério da Obras Públicas, Transportes e Comunicações, *Portaria n.º 701-A/2008.*

[42] Diário da República, 1.ª série — N.º 162 — 21 de Agosto de 2009, Ministério das Obras Públicas, Transportes e Comunicações, *Portaria n.º 959/2009*.

[43] The case of e-procurement in Portugal (www.eesc.europa.eu/resources/docs/rosax.pdf). December 2013.

[44] Observatório Obras Públicas (http://www.base.gov.pt/oop/). December 2013.

[45] Portal BASE (www.base.gov). September 2013.

[46] Diário da República, 1ª série – N.º 145 – 29th July 2008, Ministério da Obras Públicas, Transportes e Comunicações, *Portaria n.º 701-I/2008*.

[47] Diário da República, 1ª série – N.º 145 – 29th July 2008, Ministério da Obras Públicas, Transportes e Comunicações, *Portaria n.º 701-D/2008.*

[48] Diário da República, 1ª série – N.º 145 – 29th July 2008, Ministério da Obras Públicas, Transportes e Comunicações, *Portaria n.º 701-E/2008.*

[49] Bowker, G., Star, S.L.. *Sorting Things Out: Classification and Its Consequences*, Mit Press, 1999.

[50] Parts of human body structure (http://www.freepik.com/index.php?goto=41&idd=513377&url=aHR0cDovL3d3dy55b3V0b2FydC5jb20vaHRtbC9WZWN0b3IvQ2hhcmFjdGVyLzI1NjIuaHRtbA==). February 2013.

[51] Kang, L.S., Paulson, B.C.. *Adaptability of information classification system for civil works*. Journal of Construction Engineering and Management, (12), (2002), 10-12.

[52] Sousa, H., Moreira, J. Mêda, P.. *ProNIC© and the evolution of the Construction Information Classification Systems*, in: GEQUALTEC (Ed.), GESCON 2008 – International Forum on Construction Management, FEUP, Porto, 2008, pp. 35-47.

[53] Yoon, C.S.. *A chronological study on the U.K. building classification system since CI/SfB*. Korean Soc. of Arch. Engrg.,Seoul, 79-88.

[54] European Commission. *Public Procurement in the European Union - Guide to the Common Procurement Vocabulary (CPV)*. European Commission, Luxemburg, 1998.

[55] European Committee for Standardization. *CWA 16138:2010 - Classification and catalogue systems used in electronic public and private procurement*. European Committee for Standardization, Brussels, 2010.

[56] EUROSTAT – Classification of Types of Constructions (http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_CLS_DLD&StrNom=CC_1998&StrLanguageCode=EN&StrLayoutCode=HIERARCHIC). July 2013.

[57] INE. *Classificação Portuguesa das Construções (CC-PT)*, Lisboa, INE, 2004.

[58] Maritz, T., Klopper, C., Sigle, T. *Developing a national standard/code of practice for the classification of construction information in South Africa*. Journal of Building and Environment 40, 1003–1009, 2005.

[59] Race, S. *BIM demystified (2nd edition)*, RIBA Publishing, United Kingdom, 2013.

[60] Biscaya, S. *Coordination and Management of Information for Construction Design Projects – A Framework for Portugal*. PhD Thesis in Philosophy, University of Salford, School of the Built Environment, College of Science and Technology, United Kingdom, 2012.

[61] RIBA. *Uniclass - Unified Classification for the Construction Industry*, 1st edition, RIBA publications, UK, 1997.

[62] Monteiro, M. D.. *Classificação da Informação na Industria da Construção - Perspectivas e Percursos*, Master Thesis in Civil Engineering, Faculty of Engineering of the University of Porto, Portugal, 1998.

[63] Corvacho, H., Sousa, H., Moreira da Costa, J., Amorim Faria, J., Gonçalves, M., Pinho, P., *O Projecto CIC-NET: Rede de cooperação estratégica entre empresas do processo de construção*, Engenharia Civil - UM, n.º13, 2002, pp. 19-34.

[64] Wiki GEQUALTEC (http://paginas.fe.up.pt/~gequaltec/w/index.php?title=P%C3%A1gina_principal). November 2013.

[65] Jonh Gender – Uniclass and Classification (http://www.cpic.org.uk/wp-content/uploads/2013/06/classification_v1.2.pdf). September 2013.

[66] Construction Project Information - New Uniclass Proposals, (http://www.cpic.org.uk/en/uniclass/new-uniclass-proposals.cfm). March 2013.

[67] Construction Project Information – Uniclass 2 (http://www.cpic.org.uk/uniclass/uniclass2/). September 2013.

[68] Construction Project Information – Uniclass (http://www.cpic.org.uk/uniclass/consultation/). September 2013.

[69] NBS – Uniclass Work Sections table (http://www.thenbs.com/topics/practicemanagement/articles/newUniclassWorkectionsTable.asp). October 2013.

[70] Charette, R. P., Marshall, H. E.. *UNIFORMAT II Elemental Classification for Building Specifications, Cost Estimating, and Cost Analysis* - NISTIR 6389. National Technical Information Service (NTIS), Technology Administration, U.S. Department of Commerce, Springfield, VA 22161, 1999.

[71] Work Breakdown Structure UNIFORMAT II. (http://caisinfo.doe.gov/documents/caswbsII.pdf). July 2013.

[72] Miller, K.R., Newitt, J.S.. *MasterFormat 2004 impact on construction organizations*, ASC Proceedings of the 41st Annual Conference, University of Cincinnati, 2005.

[73] Construction Specification Institute – Masterformat. (http://www.csinet.org/masterformat) October 2013.

[74] Omniclass site (http://www.omniclass.org/). July 2013.

[75] Bundesverband Materialwirtschaft, Einkauf und Logistik. *Final Report: Review of the Functioning of the CPV Codes/System*. European Commission, Germany, 2012.

[76] UNSPSC. (www.unspsc.org). February 2013.

[77] EUROSTAT. Classification of Types of Constructions. European Commission, Luxemburg, 1997.

[78] United Nations. *Statistical Standards and Studies*, No 43, United Nations, New York, 1994

[79] United Nations. *Statistical Standards and Studies*, No 40, United Nations, New York, 1987

[80] INE – National Classification of Goods and Services (http://smi.ine.pt/Versao/Detalhes/1849). October 2013.

[81] Diário da Républica, IIª série de, 31 de Dezembro de 2004, *283ª Deliberação do Conselho Superior de Estatística, de 26 de Novembro 2004*.

[82] BSI - British Standards Institute. *BS 1192:2007 Collaborative Production of Architectural, Engineering and construction information- Code of practice*, British Standards Institute, UK, 2007.

[83] The British Standards Institution. *PAS 1192-2 Specification for information management for the capital/delivery phase of construction projects using building information modelling*. The British Standards Institution, London, 2013.

[84] RIBA Plan of Work 2007 (http://www.architecture.com/Files/RIBAProfessionalServices/ClientServices/RIBAOutlinePlanOfWork2008Amend.pdf.). April 2013.

[85] RIBA Plan of Work 2013 (http://www.architecture.com/files/ribaprofessionalservices/practice/frontlineletters/ribaplanofwork2013consultationdocument.pdf.). October 2013.

[86] CSI - Construction Specification Institute. *The CSI Project Delivery Practice Guide*. Willey, United States of America, 2011.

[87] Common BIM Requirements 2012 (http://www.en.buildingsmart.kotisivukone.com/3). June 2013.

[88] Finne, C. *The Finnish COBIM project-common national BIM requirements*. ECPPM 2012 - 9th European Conference on Product and Process Modelling, Reykjavik - Iceland, 25-27th July, 471-475;

[89] BuildingSmart Finland (http://www.buildingsmart.fi/). November 2013.

[90] Chapman, R.E.. *Measuring and Improving U.S. Construction Productivity*. CIB World Building Congress 2010, 10-13 May 2010. The Lowry, Salford Quays, United Kingdom.

[91] Egan J.. *Accelerating change*. London: Department of the Environment, Transport and the Regions, 2002.

[92] Betts M, Clark A, Ofori G. *The importance of new approaches to management*. In: Betts M, editor. Strategic management of IT in construction. Oxford: Blackwell Science; 1999. p. 3–13.

[93] Kim, J.R., Kwan, O., Shin, E., Kim, K.J., and Cho, M.Y.. *Development of an integrated construction information management system for improving construction productivity*. Journal of The Architectural Institute of Korea, 15(10): 101–110.

[94] Sousa, H., Moreira, J., Mêda, P.: *Projeto, Gestão e Execução de Obras – Contributos do ProNIC*. ICEUBI2011 International Conference on Engineering UBI2011 - Innovation and Development, Covilhã, November 28-30th.

[95] Sorli, M., et al. *Knowledge-based Collaboration in Construction Industry*. ICE 2006, 12th International Conference on Concurrent Enterprising, Milano, Italy, 26-28 June 2006.

[96] Sousa, H., Mêda, P. *Collaborative Construction based on Work Breakdown Structures*, ECPPM 2012 - 9th European Conference on Product and Process Modelling, Reykjavik - Iceland, 25-27th July 2012, 839-845.

[97] Boddy, S., Rezgui, Y.. *Computer Integrated Construction: A Review and Proposals for Future Direction*. Advances in Engineering Software, Volume 38, Issue 10, October 2007, Pages 677-687.

[98] Rezgui, Y., *Intelligent Models for Collaborative Construction Engineering*. Computer-Aided Civil and Infrastructure Engineering, vol. 13, 1998. P.151-161.

[99] Hollermann, S.; et al., *BIM – a challenge for communication between parties involved in construction*, ECPPM 2012 - 9th European Conference on Product and Process Modelling, Reykjavik - Iceland, 25-27th July, 833-838.

[100] Diário da República, Série II — N.º 55 — 18 de Março de 2005, Ministérios das Cidades, Administração Local, Habitação e Desenvolvimento Regional e das Obras Públicas, Transportes e Comunicações, *Despacho Conjunto n.º 260/2005*.

[101] Elios. *Liability and insurance regimes in the construction sector: national schemes and guidelines to stimulate innovation and sustainability*, Special report on liability and insurance regimes in 27 EU Member States European Union, Paris, 2010.

[102] Estradas de Portugal – Caderno de Encargos Tipo (http://www.estradasdeportugal.pt/index.php/pt/areas-de-atuacao/empreendimentos). Julho 2013.

[103] Reis Cabrita, A. M., *Organização de Projectos de Edifícios*. Curso de Promoção Profissional 506, LNEC, Lisboa, 1974.

[104] Laboratório Nacional de Engenharia Civil, Caderno de encargos-tipo para a construção de edifícios, Vol 1, 2, 3, 4, Lisboa, 1970-1972.

[105] Fonseca, M. Santos. *Curso sobre Regras de Medição na Construção*, LNEC, Lisboa, 1997.

[106] Manso, A. C.; Fonseca, M. Santos; Espada, J. C. *Informação sobre custos: Fichas de Rendimentos* – Vol. 1 e 2, LNEC, Lisboa, 1997.

[107] CSI - Construction Specification Institute. *The Project Resource Manual, CSI Manual of Practice – 5th Edition*. McGraw-Hill, Alexandria, 2004.

[108] Fonseca, M.S. Knowledge base for construction safety. *Implementation of Safety and Health on Construction Sites*, Alves Dias & Coble, Rotterdam, 1996.

[109] Mêda, P., Moreira, J., Sousa, H., *Contributos do ProNIC para a melhoria da gestão do processo construtivo, Contratação Pública*, Erros & Omissões – Perspectivas e Responsabilidades, Universidade do Minho – Campus de Gualtar, Braga, 28 Maio, 2013.

[110] Sousa, H., Moreira, J., Mêda, P. *ProNIC – ambiente colaborativo para o desenvolvimento de um projeto*, Gescon2011 – Construction Information Systems, October 27 and 28th 2011, Porto.

[111] Sousa, H., Moreira, J., Mêda, P. *Aspetos introdutórios sobre a Coordenação de Projectos em ProNIC*, Construção 2012 – 4th National Congress, December 18-20th, Coimbra.

[112] Sousa, H., Moreira, J., Mêda, P. *Avaliação de custos de construção com base na normalização de trabalhos de construção – contributos para a sustentabilidade*, CINCOS' 12 – Congress on Sustainable Construction Innovation, September 20-22nd 2012, Aveiro.

[113] Sousa, H., Mêda, P., Carvalho, P. *Electronic procurement on construction works – offer evaluation methodologies*, ECPPM 2012 - 9th European Conference on Product and Process Modelling, Reykjavik - Iceland, July 25-27th 2012, 701-706;

[114] Sousa, H., Martins, V., Mêda, P. *Aprofundamento da análise do critério preço em propostas de empreitadas*, Construção 2012 – 4th National Congress, December 18-20th, Coimbra.

[115] Monteiro, A. *Avaliação da aplicabilidade do modelo IFC no licenciamento automático de projectos de redes de distribuição predial de água*. Master Thesis in Civil Engineering, Faculty of Engineering of the University of Porto, 2010.

[116] Ghosh, S., Skibniewski, M., *Enterprise resource planning systems implementation as a complex project: A conceptual framework.*, Journal of Business Economics and Management, Volume 11, 2010, Issue 4, 533-549.

[117] Castro, S., Caracterização da adopção de sistemas ERP nas grandes empresas portuguesas Dissertação de Master Thesis in Informatics, Universidade de Trás-os-Montes e Alto Douro, 2009.

[118] Shi, J., Halpin, D., *Enterprise Resource Planning for Construction Business Management " Journal of construction engineering and management*, ISSN 0733-9364, Vol. 129, Nº 2, 2003, 214-221.

[119] Corrêa, B., *Acompanhamento da implementação de um sistema ERP numa empresa do sector da construção civil*, Trabalho de conclusão de curso, Escola de Administração, Universidade Federal do Rio Grande do Sul, 2011.

[120] Diário da República, 2ª série – N.º 8 – 13 de Janeiro de 2014, Ministérios da Economia e do Ambiente, Ordenamento do Território e Energia, *Despacho n.º 578/2014*.

[121] Tribunal de Contas. *Relatório de Auditoria N.º 17/2009 – 2ªS. – Auditoria a empreendimentos de obras públicas por gestão directa*, Lisboa, 2009.

[122] Taylor, M. *Delivery of a Major Infrastructure Project with BIM (docs.google.com/file/d/0B-Q65lRX0S3wU2xIYnBwa295djg/edit?usp=sharing)*, I BIM International Conference, 20 and 21st June 2013, Porto.

[123] Crossrail (www.crossrail.co.uk). September 2013

[124] Owen, R. *CIB White Paper on IDDS Integrated Design & Delivery Solutions*. CIB International Council for Research and Innovation in Building and Construction – Publication 328, Rotterdam, 2009.

[125] AECbytes - Are We Forgetting Design? (http://www.aecbytes.com/viewpoint/2004/issue_10.html). November 2013.

[126] Monteiro, A., Poças Martins, J.P. *Building Information Modeling - features and application*. Gescon2011 – Construction Information Systems, October 27 and 28th 2011, Porto.

[127] Kalay YE., *The future of CAAD: from computer-aided design to computer-aided collaboration*. In: Proceedings of the eighth international conference on computer-aided architectural design futures, Atlanta, 7–8 June 1999. p. 14–30.

[128] Mêda, P., Sousa, H., *Introductory concepts on BIM – The importance of Information*, I BIM International Conference, 20 and 21st June 2013, Porto.

[129] Eastman, C., Teicholz, P., Sacks, R., Liston, K., *BIM Hand-book (2nd edition) A guide to building information modeling for owners, managers, designers, engineers and contractors*. NewJresey, Jonh Wiley & Sons, 2011.

[130] Paavola, S.; et al., *BIM technologies and collaboration in a life-cycle project*, ECPPM 2012 - 9th European Conference on Product and Process Modelling, Reykjavik - Iceland, 25-27th July 2012, 855-862.

[131] RICS – Royal Institute of Chartered Surveyors, Guide to Life Cycle Costing, Dublin, Ireland, 2011.

[132] Davis, K.A., Songer, A.D. *Technological change in the AEC industry: a social architecture factor model of individuals' resistance*. Proceedings of engineering management conference, IEMC'02, IEEE International, vol. 1, 2002, 286–291.

[133] European Commission - ICT and e-Business in the Construction Industry: ICT adoption and e-business activity in 2006, e-Business W@atch – 2005.

[134] Mêda, P., Sousa, H. *Towards software integration on construction industry – ERP and ICIS case study*, CIB W078 2012 Conference – The 29th International Conference on Applications of IT in the AEC Industry, Beirut – Lebanon, 17-19th October 2012, 304-313.

[135] Poças Martins, J. P. *Modelação do Fluxo de Informação no Processo de Construção - Aplicação ao Licenciamento Automático de Projectos*. PhD Thesis, Faculty of Engineering of the University of Porto, 2009.

[136] Santos, E. T., *BIM and ERP: Finding similarities on two distinct concepts*. CIB-W102, Rio de Janeiro, June 2009.

[137] SIGABIM Project (http://paginas.fe.up.pt/~gequaltec/w/index.php?title=SIGABIM). September 2013.

[138] Monteiro, A., Mêda, P., Poças Martins, J.P. *Framework for the coordinated application of two different integrated project delivery platforms*, Automation in Construction, Volume 38, November 2014, Pages 87–99.

[139] Monteiro, A., Poças Martins, J.P., *A survey on modeling guidelines for quantity takeoff-oriented BIM-based design,* Automation in Construction, Volume 35, February 2013, Pages 238–253.

[140] Productspec Database (http://www.productspec.net/). June 2013.

[141] IFC (http://www.buildingsmart-tech.org/specifications/ifc-releases/ifc4-release/ifc4-release-summary). June 2013.

[142] apdSI - Associação para a promoção e desenvolvimento da Sociedade da Informação, Os Serviços Partilhados na Administração Pública. (http://www.apdsi.pt/uploads/news/id367/servi%C3%A7os%20partilhados%20na%20ap_3098_2101020.pdf). July 2013.

[143] Shared Services Definition. (http://www.inc.com/encyclopedia/shared-services.html). July 2013.

[144] Henricks, M., *Learn to Share*. Entrepreneur, Vol. 29, Issue 3, 2001, p80.

[145] Wang, S., Wang, H., *Shared services beyond sourcing the back offices*, Organizational design. Human Systems Management, Vol.26, 2007, pp. 281–290.

[146] Ministry of Health Shared Services Unit. (http://www.spms.pt). June 2013.

[147] Bergeron, B. *Essentials of Shared Services*. John Wiley & Sons, New Jersey, 2002.

[148] Shared Services Definition. (http://www.gerap-epe.pt/perguntas-mais-frequentes-sobre-servicos-partilhados/faq-perguntas-mais-frequentes). June 2013.

[149] Quinn, B., Cooke, R., Andrew, K. *Shared Services, Mining for Corporate Gold*. Pearson Education Limited, Great Britain, 2000.

[150] Carapeto, C. *Sobre o modelo de serviços partilhados*. Revista Interface Administração Pública, 2007.

[151] Janssen, M., Joha, A., *Motives for establishing shared service centers in public administrations,* International Journal of Information Management, Vol.26(2), 2006, 102–112.

[152] Direção-geral da Administração e do Emprego Público. Análise da evolução das estruturas da administração pública central portuguesa decorrente do PRACE e do PREMAC. (http://www.dgaep.gov.pt/upload/Estudos/Evolucao_estruturas_AP_Web.pdf) August 2013.

[153] Matos, M., *Serviços Partilhados na Administração Pública: Avaliação do caso da Universidade de Lisboa*. Master Thesis in Management and Public Policies, Instituto Superior de Ciências Sociais e Políticas – Universidade Técnica de Lisboa, 2012.

[154] Diário da República, 1.ª série — N.º 56 — 22 de Março de 2010, Ministério da Saúde, *Decreto-Lei n.º 19/2010*.

[155] Santo, F., *As Diferentes Políticas de Administração do Património Público Edificado,* Ingenium, II Série n.º127 (2012), pp. 22-23.

[156] Entidade de Serviços Partilhados da Administração Pública. (http://www.espap.pt). August 2013.

[157] Carapeto, C., Fonseca, F. *Administração Pública: modernização, qualidade e inovação.* Edições Sílabo, Lisbon, 2006.

[158] Tomkinson, R. *Shared Services in local Government: improving service delivery*. Gower Publishing Limited, Hampshire, England, 2007.

[159] Mêda, P. et al. *Serviços Partilhados na Construção – Uma proposta para o setor*. ICEUBI2013 - International Conference on Engineering UBI2013 – Engineering for Economic Development, November 27-29th 2013, Covilhã, Portugal.

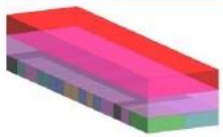
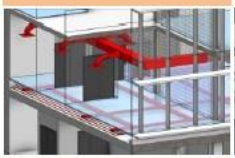
[160] CentroHabitat (http://www.centrohabitat.net/pt). September 2013.

[161] Portuguese Construction Technology Platform (http://www.ptpc.pt/index.php/pt/). July 2013.

[162] Wolstenholme, A., *Never waste a Good Crisis - A Review of Progress since Rethinking Construction and Thoughts for Our Future*, Constructing Excellence, London, 2009.

ANNEX 1 – FIGURE 3.10

RIBA Work Stages

	1	2	3	4	5	6	7
	Preparation	Concept Design	Developed Design	Technical Design	Specialist Design	Construction	Use & Aftercare
Description of Key Tasks	- Identify Project Objectives, the client's Business Case, Sustainability Aspirations and other parameters or constraints and develop the Initial Project Brief. - Examine Site Information and make recommendations for further information, including surveys, required. - Preparation of Feasibility Studies and assessment of options to enable the client to decide how to proceed. - Determine client's Risk Profile and agree the Project Programme and preliminary Procurement Strategy. - Assemble Project Team, agree Scope of Service, Contract Relationship and Design Responsibilities for each participant. Develop BIM and Soft Landings Strategies, Information Exchanges and conclude Appointment Documents.	- Preparation of Concept Design including outline proposals for structural design, services systems, site landscape, outline specifications and preliminary cost plan along with environmental, energy, ecology, access or other Project Strategies. - Agree developments to Initial Project Brief and issue Final Project Brief. - Review Procurement Strategy, finalise Design Responsibility including extent of Performance Specified Design and take action where required. - Prepare Project Manual including agreement of Software Strategy, BIM Execution Plan and extent of Performance Specifed Work. - Prepare Construction Strategy including review of off-site fabrication, site logistics and H&S aspects.	- Preparation of Developed Design including co-ordinated and updated proposals for structural design, services systems, site landscape, outline specifications, cost plan and Project Strategies. - Prepare and Submit Planning Application - Implement Change Control Procedures, undertake Sustainability Assessment and take actions determined by Procurement Strategy. - Review Construction Strategy including H&S aspects.	- Preparation of Technical Design information to include all architectural, structural and mechanical services information and specifications including the Lead Designer's review and sign-off of all information. - Performance Specified Work to be developed in sufficient detail to allow development and integration by Specialist Subcontractors during Completed Design stage. - Take actions determined by Procurement Strategy including issuing in packages where appropriate. - Prepare and submit Building Regulations Submission - Review Construction Strategy including sequencing, programme and H&S aspects.	- Progression of Specialist Design by Specialist Subcontractors including the integration, review and sign-off of Performance Specified Work by the Lead Designer and other designers as set out in Design Responsibility document - Review Construction Strategy including sequencing and critical path. - Undertake actions from Procurement Strategy or administration of Building Contract as required.	- Offsite manufacturing and onsite construction in accordance with the Construction Programme - Regular review of progress against programme and any Quality Objectives including site inspections. - Administration of Building Contract.. - Resolution of Design Queries from site as they arise - Implementation of Soft Landing Strategy including agreement of information required for commissioning, training, handover, asset management, future monitoring and maintenance and ongoing compilation of "as-constructed" information.	- Implementation of Soft Landings Strategy including Post Occupancy Evaluation. - Conclude administration of Building Contract - Review of Project Performance in use and analysis of Project Information for use on future projects. - Updating of Project Information, as required, in response to Asset Management and Facilities Management feedback and modifications.
Procurement	The stage 1, 2, 3 and 4 outputs may be used for tendering and contract purposes depending on the Procurement Strategy as influenced by the client's Risk Profile, time, cost and quality aspirations and how Early Contractor Involvement and Specialist Subcontractor input is to be undertaken.						
Programme				Stage 4, 5 and 6 activities may occur concurrently depending on the Procurement Strategy. Work may also be undertaken in packages to facilitate its development by Specialist Subcontractors. Early package procurement may also occur during stage 3 depending on the procurement route. The Project Programme should set out the timescales for these overlapping design and, where appropriate, construction stages.			
Planning		Planning Applications typically be made using the stage 3 (Developed Design) output, however, certain clients may wish this task to be undertaken earlier. The project or practice specific Plan of Work identifies when the Planning Application is to be made. Certain aspects of the Technical Design may also be required as part of the application or in respond to planning conditions.					
Key Information Exchanges (at stage Completion)	The Initial Project Brief	The Concept Design including Outline Structural and Mechanical Services Design, associated Design Strategies, Preliminary Cost Information and Final Project Brief.	The Developed Design including the Co-ordinated Architectural, Structural and Mechanical Services Design and Developed Cost Information.	The Technical Design of consultant aspects in sufficient detail to enable construction or Performance Specified Work to commence.	The Specialist Design including the integration of Performance Specified Work.	"As Constructed" Information.	"As constructed" Information updated in response to on-going client feedback, Asset Management updates and Facilities Management information.
							
Government Gateway	Information Exchange 1	Information Exchange 2	Information Exchange 3			Information Exchange 6	As Required

ANNEX 2 – FIGURE 4.21

Technical Directorate

25th May 2013
Period 2

Benchmarking Data Applications & Contract Performance Summaries

Scoring
1-2: Poor
3: Concern
4-5: Good
Wold Class
N/A / TBC

Ref.	Contractor	Contract	Area	Modelling (CAD)						Document Control (eB)						GIS (Crossrail Maps)			Asset Info
				System connectivity	Applications correct	Level of system support	Correct use of application	Use of 4D	BIM in Delivery Working Group Engagement	IT System Reliability	Applications Set Up	Level of system support	Correct use of EDMS by Delivery	Correct use of EDMS by Tier 1	Level of support from CRLDMT	Accessibility	Degree of use	Volume of use	Contractor Engagement
1	E									3	3	3	3	2	4	5	4	5	4
2	D			5	5	5	5	3	4	3	3	3	3	3	5	5	4	5	4
3	H			5		4				3	3	3	2	3	5	5	3	5	3
4	V			5	5	4	4		5	3	2	3	3	3	4	3	2	3	4
5	H			4	4	4	4	3	1	3	4	3	3	2	3	5	2	2	4
6	M			4	3	4	3	3	1	3	4	3	3	2	3	3	1	1	3
7	C			4	4	4	4	4	4	3	3	3	3	2	3	5	3	3	2
8	E									3	3	3	3	3	4	5	4	5	
9	C			4	4	4	4	3		3	3	3	3	2	3	5	1	1	
10	E			4	4	4	4			3	3	3	3	2	3				2
11	L			3	3	3	3	1	1	3	3	3	3	3	3	3	2	2	2
12	E			5	4	4	4	3	2	3	3	3	3	3	4	5	4	5	5
13	E			3	3	3	3	5	4	3	3	3	4	3	2	5	2	2	2
14	L			4	4	4	4	3	4	3	3	3	3	3	3	5	2	3	3
15	V			3	3	3	3		5	3	3	3	3	3	4	5	3	3	3
16	E			4	4	5	4	3	4	3	3	3	3	3	3	5	4	5	4
17	E			3	3	3	3	2	3	3	3	3	3	3	4	5	1	1	2
18	E			5	5	5	5	3	4	3	3	3	3	3	4	5	2	2	3

ANNEX 3 – MAPPING BETWEEN CC-PT AND CPV

CC-PT		CPV	
Code	Term	Code	Term
1	Buildings	45210000-2	Building construction work
11	Residential buildings	45211000-9	Construction work for multi-dwelling buildings and individual houses
111	One-dwelling buildings	45211300-2	Construction work for houses
1110	One-dwelling buildings	45211300-2	Construction work for houses
		45211341-1	Flats construction work
11101	Detached houses one-dwelling	45211341-1	*idem*
11102	Twined/semi-detached or terraced houses one-dwelling	45211341-1	*idem*
11103	Band houses one-dwelling	45211341-1	*idem*
112	Two-and more dwelling buildings	45211340-4	Multi-dwelling buildings construction work
1121	Two-dwelling buildings	45211340-4	Multi-dwelling buildings construction work
11211	Detached houses two-dwelling	45211340-4	*idem*
11212	Twined/semi-detached or terraced houses two-dwelling	45211340-4	*idem*
11213	Band houses two-dwelling	45211340-4	*idem*
1122	Three-and more dwelling buildings	45211340-4	Multi-dwelling buildings construction work
11220	Three-and more dwelling buildings	45211340-4	*idem*
113	Residences for communities	45211200-1	Sheltered housing construction work
113		45215210-2	Construction work for subsidised residential accommodation
113		45215220-5	Construction work for social facilities other than subsidised residential accommodation
1131	*Residences for children and young people communities*	45211200-1	Sheltered housing construction work
1131		45215210-2	Construction work for subsidised residential accommodation
11311	Homes for children and young/orphanages		idem 1131
11312	Temporary centers for children and young people		idem 1131
1132	*Residences for communities of people with disabilities (rehabilitation and integration)*	45211200-1	Sheltered housing construction work
1132		45215210-2	Construction work for subsidised residential accommodation
11321	Support centers for children and youth with disabilities	45215213-3	Nursing home construction work
11322	Residential centers for youth and adults with disabilities	45215213-3	Nursing home construction work
1133	*Residences for communities of elderly people*	45211200-1	Sheltered housing construction work
1133		45215210-2	Construction work for subsidised residential accommodation
11331	Homes for the elderly	45215212-6	Retirement home construction work

11332	Residences for the elderly	45215214-0	Residential homes construction work
11333	Hostels for the elderly/		idem 1133
11334	Residences for communities of elderly people, others		idem 1133
1134	*Residences for household communities*	45211200-1	Sheltered housing construction work
1134		45215210-2	Construction work for subsidised residential accommodation
11340	Residences for household communities		idem 1134
1135	*Student residences/Fraternity homes*	45214700-7	Construction work for halls of residence
11350	Student residences/Fraternity homes	45214700-7	*idem*
1136	*Workers' hostels*	45213400-7	Installation of staff rooms
11360	Workers' hostels	45213400-7	*idem*
1137	*Convents and monasteries*	45212360-7	Religious buildings construction work
11370	Convents and monasteries	45212360-7	*idem*
1138	*Residences for communities, others*	45211200-1	Sheltered housing construction work
1138		45215210-2	Construction work for subsidised residential accommodation
11380	Residences for communities, others		idem 1138
12	Non-residential buildings		
121	Hotels and similar buildings	45212400-0	Accommodation and restaurant buildings
1211	Hotel buildings	45212410-3	Construction work for lodging buildings
12111	Hotels	45212411-0	Hotel construction work
12112	Apartment hotel	45212410-3	*idem*
12113	Pensions	45212410-3	*idem*
12114	Hostel	45212412-7	Hostel construction work
12115	Motels	45212410-3	*idem*
12116	Historic Hotels	45212410-3	*idem*
12117	Lodging buildings, others	45212410-3	*idem*
1212	*Additional resources for tourist accommodation*	45212410-3	*idem*
12121	Holiday Village/Resort	45212410-3	*idem*
12122	Touristic apartments	45212410-3	*idem*
12123	Tourism dwellings/chalets	45212410-3	*idem*
1212	*Camping sites*	45212410-3	*idem*
12130	Camping sites	45212410-3	*idem*
1214	*Tourism sets (facilities)*	45212410-3	*idem*
12140	Tourism sets (facilities)	45212410-3	*idem*
1215	*Buildings for tourism in rural areas*	45212410-3	*idem*
12151	Buildings for guest houses	45212410-3	*idem*
12152	Buildings for country holiday	45212410-3	*idem*
12153	Buildings for agriculture-tourism	45212410-3	*idem*
12154	Buildings for tourism in rural areas, others	45212410-3	*idem*
1216	*Other short-stay accommodation buildings*	45212413-4	Short-stay accommodation construction work

12161	Youth hostels	45212413-4	*idem*
12162	Holiday camps	45212413-4	*idem*
12163	Other short-stay accommodation buildings, others	45212413-4	*idem*
1217	*Buildings for food and beverage*	45212420-6	Construction work for restaurants and similar facilities
12171	Restaurants	45212421-3	Restaurant construction work
12172	Buildings for pubs without room for dance	45212420-6	*idem*
12173	Buildings for pubs or discotheques with room for dance	45212420-6	*idem*
122	Office buildings		
1221	*Government buildings*	45216114-6	Parliament and public assembly buildings
12211	Court buildings	45216112-2	Court building construction work
12212	Town hall buildings	45216114-6	*idem*
12213	Government buildings, others	45216114-6	Parliament and public assembly buildings
1222	*Buildings of monetary and financial institutions*		
12221	Buildings of monetary institutions	45213130-3	Bank construction work
12221		45213150-9	Office block construction work
12222	Insurance buildings	45213150-9	Office block construction work
12223	Buildings of financial institutions, others	45213150-9	Office block construction work
12223		45211350-7	Multi-functional buildings construction work
1223	*Post offices buildings, conference centers and similar services*		
12231	Postal treatment building centers	45213120-0	Post office construction work
12232	Postal distribution building centres	45213120-0	Post office construction work
12232		45231510-3	Compressed-air pipeline work for mailing system
12233	Post offices and support facilities buildings	45213120-0	Post office construction work
12234	Conference centers and congress buildings	45212310-2	Construction work for buildings relating to exhibitions
12234		45212340-1	Lecture hall construction work
12235	Buildings for service activities, others	45211350-7	Multi-functional buildings construction work
123	Wholesale and retail trade buildings	45213100-4	Construction work for commercial buildings
1231	Wholesale buildings	45213100-4	*idem*
12311	Wholesale markets	45213140-6	Market construction work
12312	Fish markets	45213140-6	Market construction work
12313	Large wholesalers surface buildings	45213140-6	Market construction work
12314	Wholesale buildings, others	45213100-4	Construction work for commercial buildings
1232	*Retail trade buildings*	45213100-4	*idem*
12321	Municipal squares or markets	45213140-6	Market construction work
12322	Service and fuel stations	45213313-0	Service-area building construction work
12322		45223700-3	Service area construction work
12322		45223710-6	Motorway service area construction work

12322		45223720-9	Petrol/gas stations construction work
12323	Shopping centers/shopping malls	45213110-7	Shop buildings construction work
12323		45213111-4	Shopping centre construction work
12323		45213112-1	Shop units construction work
12324	Retail trade buildings, others	45213100-4	Construction work for commercial buildings
124	Traffic and communication buildings	45213300-6	Buildings associated with transport
1241	*Buildings and installations for air transport*	45213330-5	Construction work for buildings relating to air transport
1241		45235100-4	Construction work for airports
12411	Buildings and installations of civil (passenger and freight) and military airports	45213331-2	Airport buildings construction work
12411		45213333-6	Installation works of airport check-in counters
12411		45235110-7	Construction work for airfields
12411		45213332-9	Airport control tower construction work
12411		45223400-0	Radar station construction work
12412	Buildings and installations for aviation vehicles repair and maintenance	45213351-8	Maintenance hangar construction work
12413	Buildings and installations for air transport, others		idem 1241
1242	*Buildings and installations for rail transport*	45213320-2	Construction work for buildings relating to railway transport
1242		45234000-6	Construction work for railways and cable transport systems
12421	Buildings and installations related with rail transportation (passenger and freight)	45213321-9	Railway station construction work
12421		45213322-6	Rail terminal building construction work
12421		45234125-8	Underground railway station
12421		45234170-8	Locomotive-substations construction works
12421		45234181-8	Construction work for rail track sectioning cabins
12422	Buildings and installations related with other rail transport	45234127-2	Tramway depot construction work
12422		45234128-9	Tramway platforms construction work
12423	Buildings and installations for railway vehicles repair and maintenance	45213351-8	Maintenance hangar construction work
12423		45234180-1	Construction work for railways workshop
12424	Buildings and installations for rail transport, others		idem 1242
1243	*Buildings and installations for road transportation*	45213310-9	Construction work for buildings relating to road transport
12431	Truck central stations	45213311-6	Bus station construction work
12431		45213314-7	Bus garage construction work
12432	Sheds (bus and other road vehicles)	45213315-4	Bus-stop shelter construction work
12433	Interfaces (bus station)	45213350-1	Construction work for buildings relating to various means of transport

12433		45213311-6	Bus station construction work
12433		45213352-5	Service depot construction work
12434	Buildings and installations for road vehicles repair and maintenance	45213351-8	Maintenance hangar construction work
12435	Buildings and installations for road transportation, others	45213310-9	Construction work for buildings relating to road transport
1244	*Buildings and installations for maritime and inland waterway transport*	45213340-8	Construction work for buildings relating to water transport
12441	Buildings and installations related with sea shipping (passenger and freight)	45213341-5	Ferry terminal building construction work
12441		45213342-2	Ro-ro terminal construction work
12441		45213353-2	Installation works of passenger boarding bridges
12442	Buildings and installations related with inland waterway transport (passenger and freight)	45213341-5	Ferry terminal building construction work
12442		45213353-2	Installation works of passenger boarding bridges
12443	Buildings and installations for water vehicles (boats, others) repair and maintenance	45213351-8	Maintenance hangar construction work
12444	Buildings and installations for maritime and inland waterway transport, others	45213340-8	Construction work for buildings relating to water transport
12444		45216128-7	Lighthouse construction work
12444		45241600-4	Installation of port lighting equipment
1245	*Buildings and installations for communication*		
12451	Radio and television broadcast buildings	45232331-1	Ancillary works for broadcasting
12452	Telecommunication centers	45232332-8	Ancillary works for telecommunications
12453	Telephone booths	45232332-8	Ancillary works for telecommunications
12454	Forest watch posts	45216120-1	Construction work for buildings relating to emergency services
12455	Buildings and installations for communication, others	45232332-8	Ancillary works for telecommunications
1246	*Garage buildings*	45223300-9	Parking lot construction work
12461	Garages and roofed car parks (underground)	45223310-2	Underground car park construction work
12462	Garages and roofed car parks (overground)	45223300-9	Parking lot construction work
12462		45213312-3	Car park building construction work
125	Industrial buildings and warehouses	45213200-5	Construction work for warehouses and industrial buildings
1251	Industrial buildings	45213250-0	Construction work for industrial buildings
12511	Mills and facilities for olive oil industry	45213250-0	*idem*
12512	Buildings and facilities for wine industry	45213250-0	*idem*
12513	Buildings and facilities for textile and clothing industries	45213250-0	*idem*
12514	Buildings and facilities slaughterhouses	45213230-4	Abattoir construction work
12515	Buildings and industrial facilities, others	45213250-0	Construction work for industrial buildings
12515		45213251-7	Industrial units construction work

12515		45213252-4	Workshops construction work
1252	Reservoirs, silos and warehouses	45213220-1	Construction work for warehouses
12521	Reservoirs for oil	45213220-1	*idem*
12522	Reservoirs for gas	45213220-1	*idem*
12523	Silos for cereals, cement or other dry aggregates	45213220-1	*idem*
12524	Cold stores	45213210-8	Cold-storage installations
12525	Specialized warehouses	45213220-1	Construction work for warehouses
12526	Reservoirs and warehouses, others	45213220-1	*idem*
12526		45247270-3	Reservoir construction works
126	Public entertainment, education, hospital or institutional care buildings		
1261	Public entertainment buildings	45212170-8	Entertainment building construction work
1261		45212320-5	Construction work for buildings relating to artistic performances
12611	Cinemas and theatres (concert halls, opera houses)	45212322-9	Theatre construction work
12611		45212150-2	Cinema construction work
12612	Casinos	45212160-5	Casino construction work
12613	Bullfight arenas	45212320-5	Construction work for buildings relating to artistic performances
12614	Multi-purpose halls mainly used for public entertainment	45212321-2	Auditorium construction work
12614		45212171-5	Entertainment centre construction work
12614		45212340-1	Lecture hall construction work
12614		45212172-2	Recreation centre construction work
12614		45212312-6	Exhibition centre construction work
12614		45212600-2	Pavilion construction work
12615	Bandstands	45212320-5	Construction work for buildings relating to artistic performances
12616	Buildings for recreational or cultural purposes, others	45212300-9	Construction work for art and cultural buildings
12616		45212170-8	Entertainment building construction work
12616		45212100-7	Construction work of leisure facilities
12616		45212140-9	Recreation installation
12616		45212172-2	Recreation centre construction work
12616		45212321-2	Auditorium construction work
1262	Museums and libraries		
12621	Museums	45212313-3	Museum construction work
12622	Art galleries	45212311-9	Art gallery construction work
12623	Libraries	45212330-8	Library construction work
12624	Archives buildings	45212300-9	Construction work for art and cultural buildings
12625	Resource centers and other similar buildings	45212300-9	Construction work for art and cultural buildings
12625		45212312-6	Exhibition centre construction work

1263	School, university and research buildings	45214000-0	Construction work for buildings relating to education and research
12631	Pre-primary education buildings	45214100-1	Construction work for kindergarten buildings
12632	Primary education buildings	45214210-5	Primary school construction work
12633	Secondary education buildings	45214220-8	Secondary school construction work
12634	Higher education buildings	45214300-3	Construction work for college buildings
12634		45214320-9	Technical college construction work
12634		45214400-4	Construction work for university buildings
12634		45214410-7	Polytechnic construction work
12634		45214420-0	Lecture theatre construction work
12634		45214430-3	Language laboratory construction work
12634		45214500-5	Construction work for buildings of further education
12635	Scientific research laboratories	45214600-6	Construction work for research buildings
12636	Weather stations, observatory buildings	45214640-8	Meteorological stations construction work
12637	Educational and research establishments, others	45214000-0	Construction work for buildings relating to education and research
12637		45214230-1	Special school construction work
1264	Institutional care buildings	45215200-9	Construction work for social services buildings
12641	Kindergartens	45215215-7	Children's home construction work
12641		45214100-1	Construction work for kindergarten buildings
12642	Leisure time activities centers	45212110-0	Leisure centre construction work
12643	Centers for occupational activities	45212110-0	Leisure centre construction work
12644	Day care centers	45215221-2	Day-care centre construction work
12645	Community centers	45212110-0	Leisure centre construction work
12646	Institutional care buildings and facilities, others	45215200-9	Construction work for social services buildings
12646		45212100-7	Construction work of leisure facilities
1265	Vocational training buildings	45214800-8	Training facilities building
12651	Schools and training centers	45214800-8	Training facilities building
12652	Art academies	45214800-8	Training facilities building
12653	Vocational training buildings, others	45214800-8	Training facilities building
12653		45214310-6	Vocational college construction work
1266	*Health Buildings with inpatient*	45215100-8	Construction work for buildings relating to health
12661	General Hospital	45215140-0	Hospital facilities construction work
12662	Specialized hospitals	45215120-4	Special medical building construction work
12663	Health Buildings with inpatient, others	45215140-0	Hospital facilities construction work
1267	*Health Buildings without inpatient*	45215100-8	Construction work for buildings relating to health
12671	Healthcare centers	45215100-8	Construction work for buildings relating to health
12671		45215222-9	Civic centre construction work

12672	Diagnostic and therapeutic	45215130-7	Clinic construction work
12673	Sanatoria/Thermal facilities	45215110-1	Spa construction work
12674	Health Buildings without inpatient, others	45215100-8	Construction work for buildings relating to health
1268	*Sports hall*	45212200-8	Construction work for sports facilities
12681	Sport room	45212222-8	Gymnasium construction work
12682	Multipurpose sports halls	45212220-4	Multi-purpose sports facilities construction work
12682		45212225-9	Sports hall construction work
12683	Indoor swimming pools	45212212-5	Construction work for swimming pool
12684	Indoor tennis courts	45212221-1	Construction work in connection with structures for sports ground
12685	Indoor sports facilities and grounds, others	45212200-8	Construction work for sports facilities
12685		45212210-1	Single-purpose sports facilities construction work
12685		45212211-8	Ice rink construction work
12685		45212213-2	Sport markings works
12685		45212221-1	Construction work in connection with structures for sports ground
12685		45212222-8	Gymnasium construction work
12685		45212223-5	Winter-sports facilities construction work
12685		45212225-9	Sports hall construction work
127	Other non-residential buildings		
1271	Non-residential farm buildings	45213240-7	Agricultural buildings construction work
12711	Greenhouses	45213240-7	*idem*
12712	Poultry	45213240-7	*idem*
12713	Piggeries	45213240-7	*idem*
12714	Stud farm	45213240-7	*idem*
12715	Cowsheds and corrals	45213242-1	Cowsheds construction work
12716	Hangars and agricultural outhouses, cellars and agricultural silos	45213241-4	Barn construction work
12716		45213221-8	Warehouse stores construction work
12717	Buildings and facilities for agricultural and animal production, others	45213240-7	Agricultural buildings construction work
1272	Buildings used as places of worship and for religious activities	45212360-7	Religious buildings construction work
12721	Churches, chapels, mosques, synagogues, etc.	45212361-4	Church construction work
12722	Cemeteries and associated constructions, funeral parlors, crematoriums	45215300-0	Construction work for crematoriums
12722		45215400-1	Cemetery works
12723	Buildings for worship and religious practices, others	45212360-7	Religious buildings construction work
1273	Historic or protected monuments	45212350-4	Buildings of particular historical or architectural interest

12731	Classified or with potential classification monuments, historical sets and places	45212350-4	Buildings of particular historical or architectural interest
12731		45212351-1	Prehistoric monument construction work
12731		45212352-8	Industrial monument construction work
12731		45212353-5	Palace construction work
12731		45212354-2	Castle construction work
12732	Non classified monuments, historical sets and places	45212350-4	Buildings of particular historical or architectural interest
12732		45212314-0	Historical monument or memorial construction work
1274	Other buildings not elsewhere classified		
12741	Prisons	45216113-9	Prison building construction work
12742	Barracks for armed forces	45216200-6	Construction work for military buildings and installations
12743	Police stations	45216111-5	Police station construction work
12744	Fire stations	45216121-8	Fire station construction work
12745	Public toilets, wash houses	45215500-2	Public conveniences
12746	Bus shelters and other non-residential structures	45213100-4	Construction work for commercial buildings
12746		45216120-1	Construction work for buildings relating to emergency services
12746		45216122-5	Ambulance station construction work
12746		45216123-2	Mountain-rescue building construction work
12746		45216124-9	Lifeboat station construction work
12746		45216125-6	Emergency-services building construction work
12746		45216126-3	Coastguard building construction work
12746		45216127-0	Rescue-service station construction work
12746		45216129-4	Protective shelters
12746		45217000-1	Inflatable buildings construction work
12746		45223600-2	Dog kennels construction work
12746		45223800-4	Assembly and erection of prefabricated structures
12746		45237000-7	Stage construction works
2	Civil engineering works	45220000-5	Engineering works and construction works
21	Transport infrastructures		
211	Highways, streets and roads	45233100-0	Construction work for highways, roads
2111	Highways	45233100-0	Construction work for highways, roads
21111	Motorways	45233110-3	Motorway construction works
21111		45233130-9	Construction work for highways
21111		45233131-6	Construction work for elevated highways
21111		45233139-3	Highway maintenance work
21112	National, regional and local roads	45233120-6	Road construction works

21112		45233121-3	Main road construction works
21112		45233122-0	Ring road construction work
21112		45233123-7	Secondary road construction work
21112		45233124-4	Trunk road construction work
21112		45233125-1	Road junction construction work
21112		45233126-8	Grade-separated junction construction work
21112		45233127-5	T-junction construction work
21112		45233128-2	Roundabout construction work
21112		45233129-9	Crossroad construction work
21113	Retaining walls, slopes and embankments on motorways, national, regional and local roads	45233140-2	Roadworks
21114	Support installations for highways (lighting, signalling, safety and parking)	45233221-4	Road-surface painting work
21114		45233270-2	Parking-lot-surface painting work
21114		45233280-5	Erection of road-barriers
21114		45233290-8	Installation of road signs
2112	Streets and roads	45233100-0	Construction work for highways, roads
21121	Streets	45233120-6	Road construction works
		45233160-8	Paths and other metalled surfaces
21122	Other roads	45233160-8	Paths and other metalled surfaces
21122		45233162-2	Cycle path construction work
21123	Farm or forest tracks		
21124	Foot paths	45233260-9	Pedestrian ways construction work
21124		45233161-5	Footpath construction work
21125	Support installations for streets and roads (lighting, signalling, safety and parking)	45233221-4	Road-surface painting work
21125		45233270-2	Parking-lot-surface painting work
21125		45233280-5	Erection of road-barriers
21125		45233290-8	Installation of road signs
212	Railways	45234100-7	Railway construction works
2121	Long-distance railways	45234110-0	Intercity railway works
21211	Main railway lines	45234110-0	Intercity railway works
21212	Shunting and sorting stations	45234112-4	Railway depot construction work
21213	Support installations for long-distance railways (lighting, signalling, safety and electrification)	45234114-8	Railway embankment construction work
21213		45234115-5	Railway signalling works
21213		45234123-4	Partially underground railway works
21213		45234130-6	Ballast construction works
21213		45234140-9	Level crossing construction works
21213		45234160-5	Catenary's construction works
2122	Urban railways	45234120-3	Urban railway works
21221	Urban and local railways for heavy trains	45234111-7	City railway construction work
21222	Urban and local railways for metropolitan railways	45234122-7	Underground railway works
21223	Urban and local railways for trams	45234126-5	Tramline construction works

21224	Pathways for funiculars, cable cars and similar	45234200-8	Cable-supported transport systems
21224		45234210-1	Cable-supported transport systems with cabins
21224		45234220-4	Construction work for ski lifts
21224		45234230-7	Construction work for chair lifts
21224		45234240-0	Funicular railway system
21224		45234250-3	Teleferic construction work
21225	Support installations for local and urban railways (lighting, signalling, safety and electrification)	45234114-8	Railway embankment construction work
21225		45234115-5	Railway signalling works
21225		45234121-0	Tramway works
21225		45234123-4	Partially underground railway works
21225		45234124-1	Underground passenger railway transport
21225		45234130-6	Ballast construction works
21225		45234140-9	Level crossing construction works
21225		45234160-5	Catenary's construction works
213	Airfield runways	45235000-3	Construction work for airfields, runways and manoeuvring surfaces
2130	Airfield runways	45235000-3	*idem*
21301	Runways for take-off and landing	45235200-5	Runway construction works
21302	Taxiways	45235310-9	Taxiway construction work
21303	Platforms for aircraft parking	45235320-2	Construction work for aircraft aprons
21304	Support installations for airfield runways (lighting, signalling and safety)	45235000-3	Construction work for airfields, runways and manoeuvring surfaces
214	Bridges, elevated highways, tunnels and subways	45221000-2	Construction work for bridges and tunnels, shafts and subways
2141	Bridges and elevated highways	45221100-3	Construction work for bridges
21411	Bridges	45221110-6	Bridge construction work
21411		45221111-3	Road bridge construction work
21411		45221112-0	Railway bridge construction work
21411		45221113-7	Footbridge construction work
21411		45221114-4	Construction work for iron bridges
21411		45221115-1	Construction work for steel bridges
21411		45221118-2	Pipeline-carrying bridge construction work
21412	Viaducts	45221120-9	Viaduct construction work
21412		45221121-6	Road viaduct construction work
21412		45221122-3	Railway viaduct construction work
21413	Overpasses	45233144-0	Overpass construction work
21414	Support installations for bridges and overpasses (lighting, signalling and safety)	45221000-2	Construction work for bridges and tunnels, shafts and subways
2142	Tunnels and subways	45221200-4	Construction work for tunnels, shafts and subways
21421	Tunnels	45221240-6	Construction work for tunnels

21421		45221241-3	Road tunnel construction work
21421		45221242-0	Railway tunnel construction work
21421		45221243-7	Pedestrian tunnel construction work
21421		45221245-1	Under-river tunnel construction work
21421		45221246-8	Undersea tunnel construction work
21422	Subways or underpasses	45221211-4	Underpass
21423	Support installations for tunnels and subways (lighting, signalling and safety)	45221200-4	Construction work for tunnels, shafts and subways
215	Harbours, waterways, dams and other waterworks	45247000-0	Construction work for dams, canals, irrigation channels and aqueducts
2151	Harbours and navigable canals		
21511	Sea or river port and quays	45241000-8	Harbour construction works
21512	Sea or river docks or side-docks	45241400-2	Dock construction work
21512		45248200-9	Dry docks construction work
21512		45248300-0	Construction work for floating docks
21513	Navigable canals	45247100-1	Construction work for waterways
21513		45247120-7	Waterways except canals
21514	Port terminals	45241100-9	Quay construction work
21514		45241200-0	Offshore terminal in situ construction work
21514		45243600-8	Quay wall construction work
21515	Shipyards	45244100-0	Marine installations
21516	Jetties or seawalls	45241300-1	Pier construction work
21516		45241500-3	Wharf construction work
21516		45244200-1	Jetties
21516		45243200-4	Breakwater construction work
21516		45243300-5	Sea wall construction work
21517	Harbour infrastructures, others	45244000-9	Marine construction works
21517		45252124-3	Dredging and pumping works
2152	Dams	45247200-2	Construction work for dams and similar fixed structures
21521	Hydro-electricity dams and similar water-retaining constructions	45247210-5	Dam construction work
21522	Irrigation dams and similar water-retaining constructions	45247210-5	Dam construction work
21523	Hydro-agricultural dams	45247210-5	Dam construction work
21524	River flow regulation dams and similar water-retaining constructions	45246000-3	River regulation and flood control works
21525	Dams, others	45247200-2	Construction work for dams and similar fixed structures
21525		45247240-4	Static barrage construction work
21525		45248500-2	Movable barrages construction work
21526	Hydro-agricultural water-retaining constructions	45247220-8	Weir construction work
21527	Hydraulic tunnels	45221244-4	Canal tunnel construction work

21528	Flood prevention dam and similar water-retaining constructions/dikes	45247230-1	Dyke construction work
21528		45246100-4	River-wall construction
21529	Bank protection structures	45243000-2	Coastal-defence works
21529		45243100-3	Cliff-protection works
21529		45243400-6	Beach-consolidation works
21529		45243500-7	Sea defences construction work
21529		45246200-5	Riverbank protection works
21529		45246400-7	Flood-prevention works
21529		45246500-8	Promenade construction work
2153	Aqueducts, irrigation and cultivation waterworks	45232450-1	Drainage construction works
2153		45247110-4	Canal construction
21531	Irrigation canals and other water supply constructions working without pressure	45247111-1	Irrigation channel construction work
21531		45247130-0	Aqueduct construction work
21532	Pressurized water supply constructions for irrigation	45232121-6	Irrigation piping construction work
21533	Drainage works and open drain ditches	45247112-8	Drainage canal construction work
22	Pipelines, communication and electricity lines	45231000-5	Construction work for pipelines, communication and power lines
221	Long-distance pipelines, communication and electricity lines	45231000-5	Construction work for pipelines, communication and power lines
2211	Long-distance oil and gas pipelines	45231200-7	Construction work for oil and gas pipelines
22111	Long-distance oil pipelines (petroleum products)	45231210-0	Construction work for oil pipelines
22112	Long-distance gas pipelines	45231220-3	Construction work for gas pipelines
22113	Long-distance overland, underground or submarine pipelines for chemicals and other product	45231210-0	Construction work for oil pipelines
22114	Pumping stations on oil pipelines	45231200-7	Construction work for oil and gas pipelines
22115	Compression stations on gas pipelines	45231222-7	Gasholder works
22115		45231223-4	Gas distribution ancillary work
2212	Long-distance water pipelines	45231300-8	Construction work for water and sewage pipelines
2212		45232100-3	Ancillary works for water pipelines
22121	Catchment, pumping and filtering stations	45247270-3	Reservoir construction works
22121		45232152-2	Pumping station construction work
22121		45232153-9	Construction work for water towers
22121		45232154-6	Construction work of elevated tanks for drinking water
22121		45252121-2	Sedimentation installations
22121		45252122-9	Sewage digesters
22121		45252123-6	Screening installations
22122	Water treatment stations	45252120-5	Water-treatment plant construction work
22122		45252126-7	Drinking-water treatment plant construction work

22123	Long-distance overland, underground or submarine pipelines for the conveyance of water	45232100-3	Ancillary works for water pipelines
2213	Long-distance telecommunication lines	45232300-5	Construction and ancillary works for telephone and communication lines
22131	Long-distance overland, underground or submarine telecommunication lines	45232310-8	Construction work for telephone lines
22132	Television cable networks	45232320-1	Cable broadcasting lines
22133	Long-distance telecommunication lines and systems	45232300-5	Construction and ancillary works for telephone and communication lines
22134	Infrastructures for long-distance telecommunication lines support	45232330-4	Erection of aerials
22134		45232331-1	Ancillary works for broadcasting
22134		45232332-8	Ancillary works for telecommunications
22134		45232340-7	Mobile-telephone base-stations construction work
2214	Long-distance electricity lines	45231400-9	Construction work for electricity power lines
2214		45232200-4	Ancillary works for electricity power lines
22141	Long-distance overland high or medium tension electric power distribution lines	45232210-7	Overhead line construction
22142	Long-distance underground high or medium tension electric power distribution lines	45231400-9	Construction work for electricity power lines
22143	Transformer stations and substations, pylons	45232220-0	Substation construction work
222	Local pipelines and cables		
2221	Local gas supply lines	45231221-0	Gas supply mains construction work
22210	Local gas supply lines	45231221-0	*idem*
2222	Local water supply pipelines, steam and compressed air		
22221	Urban and local water supply pipelines	45232150-8	Works related to water-distribution pipelines
22222	Fonts and fountains for water supply	45232150-8	*idem*
22223	Fire hydrants	45232150-8	*idem*
22224	Urban and local pipelines for hot water, steam and compressed air distribution	45232140-5	District-heating mains construction work
2223	Local waste water pipelines	45232400-6	Sewer construction work
2223		45232130-2	Storm-water piping construction work
2223		45232450-1	Drainage construction works
22231	Sewerage and waste water networks	45232410-9	Sewerage work
22231		45232411-6	Foul-water piping construction work
22231		45232420-2	Sewage work
22231		45232421-9	Sewage treatment works
22231		45232422-6	Sludge-treatment works
22231		45232423-3	Sewage pumping stations construction work
22231		45232424-0	Sewage outfall construction work
22231		45232430-5	Water-treatment work
22231		45232431-2	Wastewater pumping station

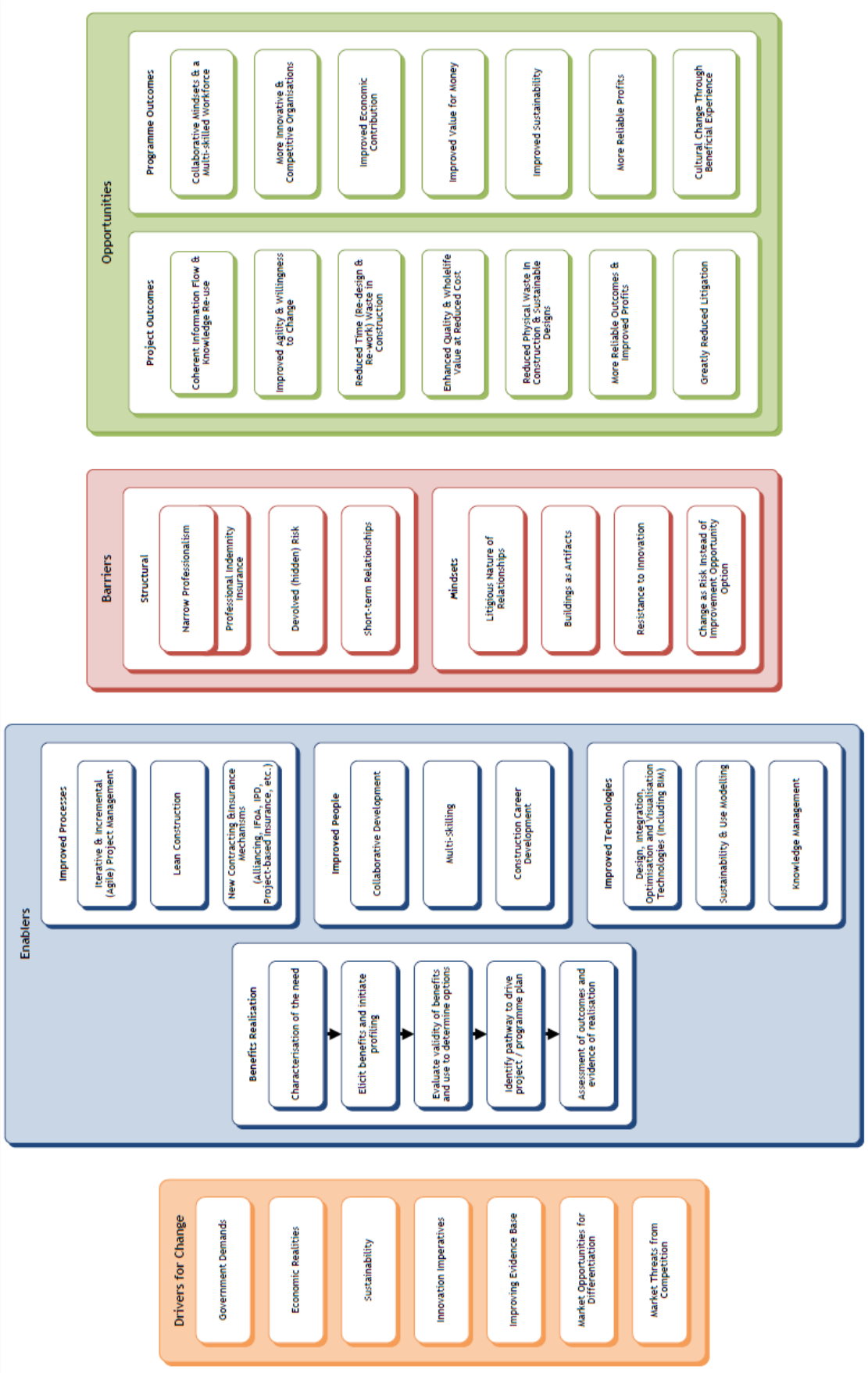
22231		45232440-8	Construction work for sewage pipes
22231		45232460-4	Sanitary works
22231		45232470-7	Waste transfer station
22231		45252120-5	Water-treatment plant construction work
22231		45252127-4	Wastewater treatment plant construction work
22232	Systems for rainwater collection	45232130-2	Storm-water piping construction work
22232		45232450-1	Drainage construction works
22232		45232451-8	Drainage and surface works
22232		45232452-5	Drainage works
22232		45232453-2	Drains construction work
22232		45232454-9	Rain-water basin construction work
22233	Waste water treatment stations	45252100-9	Sewage-treatment plant construction work
22233		45252130-8	Sewage plant equipment
22233		45252140-1	Sludge-dewatering plant construction work
22233		45252150-4	Coal-handling plant construction work
22233		45252200-0	Purification plant equipment
22233		45252210-3	Water purification plant construction work
2224	Local electricity and telecommunication cables	45231000-5	Construction work for pipelines, communication and power lines
22241	Urban and local lines for electricity, low voltage	45231400-9	Construction work for electricity power lines
22242	Transformer stations and substations for low voltage urban and local electricity lines	45232220-0	Substation construction work
22243	Urban and local electricity and telecommunication lines (overland or underground)	45231600-1	Construction work for communication lines
23	Complex constructions on industrial sites	45250000-4	Construction works for plants, mining and manufacturing and for buildings relating to the oil and gas industry
230	Complex constructions on industrial sites		
2301	Constructions for mining or extraction	45254000-2	Construction work for mining and manufacturing
23011	Installations and constructions for mining (energetic minerals)	45254100-3	Construction work for mining
23012	Installations and constructions for mining (non-energetic minerals)	45254100-3	Construction work for mining
2302	Power plant constructions	45251100-2	Construction work for power plant
23021	Hydroelectric power plants	45251120-8	Hydro-electric plant construction work
23022	Thermoelectric power plants	45251140-4	Thermal power plant construction work
23023	Wind power plants	45251160-0	Wind-power installation works
23024	Geothermal power plants	45251141-1	Geothermal power station construction work
23025	Solar power plants		
23026	Power plants, others	45251110-5	Nuclear-power station construction work
23026		45251142-8	Wood-fired power station construction work

23026		45251143-5	Compressed-air generating plant construction work
23026		45251200-3	Heating plant construction work
23026		45251220-9	Cogeneration plant construction work
23026		45251230-2	Steam-generation plant construction work
23026		45251240-5	Landfill-gas electricity generating plant construction work
23026		45251250-8	District-heating plant construction work
23027	Infrastructure for waste collection and treatment	45222100-0	Waste-treatment plant construction work
23027		45252300-1	Refuse-incineration plant construction work
2303	Chemical plant constructions	45253000-5	Construction work for chemical-processing plant
2303		45255000-9	Construction work for the oil and gas industry
23031	Facilities for oil refineries and petrochemical industries	45253400-9	Construction work for petrochemical plant
23031		45255100-0	Construction work for production platforms
23031		45255200-1	Oil refinery construction work
23032	Facilities for gas industries production and distribution	45255300-2	Gas terminal construction work
23032		45255800-7	Gas-production plant construction work
23033	Facilities and constructions of chemical industries	45253000-5	Construction work for chemical-processing plant
23033		45253100-6	Demineralisation plant construction work
23033		45253200-7	Desulphurisation plant construction work
23033		45253300-8	Distilling or rectifying plant construction work
23033		45253500-0	Construction work for pharmaceutical plant
23033		45253600-1	Deionisation plant construction work
23033		45253700-2	Digestion plant construction work
23033		45253800-3	Composting plant construction work
23033		45255700-6	Coal-gasification plant construction work
23033		45213280-9	Construction works for compost facility
2304	Heavy industrial plants, not elsewhere classified	45254200-4	Construction work for manufacturing plant
23041	Facilities and constructions for steel industry	45254200-4	Construction work for manufacturing plant
23042	Facilities and constructions for heavy industries, others	45254200-4	Construction work for manufacturing plant
24	Other civil engineering works		
241	Sport and recreation constructions		
2411	Sports grounds	45236100-1	Flatwork for miscellaneous sports installations
24111	Infrastructure for motor sports	45236100-1	Flatwork for miscellaneous sports installations
24112	Stadium	45212224-2	Stadium construction work
24113	Horse tracks and other facilities for equestrian sports	45236113-5	Flatwork for racecourse
24114	Athletic fields	45236114-2	Flatwork for running tracks

24115	Outdoor swimming pools	45212212-5	Construction work for swimming pool
24116	Outdoor tennis courts	45236112-8	Flatwork for tennis court
24117	Outdoor multi-sports court	45236100-1	Flatwork for miscellaneous sports installations
24118	Courts and grounds for sports	45236110-4	Flatwork for sports fields
24118		45242100-6	Water-sports facilities construction work
2412	Other sport and recreation constructions		
		45236200-2	Flatwork for recreation installations
24121	Amusement and leisure parks	45236250-7	Flatwork for parks
24121		45212120-3	Theme park construction work
24121		45212130-6	Amusement park construction work
24122	Games area and children playground	45236210-5	Flatwork for children's play area
24122		45212130-6	Amusement park construction work
24123	Gardens, public and forests parks	45236230-1	Flatwork for gardens
24124	Zoos	45236220-8	Flatwork for zoo
24124		45212130-6	Amusement park construction work
24125	Botanical gardens	45236230-1	Flatwork for gardens
24126	Marinas	45242200-7	Marina construction work
24127	Water park	45212120-3	Theme park construction work
24127		45212130-6	Amusement park construction work
24128	Golf courses	45236111-1	Flatwork for golf course
24129	Works and infrastructure for sport and recreation, others	45212100-7	Construction work of leisure facilities
24129		45212200-8	Construction work for sports facilities
24129		45236200-2	Flatwork for recreation installations
24129		45242000-5	Waterside leisure facilities construction work
24129		45242100-6	Water-sports facilities construction work
24129		45242110-9	Launch way construction work
24129		45242210-0	Yacht harbour construction work
242	Other civil engineering works not elsewhere classified	45223000-6	Structures construction work
2420	Other civil engineering works not elsewhere classified	45223000-6	Structures construction work
24201	Military infrastructures	45222200-1	Engineering work for military installations
24201		45213260-3	Stores depot construction work
24202	Waste disposal infrastructures	45222110-3	Waste disposal site construction work
24203	Other civil engineering works not elsewhere classified, others	45221250-9	Underground work other than tunnels, shafts and subways
24203		45223000-6	Structures construction work
24203		45213270-6	Construction works for recycling station
24203		45222000-9	Construction work for engineering works except bridges, tunnels, shafts and subways

24203		45230000-8	Construction work for pipelines, communication and power lines, for highways, roads, airfields and railways; flatwork
24203		45240000-1	Construction work for water projects

ANNEX 4 – FIGURE 6.1


Opportunities
Programme Outcomes
Collaborative Mindsets & a Multi-skilled Workforce
More Innovative & Competitive Organisations
Improved Economic Contribution
Improved Value for Money
Improved Sustainability
More Reliable Profits
Cultural Change Through Beneficial Experience
Project Outcomes
Coherent Information Flow & Knowledge Re-use
Improved Agility & Willingness to Change
Reduced Time (Re-design & Re-work) Waste in Construction
Enhanced Quality & Wholelife Value at Reduced Cost
Reduced Physical Waste in Construction & Sustainable Designs
More Reliable Outcomes & Improved Profits
Greatly Reduced Litigation
Barriers
Structural
Narrow Professionalism
Professional Indemnity Insurance
Devolved (hidden) Risk
Short-term Relationships
Mindsets
Litigious Nature of Relationships
Buildings as Artifacts
Resistance to Innovation
Change as Risk Instead of Improvement Opportunity Option
Enablers
Improved Processes
Iterative & Incremental (Agile) Project Management
Lean Construction
New Contracting &Insurance Mechanisms (Alliancing, IFOA, IPD, Project-based Insurance, etc.)
Improved People
Collaborative Development
Multi-Skilling
Construction Career Development
Improved Technologies
Design, Integration, Optimisation and Visualisation Technologies (including BIM)
Sustainability & Use Modelling
Knowledge Management
Benefits Realisation
Characterisation of the need
Elicit benefits and initiate profiling
Evaluate validity of benefits and use to determine options
Identify pathway to drive project / programme plan
Assessment of outcomes and evidence of realisation
Drivers for Change
Government Demands
Economic Realities
Sustainability
Innovation Imperatives
Improving Evidence Base
Market Opportunities for Differentiation
Market Threats from Competition