Cinzia Talamo · Marcella Bonanomi

Knowledge Management and Information Tools for Building Maintenance and Facility Management

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To Mauro

Preface

This book deals with the subject of information management; this process is analyzed within the Facility Management field, with a particular focus on the aspects connected with building maintenance management.

The market of Facility Management (FM) is significantly growing in the last ten years with a general tendency to more and more integrated services, longer-term contracts, and expansion of the strategic activities.

The increasing complexity of the organization models, the enlargement of the areas of interest and involved disciplines, the creation of new roles, the requests of new competences and support tools, the increasing expectations for the efficiency improvement in the processes, and the demand of improvements in the practices of planned maintenance are just some of the main effects of the rapid growth of the FM field which is still young but very dynamic and promising.

Furthermore, if we consider the latest developments of the BIM (Building Information Modeling) applications, the current scenario may appear even more complex, but at the same time full of potential. The possibility to have a unique and coherent three-dimensional building model, collecting all the information coming directly from the design and construction phases, paves the way for new and more advanced experimentations. These experimentations may be focused at least on two topics: on one side, the way for integrating, in the BIM model, information related to the operations and maintenance phase and, on the other side, procedures enabling the interoperability of information systems for FM within BIM environments.

Within this "multi- and interdisciplinary" scenario, information management has a fundamental role and acquires various meanings according to different timescales.

Regarding the "past", information management in a FM service means to be able to collect over time and process various data coming from several sources and concerning conditions, events, and actions that had affected the building. The aim is to create a knowledge base, constantly growing. The knowledge base is an essential condition to be able to predict next behaviors and costs, develop indexes for the systematic comparison of process and performance, and have more and more awareness about criticalities. Regarding the "present", information management means to be able to collect and process data in real time in order to monitor the conditions of the buildings, the performances of the suppliers, the development of the planned activities, the ongoing expenditures, and the requests for interventions. Regarding the "future", information management means to process data useful to develop previsions, draw scenarios, plan actions, and promote innovations.

So, information represents an important value for FM services, since it is fundamental for the efficiency and effectiveness of the service, the quality of the assets and the processes, and the evolution of the organizational models. At the same time, information is a cost. Information costs for collecting, processing, sharing, and updating. If we consider how many data are connected to the large amount of entities constituting a real estate and to the high number of operators and processes in the long life cycle of the buildings, it is easy to understand that information represents the essential condition for the development of the service, but at the same time a high risk of inefficiency and runaway expenditures. Strong inefficiencies are possible if, as it may happen, the activities that require the information collection are carried out without an adequate planning phase and appropriate coordination. The cases of negative experiences in building inventory activities are not rare: they may result excessively expensive and difficult to be completed, since they collect excessive amounts of data or because they are not oriented to a selective information acquisition.

Furthermore, about the risks of inefficiency in collecting information, we can mention the recurring situations in which different subjects collect—independently and in an uncoordinated way—information on the same building with various purposes. It is possible to find many cases in which, besides the realization of the building inventory, it is ongoing the development of other processes requiring information collection (i.e., due diligence, diagnostic, analysis for energy performance assessment, risk assessments, etc.). In the absence of a standardized schema for the identification of different spatial components and building elements, the various operators may collect information often redundantly or, in some cases, coming to conclusions that are not in accordance ones with each others. Information is used only for the specific purpose, but it is not recorded in the knowledge base of the building.

These are all effects of an inadequate analysis of information needs and deficiencies in the preliminary preparation of support tools (i.e. breakdown and coding schemes, procedures and instructions for collecting and recording, inspection plans).

From the analysis and comparison of several tender documents (both public and private), it can be noticed how the common practice is late in maturing a full awareness of the close relationship existing between management of the services and information. In many tenders, a generic demand for supply is merely included; in many others, there is even the lack of a systematic request about strategic topics that are the inventory processes, the building registry structure, and the information system.

So, this book intends to investigate these topics with the aim to offer both clients and suppliers (and also designers and students working and studying in the field of

FM), an overview of the various aspects that should be considered in designing FM agreements from the point of view of information management. The analysis proposed by the book is supported by a framework of international standards dealing with the subjects of FM services, maintenance management, and documents management, in addition to literature references and outcomes of some experimentation carried out by the authors. In particular, the system of standards, which contains useful guidelines and specifications for all the subjects concerning information management, demonstrates the worldwide interest for developing rules and references to be used and shared in order to improve communication among all the stakeholders involved in FM services during the whole life cycle and to enhance integration and coordination of all the support services.

The book is organized in seven chapters following the information management process within FM services, with a particular focus on the service of maintenance management, considered as a strategic service highly involved in the information management.

In Chap. 1, Cinzia Talamo introduces some main aspects and needs connected to information management within the Facility Management integrated services. Starting from the observation of the current evolutions in the FM market and organizational models, the aim of the chapter is to highlight the activities, developed within the various levels of a FM service, and the related information needs.

In Chap. 2, Cinzia Talamo analyzes contents, roles, characteristics, and phases of inventory activities in relation to FM services. Starting from the basic concept defining the inventory as a continuous process of retrieval, selection, validation, acquisition, and updating of information, the aim of the chapter is to propose tools and actions necessary for planning and developing the inventory. The main activities related to information collection are analyzed (documents audit, regulatory review, contract evaluation, diagnostic investigation, acquisition of information about the "history" of the building) in relation to an overview of the various information categories.

In Chap. 3, Cinzia Talamo introduces and analyzes the concept of building registry, interpreted as a database containing information collected through the inventory and necessary to describe consistency and functional and technical characteristics of the buildings. First, the chapter aims at clarifying the meaning of building registry and its relationship with the inventory process and the information system. Then, the chapter highlights criteria for the classification and the application of codes to the buildings and their construction entity parts by analyzing several international standards that propose various frameworks for the classification of information, all ascribable to a hierarchical structure.

Finally, the chapter proposes a synopsis of the information that can be acquired for the implementation of the building registry and the structure of the data sheets, interpreted as a tool for data collection.

In Chap. 4, Cinzia Talamo highlights main functions and specific requirements characterizing an information system for real estate management with a particular focus on maintenance management process. Starting from the analysis of information used in relation to some key functions (building registry, monitoring, collection, and processing of feedback information), the chapter proposes the structure of the database, which is the core of the information system, by assuming some reference standards. The aim of the chapter is to propose key aspects of the information system, useful for the client engaged in the acquisition of a FM service, when starting the investigation stage, preliminary to the setting of the service and the subsequent drafting of the tender. The key aspects focus on the definition of a gradual implementation of the service over time, storage and data processing modes, procedures for the collection of feedback information, characteristics and forms of the reporting, and management of the planned maintenance.

In Chap. 5, Cinzia Talamo proposes an interpretation of the core structure of a FM service, here named "Command Center" (CC), highlighting its characteristics and activities related to the key functions of planning and coordination of interventions, monitoring of the outcomes, and management of the information flows. The aim of the chapter is to propose some models of the command center and analyze information management, as well as the role of the information system within the various models.

In Chap. 6, Marcella Bonanomi highlights the need for an Information Lifecycle Management using BIM methodology within the context of facilities management. Therefore, the purpose of the chapter is to investigate the topic of information integration within a BIM environment focusing on information needs of FM activities. Existing BIM-Objects Information Requirements and data standards are critically analyzed in order to understand strengths and weaknesses and, at the same time, pave the way to a possible FM-based implementation.

In Chap. 7, Marcella Bonanomi investigates a possible implementation of the existing BIM-Objects Information Requirements and data standards in relation to information needs of FM processes. In order to address this topic, it is presented the output of a methodological experimentation carried out at Politecnico di Milano with the aim of defining a datasheet template enabling information exchange to support FM activities in a BIM environment. The developed data schema may implement not only current data standards which have some weaknesses concerning information needs of FM activities, but also existing interoperable overlays between BIM software and facilities information systems.

Finally, the authors propose a glossary, useful for the better understanding of terms and definitions used in this book and, at the same time, underlining some relevant terms that by now belong to the common language of the Facility Management context.

Acknowledgments Foremost, we would like to express our sincere gratitude to Professor Giancarlo Paganin, for the continuous and patient support during the writing process, as well as in editing and proofreading the text. For the same reason, we would also like to acknowledge Nazly Atta for the enthusiastic cooperation in the review process.

Contents

Chapter 1
Knowledge Management for Facility Management (FM) Services: a Rising Demand Within a Growing Market

Abstract The aim of this chapter is to introduce the main aspects and needs connected with information management within the facility management integrated services. The market of Facility Management (FM) in Europe has been significantly expanding in the last ten years with a general tendency to more and more integrated services, focusing on strategic initiatives within longer-term contracts. Within this scenario of market increase, the field of FM services has also been involved with rapid developments, related to various aspects connected with integration of services and strategic planning, such as: the enlargement of the areas of interest; the increasing complexity in the forms of contracting and in the organization models; the changing of the roles and the skills of the operators; the increasing expectations for the improvement of efficiency in the processes; the demand of improvements in the practices of planned maintenance; etc. In this situation of rapid evolutions, the information management is a subject that is becoming more and more important and strategic, highlighting several key factors, that have to be deeply investigated in order to pursue the improvement of the effectiveness and the integration of FM services. The main key factors may be summarized as: knowledge-bases for the strategic, tactical and operational levels of the integrated services; procedures and tools for selecting, collecting and managing information; procedures and criteria for orienting and checking the quality of information; requirements for the information systems.

Keywords Facility Management · Integrated services · Information management · Knowledge base

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This chapter is authored by Cinzia Talamo.

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1.1 Developments in the FM Field

The market of Facility Management (FM) in Europe has been significantly expanding in the last ten years with an estimated volume of several hundred billion Euros. The growth of FM has to be considered in relation to the data about the European market: maintenance and renovation building activities continue to have an important cushioning effect for the entire construction sector (Fig. 1.1). Several studies and researches highlight that they have been able to absorb part of the decline in the past period and will stabilize the trend in the next future (Table 1.1) [1].

According to ISS[1] (Integrated Service Solutions) [2, 3], the worldwide facilities management outsourcing market is expected to grow from $972 billion in 2012 to

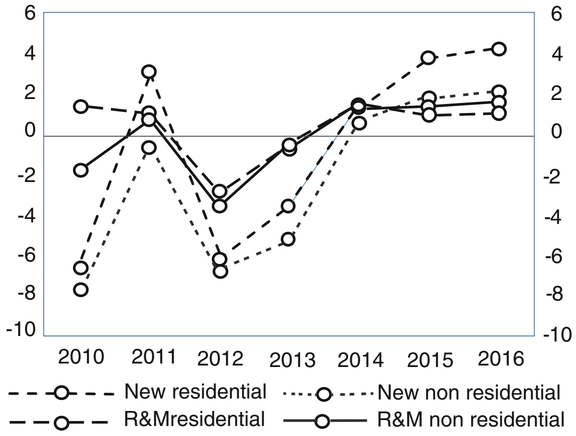

Fig. 1.1 Total building construction output from 2010 to 2016 and year to year change in % [1]

Table 1.1 Total output development in Europe by market segments and % growth rate in real terms from 2013 to 2017 [1]

Market segments	2013	2014	2015	2016	2017
New residential	−4.0	0.1	2.6	4.7	3.7
New non-residential	−5.2	0.6	2.7	2.1	2.3
Building R&M	−0.3	1.4	1.6	1.1	1.4
Civil engineering	−4.2	1.4	2.2	2.6	2.7
Total	−2.7	1.0	2.1	2.2	2.2

[1]ISS Group was founded in Copenaghen in 1901 and since then it has grown to become one of the world's leading Facility Services companies. ISS was originally the abbreviation for International Service System and from 2001 for Integrated Service Solutions, but today it is only used as the acronym.

$1.314 billion in 2018. The growth is evident across all markets, from North America and Europe to Latin America and Asia Pacific (Fig. 1.2), with a general tendency to more and more integrated services, focusing on strategic initiatives within longer-term contracts.

According to the study elaborated in the ISS White Paper [2], the revenue generated by the global Integrated Facility Management (IFM) market is predicted to expand at a compound annual growth rate of 6–8 %, to reach $1.314 billion in 2018. The study considers that North America is positioned to remain the largest IFM market, with new demand from large industrial, retail and public-sector organisations. More than 50 % of the predicted growth in the global IFM revenue from 2012 to 2018 is linked to the demand from Americas and Europe, which combine accounts for two-thirds of the global market (Table 1.2).

Furthermore, the study states that the rate of outsourcing and the demand for integrated solutions follow similar trend lines. In mature markets with higher outsourcing penetration, the demand for Integrated Facility Services is typically higher and growing, while the reverse is true in emerging markets. However, by the late 2020s, it can be predicted that China's outsourcing culture will progress to the

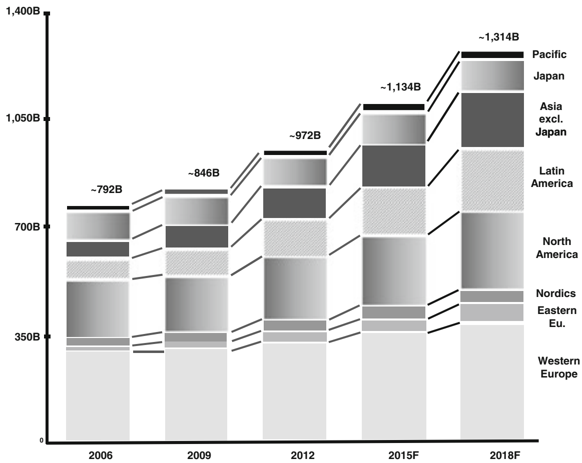

Fig. 1.2 Global outsourced facility services market by region (Billions USD) [3]

Table 1.2 Integrated Facility Services (IFS) share of total Facility Services market (%) for the period 2012–2018 [2]

	Pacific (AUS & NZ) (%)	Western Europe (%)	Americas (%)	Japan (%)	Eastern Europe (%)	Asia excl. Japan (%)
Market growth (12-18)	5	3	6	2	10	9
IFS growth (12-18)	10	9	10	6	14	12

point of accepting modern FM solutions (Fig. 1.3), opening the way for massive growth in IFM in that emerging market [4].

Within this scenario of quantitative market increase, the field of FM services has also been involved with rapid developments, related to various aspects connected with the integration of services and strategic planning, such as:

- the enlargement of the areas of interest, functions and, as a consequence, of the connected disciplines (Fig. 1.3);
- the increasing complexity of the relationships between the functions and the forms of services integration (on the side both of contracting and organization models);
- the consequent changing of operators' role, responsibilities and skills, both clients and suppliers, working in a multiple discipline context;
- the increasing expectations for cost-effectiveness, improvement of the efficiency in the processes,[2] monitoring and control of performances from many points of view (technical, economical, organizational) in the building life cycle, measurement of quality management through benchmarking[3];
- the demand of improvements in the practices of planned maintenance;

[2]In a study proposed by Goyal and Pitt [5] about the role of innovation management in facilities management a questionnaire was prepared and distributed among various personnel belonging to the business industry and the FM field.

Considering the subject of innovation, eight innovation factors were considered: technical, product, process, business, commercial, production, managerial, organization. It was noticed that business and process innovation factors received most attention within the FM field. Approximately 37 % of respondents feel that business and process innovation gain most importance further enhances the fact that FM is first and foremost about organizational effectiveness. According to the authors, the result of the responses demonstrated the evolution of FM from an operational non-core business support services function to a strategic FM position, which supports and enhances both the core and non-core activities of the organization [5].

[3]According to the standard EN 15221-7:2012, "Facility Management. Guidelines for Performance Benchmarking" the benchmark is: a reference point or metric against which a strategy, process, performance and/or other entity can be measured. Benchmarks are necessary to the process of benchmarking, that according to the EN standard is part of a process, which aims at establishing the scope for, and benefits of, potential improvements in an organization through systematic comparison of its performance with that of one or more other organizations. The measure of benchmarking may be: quantitative, qualitative, or a combination of both measures.

Quantitative benchmarking may be used for various types of assessment, such as financial expenditure (i.e. operating costs or capital costs), floor space usage (i.e. space per FTE or linear meters storage), environmental impacts (i.e. energy consumption or waste production). It uses data captured by common processes through routine systems (i.e. data collection templates and management information systems). Instead qualitative benchmarking is connected with entities that can be distinguished as intangible and it uses data captured by specific processes (i.e. focus groups and employee surveys). Qualitative benchmarking may be used for various kinds of assessments, such as: service quality, satisfaction (i.e. end-user/customer satisfaction), productivity (i.e. repeat business or employee retention). Combination benchmarking may be used for assessments such as: satisfaction in relation to space usage, service quality in relation to financial expenditure, productivity in relation to environmental impacts.

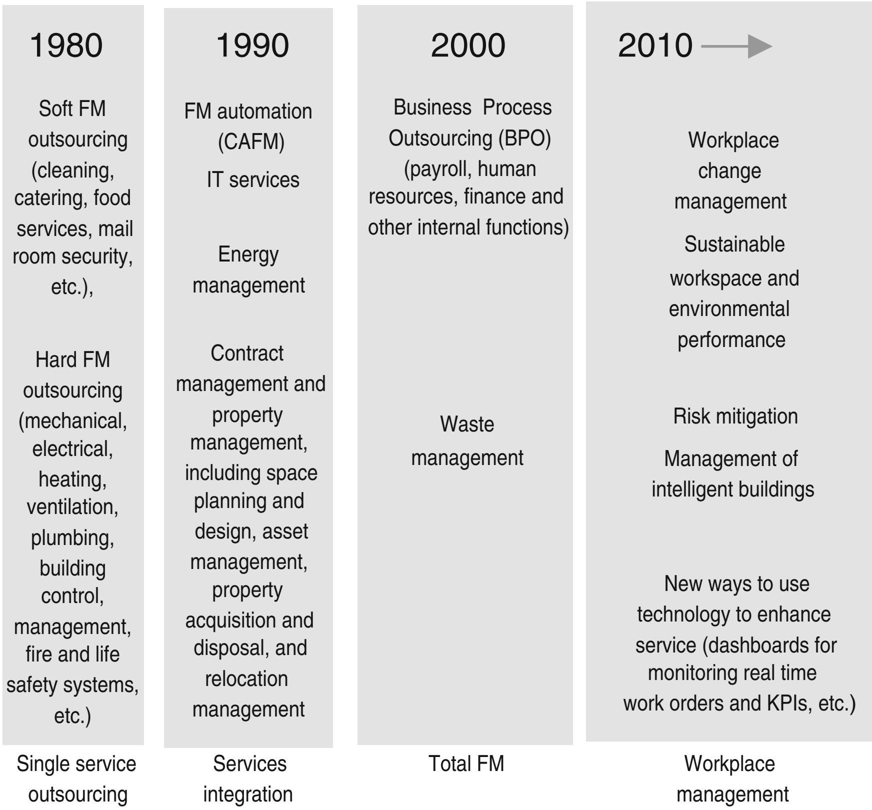

Fig. 1.3 Evolution of FM services [2]

– the need to connect more and more the maintenance and operations phase with the design and construction phases.

Among the many complex factors, that, in a situation of dynamic evolutions, characterize the FM market, the information management is a subject that is becoming more and more important, especially for the integration of the services. From this point of view, in current context, several key factors for improving the effectiveness of FM activities may be identified, such as:

– knowledge-bases constantly fostered;
– procedures and tools for managing the information flow;
– procedures and criteria for orienting and checking the quality of information;
– shared references and clear schemes for organizing input and output data in the workflow of processes;
– defined requirements for the information systems.

Facility Management professionals have to deal with a large amount of information provided by various domains [6], as they are contemporarily engaged with different areas, such as: financial management, change management, health and safety, contract management and building and engineering services maintenance, etc. [7]. Therefore, assumed the variety of domains, data have to be combined, integrated and managed in order to create an accessible knowledge, with particular regard to the information integration, which can be defined as the sharing of essential data or information between the parties involved in the process [8]. Through the information integration, the parties get an easier access to the information required, they are able to understand customers' needs and reduce lead times with better results than the ones of their competitors [9].

As Waheed and Fernie [10] emphasize, knowledge is the most significant organizational source within FM services and it holds the most strategic value in understanding and managing the relationship between the performance of the physical resources and their impact on the customers served by those resources. Furthermore, considering knowledge management in FM services is also fundamental not only for better understanding the most strategic role of facilities management, concerned with resource management, but also for going beyond the idea that facilities management is simply a form of janitorial function and thus for promoting innovation [5].

The subject of knowledge opens to a particular view within FM services, starting from the conceptual chain, that links:

- data (i.e. numbers, texts, images, etc.), that obtain meaning and value only in relation to a context and processing;
- information that is data processed according to specific goals, referred to a context and managed to be used, shared and combined;
- knowledge that is the result of applying, processing, relating, combining information in specific contexts. The process, that leads information to enter in a system able to develop knowledge, creates the actual value and competitive advantage for an organization [11].

So, information can be considered the core of this chain aiming at creating knowledge. Therefore, the activities of collecting, organizing, sharing, elaborating information have to be considered as crucial and strategic for the quality of the FM services. About the value of information, several authors [12–14] have investigated the risks of faulty or wasteful information processing activities caused by poor quality of information, underlying the significant benefits for a client's organization deriving from the improving of the overall information management [12–14].

Various problems, typical in the information management, can arise, worsening the efficiency of the processes, such as:

- information cannot flow due to various reasons, such as problems in generation, broken processes, unavailability of a critical process, etc.;
- information is unable to flow because it cannot be identified or because shared processes are not compatible;

- excessive information is generated and maintained as well as excessive information flows. So, the most appropriate and accurate information cannot be easily identified;
- inaccurate information flows resulting in inappropriate downstream activities, corrective actions or verifications.

About this topic, it is interesting to mention a Finnish study proposed by Jylhä and Suvanto [15] that analyses the quality of information and its impact on the FM service processes from a lean management perspective. Applying the categories of lean management (overproduction, inventory, transportation, motion, over-processing, defects, waiting) to FM processes, the research investigates the main reasons of waste in information management when the information consumer does not have immediate access to an adequate amount of appropriate, accurate and up-to-date information, with the consequences of additional actions or inactivity.

Based on the analysis of cases studies, the research highlights three main impacts as results of the poor quality of information in the facility service processes. First, a lot of time is wasted in the searching activity due to non-standardized information distribution and wrong quantity of information. Then, a lot of time is also spent on extra works, such as checking and double-processing due to low reliability of information delivery, low validity of information contents and incomplete information. Finally, potential is lost because information is not delivered on time, irrelevant information covers up relevant information and information is ignored.

Overall, for most authors focused on FM services, knowledge is widely recognized as a strategic asset as it enables firms to sustain distinctive competencies and discover innovation opportunities [16, 17].

The knowledge sharing contributes to innovation because it activates an inclusive process of learning. The innovation process involves the acquisition, dissemination and use of new knowledge [18].

In FM context, the relevance of information systems able to efficiently manage knowledge, in order to translate it into value or profit, arises more and more. According to Gao et al. [19]:

> "Knowledge can be classified into two dimensions. One dimension is to manage existing knowledge, which includes developing of knowledge repositories, knowledge compilation, arrangement and categorization; another is to manage knowledge-specific activities, that is, knowledge acquisition, creation, distribution, communication, sharing and application. For sustaining these processes, both "hard" conditions and "soft" environments have to be created and nurtured. Hard side means technological platforms including facilities and necessary devices. Soft side consists in trust, team spirit and learning climate for improving contributors' productivity. [...] Knowledge can be communicated, exchanged and shared thanks to database, data warehouse, statistics, data mining information system".

Therefore, the subject of information is not simply referable to a list of data to be collected. On the contrary, it should be faced by considering the many, heterogeneous aspects, interacting one to each other, that are organization models, characteristics of the various processes, fields of activities, competencies, types of clients, customers, providers, etc.

So, the basic questions about information for FM could be at least:

– What kind of organizational and operative models for managing information?
– What logical structure for collecting, relating and allocating information?
– What categories of information in the steps of the building life cycle in relation to the various demands for FM services?
– Which activities, procedures and tools can be used?
– How collected information may become a knowledge base supporting the continuous improvement of services?
– What is the value of knowledge management within FM services?

1.2 Information for Planning, Managing and Assessing FM Processes

The standard EN 15221-1:2007, “Facility Management—Part 1: Terms and Definitions” considers Facility Management as the integration of processes within an organization to maintain and develop the agreed services which support and improve the effectiveness of its primary activities. Starting from this basic concept, the subject of information should be considered in relation to some fundamental statements.

First of all, the agreed support services (facility management services) are provided in a coordinate way through an integrated management in relation to various levels, characterized by different tasks, competences and responsibilities. According to the standard EN 15221-1:2007, it is possible to list three main levels.

The first one is the strategic level, characterized by decision makers whose mission is the achievement of the objectives of the organization in the long term period through actions such as:

– defining the Facility Management strategy in compliance with the organization strategies;
– drawing policy guidelines for space, assets, processes and services;
– maintaining relations with the client and authorities, lessees and tenants, strategic partners, associations etc.;
– developing risk analysis and providing the direction to adapt changes in the organization, first simulating and then managing the impacts of services on the primary activities;
– setting the Service Level Agreements (SLAs) and the Key Performance Indicators (KPIs) for the monitoring activities[4];

[4]According to the standard EN 15341:2007, “Maintenance Key Performance Indicators”, indicator is: measured characteristic (or a set of characteristics) of a phenomenon, according to a given formula, which assesses the evolution. Indicators are related to objectives. The indicators can be used to: measure a status; compare (internal and external benchmarks); diagnose (analysis of

– constantly supervising the Facility Management organization.

The second level is the tactical one, characterized by the managers' competences, engaged in the implementation and the monitoring of the strategic objectives for the medium term, whose main tasks are:

– developing business plans and budgets;
– managing projects, processes, agreements and Facility Management teams;
– making Facility Management objectives feasible;
– defining SLAs and interpreting KPIs (performance, quality, risk and value);
– managing and optimizing the use of resources;
– monitoring compliance to laws and regulations;
– reporting results and changes;
– communicating with internal or external service providers at a tactical level.

The third level is the operational one and it is managed by operators that deliver the planned services in accordance with the SLAs to the end users day by day, constantly monitoring and checking the service processes by:

– monitoring the service providers;
– carrying out the planned activities;
– receiving requests for service, i.e. via help desk or service line;
– collecting data for performance evaluations, feedback and demands from end users;
– reporting to tactical level;
– communicating with internal or external service providers at an operational level.

These different levels, that should be integrated and coordinated, intersect a broad and open list of functions (Table 1.4), that could be present in FM services, provided to respond to the various areas of demand (Table 1.3) for managing spaces, infrastructures, people and organizations. If we compare the basic categories of demand proposed by the standards EN 15221-1:2007 and EN 115221-4:2011, "Facility Management—Part 4: Taxonomy, Classification and Structures in Facility Management" (Table 1.3) with the broad list of functions proposed by Cotts [20] (Table 1.4), we would notice that many of the various functions are involved in more than one area of demand.

It is easy to understand that the same information or document (i.e. related to the destination of a room, the type of an equipment, etc.) should be shared, without redundancies, by several functions. In the meantime, this information or document could be useful for various areas (i.e. accommodation, utilities, health-safety and security, etc.), as well as for different types of roles within the three levels. These roles (i.e. the client, the decision makers, the managers, the customers, the end

(Footnote 4 continued)

strengths and weaknesses); identify objectives and define targets to be reached; plan improvement actions; continuously measure changes over time.

Table 1.3 Basic categories of demand for FM services [34, 37]

Space and infrastructure	
Accommodation (space)	– Strategic space planning and management – Programming and briefing – Design and construction – Lease and occupancy management – Building operations and maintenance – Renovation and/or refurbishment
Workplace (working environment)	– Workplace design and ergonomics – Selection of furniture, machinery and equipment – Move management – Equip internal and external environment – Signage, decorations, partitions and furniture replacement
Technical infrastructure (utilities)	– Energy/utilities management – Environmental sustainability management – Technical infrastructure operations and maintenance – Building management systems operations and maintenance – Lighting maintenance – Management of waste (hazardous) disposal
Cleaning (hygiene and cleanliness)	– Hygiene services – Workplace cleaning, machinery cleaning – Building fabric and glass cleaning – Cleaning equipment provision and maintenance – Outdoor space cleaning and winter services
Outdoor (land, site, lot, parking)	– Hiring of special measuring equipment – Fitting out with machinery and equipment – Retail unit space management
People and organization	
Health, safety and security	– Occupational health services – Security management – Access control, I.D./smart cards, locks and key holding – Disaster planning and recovery – Fire safety and protection
Hospitality (supports for a hospitable working environment)	– Secretarial and reception services – Help desk services – Catering and vending – Organization of conferences, meetings and special events – Personal services – Provision of work wear
ICT (Information and Communication Technologies)	– Data and telephone network operations – Data centre, server hosting and operations – Personal computer support – IT security and protection – Computer and telephone connections and moves

(continued)

Table 1.3 (continued)

People and organization	
Logistics (transport and storage of goods and information)	– Internal mail and courier services – Document management and archiving – Reprographic systems, copying and printing – Office supplies – Freight forwarding, storage systems – People transport and travel services – Car park and vehicle fleet management
Other support services	– Accounting, auditing and financial reporting – Human resource management – Marketing and advertising, photographic services – Procurement, contract management and legal advice services – Project management – Quality management

Table 1.4 Basic functions in FM services [20]

Functions	Areas of activity
Management of the organization	Planning; organizing; staffing; directing; controlling; evaluating
Facility planning and forecasting	Business unit knowledge gathering; strategic facility planning (three to ten years plans); facility operational planning (twelve months to three years); space forecasting; financial forecasting and macro-level estimating; capital program development
Lease administration	Out leasing; lease administration; property management
Space planning, allocation and management	Space allocation; space inventory; space forecasting; space management
Architectural/engineering planning and design	Macro-level programming; building planning; architectural design; engineering design of major systems; macro-level estimating; as built maintenance; disaster recovery planning; design document preparation and updating; code compliance; traffic engineering; zoning compliance
Workplace planning allocation and management	Workplace planning; workplace design; furniture specification; estimating; as built maintenance; code compliance
Budgeting accounting and economic justification	Programming; work plan preparation; budget preparation (1–2 years); economic justification; financial forecasting (1–2 years); budget formulation; budget execution
Real estate acquisition and disposal	Site selection and acquisition; building purchase; building lease; real estate disposal

(continued)

Table 1.4 (continued)

Functions	Areas of activity
Sustainability	Site selection decisions to minimize environmental impacts; environmental policies to minimize waste and reduce resource usage; project management in compliance with environmental regulation; workplace improvements for productivity; aligning design with business functions
Construction project management	Project management; construction management; procurement management; preparation of "as built"; project evaluation
Move, add, change management project management (MAC)	Alteration management; renovation management; furniture installation; ICT installation; provision of furnishing; equipping; relocations; procurement; preparation of "as built"; project management
Operations, maintenance and repair	Exterior maintenance (roof, shell, window systems); preventive maintenance; breakdown maintenance; cyclic maintenance; grounds maintenance; road maintenance; custodial maintenance; pest and rodent maintenance; trash removal; hazardous waste management; energy management; inventory of systems and equipment; maintenance projects; repair projects; correction of hazards (i.e. asbestos, bad air quality, radon, underground leaks, etc.); disaster recovery; procurement
Technology management	Operations; maintenance; data system operations and reconfiguration; network management; "as built" maintenance; integrated workplace management system (IWMS)
Facility emergency management	Emergency preparedness planning; threat assessment; command, control and communication; mitigation strategies; training, drill and exercise; disaster recovery planning
Security and life-safety management	Code compliance; operations; crime prevention through environmental design; access control; physical deterrents; electronic security; vulnerability assessment
General administrative services	Food services; reprographics; fleet management; property disposal; moving services; procurement; moving services; procurement; health program management; records management and storage

users, the suppliers, etc.) could use the same information in relation to different ways and aims: for instance the decision maker for processing aggregate data and indexes, the manager for developing a report, while the technical operator for extracting precise data for the execution of a work.

The scenario of the use of information and documents becomes even more complex if we apply a process-based approach to management systems to the field of Facility Management in accordance with the EN ISO 9000:2005, "Quality management systems. Fundamentals and vocabulary" and in particular the quality cycle of Plan, Do, Check and Act (PDCA) as defined in the ISO 10014:2006, "Quality management. Guidelines for realizing financial and economic benefits".

In general, the quality management aims at ensuring that delivery meets demand, processes are optimized and continuous quality improvements are in place, and, consequently, that the results of service delivery and processes are measured over time. The standard EN 15221-3:2011, "Facility Management—Part 3: Guidance on quality in Facility Management" underlines that within the client's organization very often QMS (Quality Management Systems) already exists and that their aim is the improvement of the effectiveness of the client primary activities. So, in such situations, the existing QMS should be extended to the quality management in the FM processes especially aligning the quality indicators.

Applying quality management within FM processes (Fig. 1.4) implies the development of two parallel processes, applicable at all levels, both of them aiming at the continuous improvement, strongly interdependent, constantly sharing and interchanging information and managing key-performance indicators, as well as benchmarking data.

The result of a vision of the FM processes, developed according to the quality cycle (PDCA), is a complex framework of actions carried out within the three levels, like the one proposed by the standard EN 15221-3:2011. The large amount of information and documents (each one containing various information), that are involved in the development of the processes, are summarized below (Tables 1.5, 1.6 and 1.7).

A framework similar should be drawn before planning the whole process of FM. In fact a fundamental and preliminary task of a FM service is the definition of:

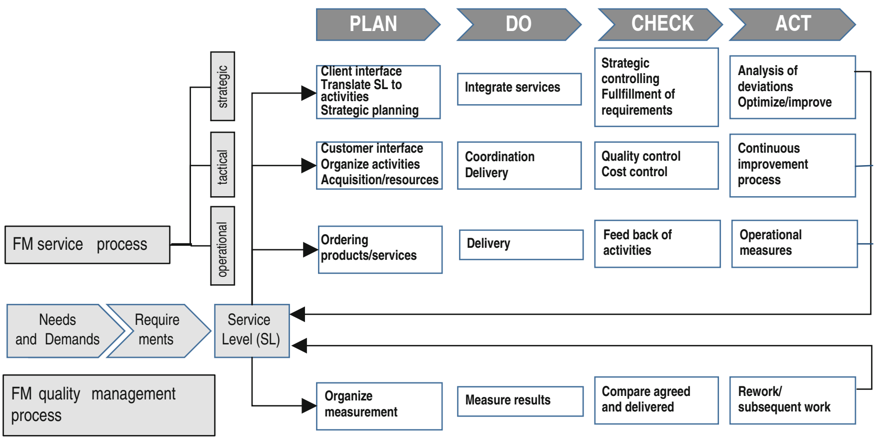

Fig. 1.4 A vision of the FM processes, developed according to the quality cycle (PDCA), derived from the quality management process [36]

– the framework of the information and the documents that are expected to be collected and used over time (information and documents taxonomy[5]);
– the rules and the procedures for their collection (inventory process) (Chap. 2);
– the organization and the logic structure of the databases (registry system) (Chap. 3).

The lack of this overall and preliminary vision is often the cause of inefficiencies and delays in the processes, superabundance or defects of information, errors in timing and costs previsions, with the risks of a poor information quality as described in the previous paragraph. Furthermore, a well-structured registry system (Chap. 3) is the fundamental condition for the development of indicators and statistical elaborations, useful for benchmarking and forecasts regarding various subjects (i.e. costs, behaviors of technical elements over time, energy performances, works durations, risk factors, resources consumption, etc.).

1.3 Key Performance Indicators and Service Level Agreement: Information to Request and Control the Quality of the Services

As several authors [21–23] emphasise a long-term strategic plan is fundamental for planning, monitoring and forecasting implications and improvements of FM services. In the development of this kind of plan, from the ealier phases of analysis, aiming at assessing the current situation and defining the long term strategic directions, data gathering represents one of the first steps. Already in these early stages, it would be appropriate that all the data gathered were collected according to a basic framework. This framework should be derived from the registry system (Chap. 3), if it already exists, or vice versa it could represent the basis for the future registry.

Later, in the phase of demand of a FM service, a client should have a clear vision of the set of information (taxonomy) that are expected to be collected in relation to several functions (Tables 1.4, 1.5, 1.6 and 1.7).

This awareness would allow to correctly develop the specifications and, in the following phases, to guide the decisions about the structure of the building registry, the tasks connected with the inventory and the choices of the information system. Defining, in the preliminary phases, the set of information is not an easy task, but the client should face the effort to analyze his needs and organization, not only understanding the types of services to ask for, but also drawing the set of basic information connected with each service (Tables 1.5, 1.6 and 1.7).

[5]See the standard EN 15221-4:2011, "Facility Management—Part 4: Taxonomy, Classification and Structures in Facility Management".

Table 1.5 Taxonomy of information and documents using PDCA cycles at strategic level

			PLAN	DO	CHECK	ACT
Strategic level	Client interface	Actions	Alignment with client's organization	Consulting	Reporting to client	Change management at strategic level
		Information and documents	– FM strategy – Action plans – Investments project plans – Reports about customer feedback/complaints – Due diligence	– Strategic topics list – Information and reports of projects	Strategic reports regarding: operating costs; space utilization and costs; benchmarks; fulfillment of quality requirements; project related cost and results; customer satisfaction survey; compliance survey; change requests and related results	– List of contact information including responsibilities and requirements of data/information – Communication guideline of the organization – Standardized means/documents for communication with the FM community – Documents about agreed changes – Documents about change management actions
	Quality management strategic level	Act.	– Identifying demand – Needs and demand specifications		Fulfillment of requirements	
		Inf. and doc.	– List of required demands (concerning space/workplace, equipment, assets, supplies, etc.) – Performance agreements – Strategic space plan			

(continued)

Table 1.5 (continued)

		Act.	FM agreement	Lead FM organization	Control FM organization	Managing improvement process
		Inf. and doc.		– FM organizations plan – Strategic FM projects – FM reporting – Laws and regulations		
	Strategy	Act.	Strategic planning and strategy development	Strategic project (Strategy implementation)	Strategic controlling	Communication external relations
		Inf. and doc.	– FM standards regarding (operations and maintenance, space, cleaning, security, etc.) – FM procedures for evaluation of facilities and buildings – Procedures for auditing of service qualities according to SLA and KPIs	– Approved demands list – FM standards – Investment projects list – Project descriptions – Project plans	– Approved demands list – FM standards – Investment projects list – Project descriptions – Project plans	– List of contact information including responsibilities and requirements of data/information – List of external contacts derived from contracts, providers, associations, etc.

Table 1.6 Taxonomy of information and documents using PDCA cycles at tactical level

			PLAN	DO	CHECK	ACT
Tactical level	Customer interface	Act.	Alignment with customer	– Coordination customer/client – Consulting of customer	Reporting to customer	– Change management at tactical level – Communication with customer
		Inf. and doc.		– Information about FM teams – Procedures of change management	– Information about FM teams – Procedures of change management	– Information about FM teams – Procedures of change management
	Quality management tactical level	Act.	– SLA elaboration		– Compare results – Quality control	
		Inf. and doc.	– List of required demands (concerning space/workplace, equipment, assets, supplies, etc.) – Performance agreements – Strategic space plan		– Information about FM teams – Procedures of change management	– Information about FM teams – Procedures of change management
	FS-organization	Act.	Service level agreement (SLA)	Manage FM team	– Evaluation performance – Cost control	Continuous improvement process
		Inf. and doc.	– List of external contacts derived from contracts, providers, associations, etc. – Contract register – Contract evaluation report	– Project register – Contract evaluation report – Competence development plan	– SLA and KPI – Facility performance report	

(continued)

Table 1.6 (continued)

	Tactics and central	Act.	Tactical planning and central functions	– Service coordination – Manage central functions	Monitoring performance	– Provider management – Communication with end users
		Inf. and doc.	– Actual provider register – Provider evaluation report – Strategic space plan – Space utilization report (occupancy and use of space) – Laws and regulations	– Facility register – Facility services contract – Evaluation reports resources register – FM KPIs	– Health, safety, security and the environment reports – Laws, regulations, insurance – List of requirements – FM KPIs	– Provider register – Provider evaluation report – Performance evaluation report

Table 1.7 Taxonomy of information and documents using PDCA cycles at operational level

			PLAN	DO	CHECK	ACT
Operational level	Facility products and facility services	Act.	Product planning	Product map	Evaluation, Reporting	Operational measures
		Inf. and doc.	– Reports about the evaluation of the planning of the facility services – Work orders – Information about FM teams – Facilities evaluation report and customer satisfaction surveys reports – Reports about the measure of the service results according to SLA and KPI – FM reports about operations and maintenance data (i.e. fulfilled activities, status data, condition data, emergency and break downs, corrective actions, etc.) – FM reports about service requests of end users and change requests of end users – Reports about complaints (i.e. cleaning, malfunctions, etc.) – Reports about security issues and moves – Building register			
	QM	Act.	Organizing measurement	Data collection	Measure results	Improve measurement

A useful way for making this task easier could be starting from the types of performances that are expected from the several areas of the services, that is defining set of indicators.[6]

Defining the services and the levels of expected quality is a fundamental operation, so the indicators[7] usually should be clear since the earlier phases of preparation of Facility Management agreements. As Varcoe [22] underlines: "Applying

[6]Major facility performance measurement practices are benchmarking, balanced scorecard approach, post occupancy evaluation and measurement through metrics of key performance indicators. Between the various effective performance models, according to a comparative study presented by Meng and Minogue [21], KPI is the most popular model for FM practitioners and organizations. The study, based on the empirical data collected from a questionnaire survey and a series of expert interviews, underlines that the ten most important performance indicators identified by the respondents are: client satisfaction, cost-effectiveness, response time, service reliability, health, safety, environmental compliance, staff commitment, client-service provider relationship, IT application.

[7]The Standard EN 15221-2:2006, "Facility Management—Part 2: Guidance on how to prepare Facility Management agreements" stresses the fact that both parties (Client and service provider) should ensure that the responsibilities for designing, updating and reporting of management information are fully understood and articulated in the Facility Management agreement. Procedures should be prescribed for the production of reports and performance indicators to any or all stakeholders, especially if financial penalties or inducements may be paid. If necessary, parties may consider an independent audit of such reports and performance indicators.

the disciplines of performance measurement helps managers and operators alike to determine firstly those issues that are crucially important to the overall organization and its success, and second those ones that are similarly critical to the successful delivery of the specific function or operation concerned. As such the technique focuses on the core information sets that are needed to effect reliable and effective management and operation—vital knowledge irrespective of whether or not it is then applied in a performance measurement system of some sort”.[8]

Since indicators need information to be developed, starting from them, it is possible to draft a list of information and to map the processes in which it is generated and elaborated.

For this purpose, it is correct to acquire a taxonomy of indicators from which to select and adopt the ones that are appropriate for the specific situation.

The taxonomy could be based on the following general categories, deduced from standard EN 15221-7:2012, “Facility Management—Part 7: Guidelines for Performance Benchmarking”:

- General Financial indicators:
  Costs per FTE,[9] workstation, square meter NFA[10] including: annual operating expenditure; annualized capital expenditure; annual revenue income; total facility costs;
- Spatial indicators:
  - Net Floor Area per FTE (sqm NFA)
  - Net Floor Area per person (sqm NFA)
  - Net Floor Area per workstation (sqm NFA)
  - Net Floor Area/Total Level Area (%)
  - Internal Area/Total Level Area (%)
  - Gross Floor Area/Total Level Area (%);
- Environmental indicators:
  - Total CO_2 emissions (tonnes per annum)
  - CO_2 emissions per FTE (tonnes per annum)
  - CO_2 emissions per sqm NFA (tonnes per annum);

[8]Varcoe [22] also reports about the tasks of the Measurement Steering Group promoted by the BIFM Council since 1995, whose aim was the development of a facilities management performance measurement standard. The Protocol draft was based on a measurement framework structured according to the following items: standard units; the organization; the estate; the buildings; facilities management (operational services/cost centers, functional use of space; financial performance; other performance); comparisons.

[9]According to the standard EN 15221-7:2012, FTE (Full Time Equivalent) can be determined by dividing the total number of hours worked by the number of regular working hours in a working week (i.e. working 32 h when a regular working week consists of 40 h equals 0.8 FTE).

[10]According to the standard EN 15221-6:2011, NFA (Net Floor Area) is the calculated area of Internal Floor Area (IFA) excluding the Interior Construction Area (ICA) that is: IFA-ICA = NFA.

- Energy indicators:
  - Total energy consumption (kWh per annum)
  - Energy consumption per FTE (kWh per annum)
  - Energy consumption per sqm NFA (kWh per annum);
- Water indicators:
  - Total water usage (cm per annum)
  - Water usage per FTE (cm per annum)
  - Water usage per sqm NFA (cm per annum);
- Waste indicators:
  - Total waste production (tonnes per annum)
  - Waste production per FTE (tonnes per annum)
  - Waste production per sqm NFA (tonnes per annum).

In order to define the information connected with the indicators, it can be useful to apply to each indicator both the attributes and the methods for data gathering proposed by the standard EN 15221-3:2011. The standard proposes the following list of attributes:

- category;
- code/number/identifier (mainly for information systems);
- name;
- description of the characteristics;
- facility product or facility service the indicator is related to;
- area (category, geographical area, level);
- area/region the indicator is related to;
- definition of the indicator;
- measured value and validity/reliability constraints;
- target value, range, tolerance, limit values and validity/reliability constraints;
- measurement method;
- timing;
- frequency of measurement;
- sample size and reliability of measurement;
- for calculated indicator, the calculation algorithms and weighting factors;
- source of data/information (i.e. measurement by whom, audit, report, etc.);
- condition when measurement shall or have been made;
- validation process.

Regarding data gathering, the standard EN 15221-3:2011 lists several types of sources, such as:

- measurements (regarding measurable characteristics);
- laboratory testing;
- inspections;
- checklists;

- counting;
- telephone surveys;
- questioners;
- mail surveys;
- research;
- analysis (i.e. complain analysis, gap analysis, etc.);
- observations;
- focus groups surveys;
- workshops;
- purchase from outside source;
- meeting client;
- market research forums;
- interviews;
- third party professional opinion.

Furthermore, considering that building maintenance is a crucial aspect of facility management and a lot of information is involved in the maintenance processes, it is advisable that facility managers, in the early phases of demand of the services, clearly define the core indicators connected with maintenance tasks. A useful list, from which it is possible to choose the indicators most appropriate for the specific situations, is the one proposed by the standard UNI EN 15341:2007, “Maintenance Key Performance Indicators”. The standard structures the indicators in levels that represent a breakdown structure. Indicators below level one are a detailed description of indicators at an higher level. The magnitude and number of levels may be established by each company. Some of the indicators most frequently present in FM agreements are summarized in the Table 1.8. These indicators should be integrated with the ones concerning health, safety and security (Table 1.9).

Studies on performance assessment of facilities [23–29] indicate the need to select core indicators and optimize the number of indicators assumed in order both to obtain a more precise but relevant set of KPIs and avoid redundant information. In particular, Lavy et al. [27] underline that facility management professionals would benefit from categorization of the core indicators, as they could more effectively utilize them. At this aim, Lavy et al. [29] propose an interesting review of the studies about the categorization of the indicators (Table 1.10). Starting from these studies, it is interesting to mention the research work proposed by Lavy et al. [28], whose aim is the identification and categorization of core indicators. The proposed indicators (Table 1.11) are arranged in a list, based on four categories of KPIs, from which facility managers can select the most appropriate ones according to the requirements dictated by their specific contexts, that is:

- financial indicators, which relate to costs and expenditures associated with operation and maintenance, energy, building functions, real estate, plant, etc.;
- physical indicators, which are associated to the physical shape and conditions of the facility, buildings, systems and components;

Table 1.8 Maintenance key performance indicators [41]

Maintenance Key Performance Indicators		
Economic indicators	Level 1	*Total maintenance cost* Assets replacement value
		Total maintenance cost Added value plus external costs for maintenance
		Total maintenance cost Quantity of output
	Level 2	*Total internal personnel cost spent in maintenance* Total maintenance cost
		Total external personnel cost spent in maintenance Total maintenance cost
		Total contractor cost Total maintenance cost
		Total cost of maintenance materials Total maintenance cost
		Total maintenance cost Total energy used
	Level 3	*Corrective maintenance cost* Total maintenance cost
		Preventive maintenance cost Total maintenance cost
		Condition based maintenance cost Total maintenance cost
		Predetermined maintenance cost Total maintenance cost
		Improvement maintenance cost Total maintenance cost
		Cost of training for maintenance Number of maintenance personnel
Technical indicators	Level 1	*Total Operating time* Total operating time + downtime due to maintenance
		Number of failures due to maintenance creating environmental damage Calendar time
		Annual volume of wastes or harmful effects related to maintenance Calendar time
		Number of injuries for people due to maintenance Working time
	Level 2	*Total operating time* (Total operating time + downtime related to failures)
		Total operating time (Total operating time + downtime related to planned and scheduled maintenance)

(continued)

Table 1.8 (continued)

	Level 3	*Preventive or Predetermined or Condition based maintenance time causing downtime* Total downtime related to maintenance
		Number of failures causing injury to people Total number of failures
		Number of failures causing damage to the environment Total number of failures
		Total operating time Number of maintenance work-orders
		Total operating time Number of failures
Organizational indicators	Level 1	*Number of internal maintenance personnel* Total internal employees
		Planned and scheduled maintenance man-hours Total maintenance man-hours available
		Number of injuries to maintenance personnel Total maintenance personnel
		Man-hours lost due to injuries for maintenance personnel Total man-hours worked by maintenance personnel
	Level 2	*Production operator maintenance man-hours* Total production operators man-hours
	Level 3	*Corrective or preventive or condition based maintenance man-hours* Total maintenance man-hours
		Overtime internal maintenance man-hours Total internal maintenance man-hours
		Number of work orders performed as scheduled Total number of scheduled work orders
		Number of maintenance internal personnel man-hours for training Total internal maintenance man-hours
		Number of the spare parts supplied by the warehouse as requested Total number of spare parts required by maintenance

– functional indicators, which are related to the facility and the buildings function and express building appropriateness through space adequacy, parking, etc.;
– users' satisfaction.

Table 1.9 Health, safety and security key performance indicators [42]

Health, safety and security indicators
Cost of solved safety non-conformances for the month
Employee perception of management commitment
Health and safety prevention costs within the month
Lost time (in hours) due to accidents (including fatalities) i.e. 100,000 h worked
Lost time (in hours) due to non-fatal accidents i.e. 100,000 h worked
Number of fatalities i.e. 100,000 h worked
Number of non-conformance with legal or internal standards in safety inspections
Number of reportable accidents i.e. 100,000 h worked (including fatalities)
Number of reportable non-fatal accidents i.e. 100,000 h worked
Number of safety inspections for the month
Number of solved safety non-conformances for the month
Percentage of attendance at occupational health and safety (OHS) committee meetings
Percentage of corrective actions closed out within specified time-frame
Percentage of fatal accidents relative to all accidents (non-fatal and fatal) i.e. 100,000 h worked
Percentage of health and safety representatives (HSR) positions filled.
Percentage of issues raised by H&S Reps implemented
Percentage of occupational health and safety (OHS) committee recommendations implemented
Percentage of products/services assessed for health and safety impacts
Percentage of significant products and services categories subject to procedures in which health and safety impacts of products and services are assessed for improvement
Percentage of staff with adequate occupational health and safety (OHS) training
Total of hours in safety and health training in the month

Table 1.10 Literature review for the categorization of KPIs [29]

Sources	Categories			
	Financial	Functional	Physical	Survey based
Amaratunga and Baldry [30]	Financial implications	FM internal processes Learning and growth		Customer's relations
Gumbus [24]	Financial implications	Operational Learning and growth		Customer's relations
Hinks and McNay [31]	Business benefits	Space equipment Change consultancy	Maintenance and service	Environment
Ho et al. [25]		Safety and security Size and use of facility	Ground and environment Energy consumption Cleaning Maintenance Parking Refurbishment	
Augenbroe and Park [32]			Energy Lighting Maintenance	Thermal comfort
Massheder and Finch [33]	Business	Acquisition disposal	Portfolio Building Performance	

The list and the categorization of KPIs (Table 1.11) is the starting point for the study[11] and it could represent a useful reference to be assumed by facility managers as basic framework of indicators.

[11]The study presented by Lavy et al. [27] aims at expressing the categories of KPIs (Table 1.11) with fewer indicators. In particular, KPIs, such as building maintenance cost, grounds keeping costs, cleaning costs and maintenance expenditure, are summarized by the maintenance efficiency indicator (MEI). KPIs, like current replacement value and deferred maintenance possess, are expressed in the form of a condition index (CI). Buildings physical condition (quantitative and qualitative) and building performance index are indicated by a CI as well. The CI includes a widely used facility condition index (FCI), which is actually a collective indicator for a building maintenance and replacement program. The indicators related to capital expenditures, such as capital cost and renewals and replacement expenditure, are conveyed by a replacement efficiency index (REI), which includes comparing the actual replacement expenditure with the cost of expired systems in the facility [27, 28].

Table 1.11 Categorization of KPIs [27–29]

Financial	Functional	Physical	User satisfaction
Operating costs	Building physical condition—qualitative	Productivity	Customer/building occupants' satisfaction with products or services
Occupancy costs	Building physical condition—quantitative	Parking	Community satisfaction and participation
Utility costs	Building performance index (BPI)	Space utilization	Learning environment, educational suitability, and appropriateness of facility for its function
Capital costs	Resource consumption: energy; water; materials	Employee or occupant's turnover rate	Appearance
Building maintenance cost	Property and real estate waste	Mission and vision, and	
Grounds-keeping cost	Health and safety	Mission dependency index (MDI)	
Custodial cost	Indoor environmental quality (IEQ)	Adequacy of space	
Current replacement value (CRV)	Accessibility for disabled		
Deferred maintenance and deferred maintenance backlog	Security		
Capital renewal	Site and location		
Maintenance efficiency indicators (MEI)			
Facility condition index (FCI)			

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Chapter 2
Inventory for the FM: Collection and Management of Information During the Life Cycle of a Building

Abstract The aim of the chapter is to analyze the contents, the role, the characteristics and the phases of the inventory activities in relation to the FM services. In the chapter the meaning of real estate inventory is introduced, underlying that it might be considered as a continuous process of retrieval, selection, validation, acquisition and updating of information. According to this vision, several criteria, characterizing the process of inventory, are highlighted: progression (it means defining in advance the purposes and the characteristics of the information to be acquired and the criteria of priority, in order to determine the timing of the progressive acquisition in relation to available resources); dynamism (the inventory should not be interpreted as an operation that is done *una tantum*); specificity (the contents of the inventory might be defined on the basis of a series of questions concerning the purposes of the services, the characteristics of the real estate, the information already in possession), the multiplicity of sources. Later, the main activities related to the collection of information are analyzed (documents audit, regulatory review, evaluation of contracts, diagnostic investigation, acquisition of information about the "history" of the building) in relation to the various categories of information, that are listed, and to the steps of development of the inventory, that are described.

Keywords Real estate inventory · Information acquisition · Procedures · Surveys

2.1 Contents and Role of the Inventory

A thorough knowledge of the real estate is an essential condition for the accurate determination of the services to be outsourced (in Global Services[1] or in other contractual formula) for the definition of the proper indicators concerning the various services, for requiring and evaluating the offers, for estimating economic

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This chapter is authored by Cinzia Talamo.

[1]See the Italian standard UNI 11336:2004, "Global service for maintenance of buildings—Guidelines".

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benefits. Probably this is the reason why the subject of Real estate inventory is becoming more and more important within FM services [1].

Contextually to the preparation process of a contract for FM services, the client, before developing the specifications of the services, should evaluate the consistency, the quality and the availability of information in his possession. This preliminary investigation ought to be carried out with a proper methodology and procedure in order to be able to document with certainty the available knowledge.

From this survey three different situations may appear:

– the available information is sufficient for the development of the contract specification;
– the information available is not exhaustive and/or it is not mutually integrated and coherent and/or not compliant to the actual situation of the assets. In this case inventory activities are necessary for integration and revision;
– the information is missing or unusable. Therefore, it is necessary to start an inventory.

In order to understand the purpose, the role and the execution modalities of a real estate inventory, first of all it is necessary to clarify its meaning. An inventory might be basically defined as a system of activities and procedures aiming at providing the knowledge of the dimensional and physical characteristics of a Real Estate.

The goal of a Real Estate inventory is to gather the information useful for planning, managing and checking the provision of facility services. This goal is achievable through a plurality of integrated activities, such as analysis, audits, surveys, collection and selection of technical, administrative and legal data and documents. These data and documents are acquired, managed and progressively updated within a systematic process.

Therefore, it is possible to introduce an extension of the general concept of real estate inventory by interpreting it as a continuous process of retrieval, selection, validation, acquisition and updating of information. In order to be able to obtain, through the support of appropriate information management tools, different kinds of information at any time, this process has to be organized in a proper way. Essentially, on one side: information about the current extent and conditions of the assets; on the other side: basic information about significant events that have marked the history of the buildings (i.e. initial situation, maintenance operations, adjustments, replacements of parts, transformations, etc.).

This interpretation of inventory as a continuous process leads to consider several criteria that converge to define the purpose and the distinctive features of the Real estate inventory:

– progression, that is, information should be progressively acquired in a systematic manner, controlled and filed appropriately. The use of resources and expertise, that a process of inventory involves, especially on large-scale assets, requires operating according to a “strategy of progression”. This means to define in advance the purposes and the characteristics of the information to be acquired and the criteria of priority, in order to determine the timing of the progressive acquisition in relation to available resources. The definition of information, to be acquired by the various activities within inventory, must consider the real possibility of their retrieval, according to the means and the time available. So, a careful preliminary analysis should be conducted, in order to define the basic information, that is information that can be considered essential and have to be present for the startup of the services and the information that instead can be acquired in a deferred time (Chap. 1). Therefore, a plan should be developed preliminary to the execution of the inventory activities:

– dynamism. The inventory should not be interpreted as an operation that is done *una tantum*, but as a continuous process of acquiring and updating information, organized in such a way that at any time it is possible to know the current state of consistency of the real estate assets;
– specificity. The inventory might not be a standard service designed in a general way; vice versa its contents might be defined on the basis of a series of questions pertaining to the purposes of the services, the characteristics of the real estate, the information already in possession. In particular, it is important to get an overall view of the offered services, that is, the set of services, their requirements and their integration forms. This allows to consider at the same time and in a unified way the information needs of all the provided services (form and contents, uses of the information that has to be collected);
– the level of detail in relation to the needs and the resources. Since the complete collection of information requires significant time and costs, the inventory procedure should be planned in advance and the extent of the collection evaluated according to a case-by-case basis and after careful evaluation, both of the functions and uses, and of the resources available. According to the standard EN 1533:2011, "Criteria for design, management and control of maintenance services for buildings*"*: "the necessary information are those that describe fully the asset and its state of compliance with respect to its usability and its asset value". Inventories aimed at gathering large amounts of information, oversized and excessive in relation to the actual needs or available resources—in terms of human, financial and time resources—determine situations characterized by high costs, difficult implementation, as well as problems in updating data;
– the multiplicity of sources. The information to be collected through an inventory can be different for type and derive from various sources (i.e. surveys, documents audit, regulatory audits, overview, etc.) (Tables 1.5, 1.6 and 1.7). Consequently, in the design and planning of the inventory, the source of the information should be clearly specified, in order to define the precise and different methodologies to be adopted in relation to the backgrounds of the information, to select the necessary skills and guide appropriately the actions of the operators.

Moreover, the inventory might be considered within a broader system of activities related to the acquisition of knowledge. The inventory can become, for instance, the opportunity for coordinating a series of cognitive activities, to be performed in series or in parallel, with the possibility of pursuing the organizational

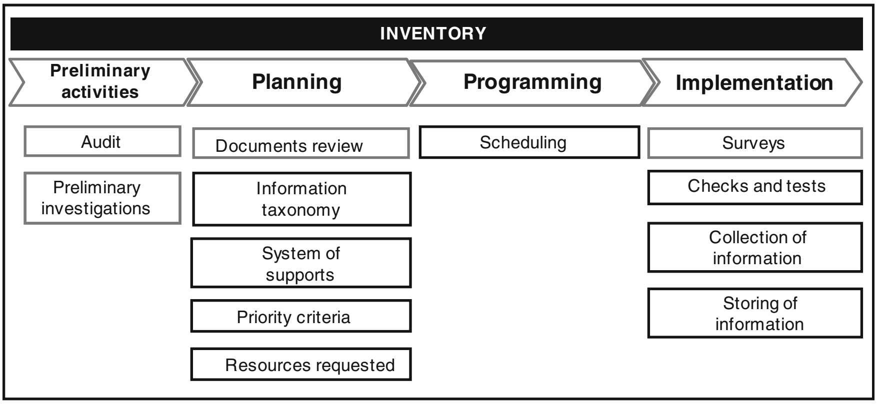

Fig. 2.1 The inventory process [7]

and economic optimization. This optimization is achievable by rationalizing operations and resources through activities such as surveys, documentary research, organization and collection of feedback data, implementation of the information system.

For this purpose, it may be useful to introduce a step, preliminary to the inventory, by developing a general information framework, which defines the taxonomy of information and their sources (Tables 1.5, 1.6 and 1.7).

Starting from this framework, two important actions can be set.

The first consists in the definition of the inventory plan, that is defining time, phases and procedures for collecting, organizing and returning information.

The second consists in the individuation of several preliminary activities, involving surveys and collection of information (Fig. 2.1) in order to avoid the risks of superabundance of data and the repetition of information acquisition [2].

The activities that should be considered in coordination with the inventory are various, such as:

– the documents audit for the realization and management of archives (Table 3.3, Chap. 3). The documents audit should be an activity always present in the development of an inventory. It consists first of all in the collection and consultation of available documentations, and subsequently in the possible search of the missing documents considered as necessary for specific goals of knowledge and control. The preliminary documents audit allows to know the information already available, thus avoiding in the inventory, during surveying and data capture, to search for information already existing. So, the real estate inventory could also represent the opportunity to develop archives where documents, regarding the buildings throughout their life cycle, can be classified, preserved and updated [3]. Many advantages and synergies may result from considering jointly the development of the inventory and the documents archives. Firstly, all the documents and the information can be organized according to the same coding system for the registry of the buildings and their parts (Chap. 3). Secondly, the operations of survey and documents research can be better organized and optimized. Thirdly, it is possible to make documents traceable and "map", within them, information that can be collected in the development of the inventory in differed times, according to a principle of gradualism. In this way, it is possible to avoid many survey operations just by extracting information from existing documents. Of course, once documents, data and existing information have been collected, selected and organized, it is necessary to assess their adequacy and make possible actions of completion/updating:

- the regulatory review (assessment of compliance). This review is usually carried out with the purpose of determining the status of compliance with respect to mandatory regulations. The application context may consist both in the planning of the works necessary for the adaptation to regulations and standards and in a due diligence[2] process. In both cases the evaluation of compliance presupposes the existence of basic information coming from the inventory, such as: morphological and dimensional spaces, their intended uses, characteristics of the technical elements, etc.;
- the evaluation of contracts, aimed at rebuilding the overall situation of existing contracts;
- the diagnostic investigation. The identification of the state and the interpretation of conditions and causes of degradation of a building require the availability of descriptive information, characteristics and performances of technical elements;
- the acquisition of information about the "history" of the building, that is information on events that have affected the building throughout its life cycle such as transformations of use, replacements, repairs, recurring failures, consumption, cost of intervention, etc. This kind of information is extremely useful for instance for the safety control, the interpretation of faults, the forecast over time of the behavior of materials and components and the mean operating time between failures.

Finally, considering the role of inventory within FM processes, it is necessary to underline its important link with information systems (Fig. 3.3) (Chap. 4).

The decision to acquire and implement an information system makes clear the need of starting inventory processes in order to collect information; vice versa inventory actions, launched in response to different needs of knowledge about the real estate, highlight the need of a well-framed platform in order to organize, manage, update and make available the collected data.

[2]According to the standard EN 15221-2:2006, "Facility Management. Guidance on how to prepare Facility Management agreements", due diligence is: compilation, comprehensive appraisal and validation of information of an organization at the appropriate stage of the Facility Management agreement required for assessing accuracy and integrity at the appropriate stage of the agreement process.

In the market of FM services, the tendency of supplying the inventory service linked with the implementation of an information system is becoming more and more widespread. This tendency makes clear that it is advisable to coordinate the setting and the development of an inventory with the activities of selection, customization and management of an information system. The benefits for the efficiency, effectiveness and coherence of the information framework concern different aspects:

- the information and the methods for the collection and storage of inventory data (i.e. sheets type, categories, form and sources of information to be collected, etc.) are defined in accordance with the structure and the operating procedures of the information system;
- the preliminary identification of the needs for knowledge defines at the same time both the information to be collected through the inventory activities and the functions and data processing requested to the information system;
- the preliminary knowledge of the framework of procedures, functions and application modules, which may characterize an information system, cooperates to define the framework of the information to be collected through the inventory;
- the definition of the overall framework of knowledge (taxonomy) to be acquired through the inventory and of the priorities in collection may opportunely guide the implementation plan of the information system;
- the activity of data entry, carried out according to a first basis of information collected through the inventory (or according to a set of data taken as a sample), allows to test and evaluate the best way to enter and use data in relation to all the various types of potential users of the information system. This test can give the opportunity of revising and improving something in the inventory plan or better defining the features of the information systems such as the design/customization of the interfaces, or the reporting standards;
- in the inventory, activities of information collection find support and facilitation in some functions, typical of the most common information systems, such as the acquisition of drawings in both digital and paper formats and the interface with databases or other information systems.

2.2 Information Categories

An inventory process aims at collecting information that can be referred to two categories of knowledge.

The first category concerns the quantitative consistency of the buildings constituting the real estate. This involves the acquisition of information relating to the quantitative aspects and dimensions of the buildings and their surrounding areas. The information related to the quantitative consistency of the spaces can take different characterizations and specifications depending on the possible uses of those data.

The second category concerns the technical characteristics of the building. This involves the acquisition of information on technical elements (building and equipments). These kinds of information can significantly vary in quantity and contents in relation to the level of detail of the technical analysis. In general, for the description of the technical characteristics, the inventory should identify at the minimum level the kinds and amounts of technical elements present in each building. At a superior level, the inventory should instead collect information identifying technical and commercial characteristics (i.e. data relating to constituent materials and components, the method of execution, the type and/or structural arrangement, the geometrical configuration and dimensions, etc.).

Concerning the issue of diversification and progression of information over time, the European standard EN 15331:2011 proposes two levels of data collection for the aspects related to buildings maintenance services.

The first one, the preliminary level of data collection, is related to the needs of identifying and quantifying the property to be maintained. This level includes:

- location;
- gross volume and surface area, divided according to the intended use (refer to standards if applicable);
- general characteristics of component parts (i.e. position inside the building, drawings, technical datasheet, instructions for maintenance issued by manufacturer, etc.);
- level of compliance with legal and regulatory requirements (objectives to be attained);
- status of maintenance upgrading in accordance with pre-determined operational specifications;
- external constraints (monumental and environmental, servitudes (i.e. right of way), agreements with public bodies and bordering landowners, etc.);
- legal and/or technical documents relating to the installation, operation and maintenance of systems and equipments;
- status of distribution systems and data concerning consumption (i.e. energy, water, etc.);
- type and characteristics of services required to ensure operation of the building (i.e. premises for doorkeeper and cleaners, heating, etc.).

The second level, suggested by the European standard, deals with a detailed information that could be collected, after the preliminary data collection. The information categories required may include, according to the specific needs of the case, for example:

- for buildings and equipment: identification, location and description supported by an appropriate coding system;
- drawings with sizes, position and layout of the various building components (referred to the "as built" status of the building and updated during maintenance);

- data about maintenance activities already performed (history of the components);
- assessment of efficiency, functionality and compliance with applicable rules and standards;
- residual service life, for each component, predicted in accordance with age, quality and use conditions, and in relation with the initially foreseen service life;
- technical specifications: especially concerning equipments and building services in order to identify characteristics and 'established operating conditions';
- repair or replacement costs (i.e. estimates in accordance to official or regional price list);
- cost for unavailability and/or down-state: cost estimates, at least for critical components, arising from the down-state of the components or from their inability to provide the services for which they are intended to (i.e. costs for liabilities, damages, damage to the corporate image, etc.);
- information about critical construction techniques;
- instructions for inspections, operation manuals and maintenance manuals: experience and recommendations of the builder/manufacturer useful to develop an appropriate maintenance plan.

The level of detail of the information to be collected is determined by several considerations, such as:

- cognitive purposes;
- types of management services to be activated;
- information already available before the inventory;
- data availability;
- technical characteristics of the elements and their criticality in relation to the building, the function it performs, the faults that may affect them and related risks.

Given these considerations, a building may be described with different levels of detail, according to the different classes of installed technical elements.

Considering the difficulties related to the exact description of the technical characteristics of the building elements, the manager of the inventory should previously define the framework of the information needs and develop a careful preliminary assessment of the acquisition priorities related to the uses of the data.

Several activities are involved in defining the quantitative consistency and the technical characteristics of the buildings:

- retrieval, analysis and organization of available technical documents, such as: design drawings, "as built" drawings, specifications, technical project documents, supply contracts, documentation of any changes of the original project, manuals and maintenance plans, works archives, archives of the building, etc. (Chap. 3);
- verification of the reliability of the examined data;
- evaluation of the possible integration/update of available data through targeted technical surveys;

– general dimensional and technical surveys extended to the whole building in case of lack or unreliability of data;
– making other integrative kinds of surveys (i.e. photographic, about materials).

Information about quantities and technical characteristics of the buildings is fundamental for the development of a knowledge base responding to various purposes related to the management of real estate assets, such as, among others:

– expression of demand requirements for the supply of building management services;
– startup of the information system;
– definition of policies and strategies for the management of the real estate (i.e. maintenance, renovation, enhancement, alienation, etc.);
– planning of maintenance activities;
– support to management functions (i.e. administrative, technical, logistics, etc.);
– programming, implementation, monitoring and controlling the facility management services;
– security management.

2.3 Sheets and Procedures for the Inventory

The inventory, considered as a long term process, needs a well-structured system of supports. This system should be prepared before starting the inventory and it should be based, first of all, on sheets and procedures. The creation of the apparatus of sheets must carefully follow planned activities, starting from a general information framework (taxonomy) that may be required by the various basic processes in Facility Management services (Chaps. 1 and 3). Although at the beginning of the inventory several sheets might not be immediately filled in, it is appropriate, before starting the information collection, to have an overall reference frame, as organic as possible, of all the information that are needed, of their use and sources (Table 3.18). In this way, it is possible to achieve two purposes: firstly, to avoid problems of both deficiency and data overlap [4] (Chap. 1); secondly, to check that all the information necessary to carry out basic facility management processes is collected. If operating according to the criterion of gradualism, it will be possible to define an order of priority in the data collection over time just by selecting types of information from the taxonomy [5, 6].

To make the system of sheets actually effective, it is necessary to preliminarily identify and acquire criteria for the classification and the application of codes to the buildings and their construction entity parts. In this way any information, gathered during the inventory process, can be related to an entity uniquely identifiable and located. The classifying and coding criteria should be applicable to the whole building, divided hierarchically into technological units, technical elements, components and their constituent materials [5]. These criteria, that allow to define the registry system, may be defined by assuming classification standards such as the UNIFORMAT II E 1557-09, "Criteria and standards for classification" (Chap. 3).

Therefore, in brief, preliminary, fundamental operations are:

– the assumption of a classification and coding system in order to allocate the collected information;
– the development of a system of sheets in order to have always the same reference frame for the organization of information.

In fact, these are the two basic conditions for the coherence and continuity in the process of information acquisition. Both the activities of the inventory can be developed in a deferred way over time, even by different operators, and the data can be constantly updated.

Besides these aspects, a further condition must be considered to provide an adequate basis to the inventory process: a system of procedures must be developed coherently with the contents of the sheets. The procedures have to provide guidelines for the inventory activities by defining, in a systematic and formalized way, subjects such as: methods of surveying; data collection parameters and measurement criteria, tools, necessary skills and responsibility.

The system of procedures ensures the possibility to make the inventory activities always repeatable in the same way; consequently the information, acquired over time, will be easily aggregated, controlled and compared. In this sense, a useful reference for defining procedures can be found in the standard UNI 11150-3:2005, "Qualification and control of building design for building rehabilitation Part 3: Diagnostic for building rehabilitation". This standard provides basic guidelines, useful for the development of procedures, dealing with the various kinds of operations that can be conducted during an inventory, such as: surveys investigating the geometric and dimensional characteristics of buildings and identifying materials and construction techniques, as well as photo collection.

In particular, the standard defines:

1. the geometric-dimensional survey. According to the standard, the geometric-dimensional survey has to be conducted on the basis of a survey plan that should define:

   – the object to be detected and its parts;
   – the level of precision and the extension in relation to the complexity and nature of the object and/or its parts;
   – procedures and instruments to be adopted in relation to the levels of precision and extension assumed (i.e. measuring procedures with manual, optical, electronic, photographic, photogrammetric tools, etc.);
   – how to record and process measures (i.e. averages, statistical evaluations, etc.);
   – the selection criteria of the scale and the symbolisms of representation;

2. the photographic survey. The standard suggests that the photographic survey should be conducted on the basis of a survey plan defining:
   - terms and conditions of registration, relatively to the object building and its parts;
   - size ratios and technical elements visible (materials and conformations) at the moment of the survey;
   - equipments (i.e. camera, video camera, etc.), points and modes of shooting and return;
3. the observation and description of materials and construction techniques. The standard states that the survey of materials and construction techniques has the purpose of describing the technological system of the building. It may take the form of a report or various kinds of drawings (i.e. the board mapping the materials). The survey of materials should be conducted on the basis of a plan describing at least (according to the type of element): the structural and functional model, the techniques and materials of construction, the types of joints.

Moreover, aiming at planning the inventory activities in a more efficient way, the procedures should also indicate the average time needed for the execution of the various main activities. The time can be expressed in indices, defined according to the specific nature of the survey, for example, man hours/sq. meter or man hours/room or man hours/building. In this sense, considering the inventory as a gradual and continuous process of acquiring information, in order to collect relevant benchmarks for the future activities, every survey campaign should be monitored in an appropriate way, recording the length of time of the various types of activity.

It should be stressed that the time required for the different activities of the inventory varies widely in relation to a number of conditions, such as:

- characteristics of the buildings;
- presence, in a real estate, of similar buildings;
- geographic location and accessibility;
- consistency, adequacy and level of updating of information and documents already available;
- organization of the existing documents;
- availability of information to be collected;
- human resources involved in the inventory activities;
- support tools;
- sources of information;
- ways of recording information;
- presence of information systems already operating, etc.

2.4 Phases and Operators in the Inventory Process

The inventory can be considered as a set of activities developed within a process organized in different stages and according to several operating modes. An inventory process may be activated within various situations, for example: services of planned maintenance; outsourcing processes of management functions; interventions of renewal and valorization or exploitation of real estate; start-up of an information system; processes of acquisition/sale of real estate, etc. Each of these situations can influence in some ways the various phases and/or procedures of an inventory. However, it is possible to draw a general description of the process necessary for its development by identifying the main steps:

The preliminary phase
The preliminary phase of an inventory includes a series of activities that lead to a preliminary definition of the overall framework of the information that have to be acquired. This phase focuses primarily on some preliminary investigations, mainly concerning: characteristics of the services and priority objectives of management; characteristics of the Real Estate (i.e. age, technical characteristics and recurring types, location, functions, etc.); clients' requirements; existing information, documents and drawings already available. These investigations are carried out primarily through interviews with the client, visits to the archives of documents and buildings surveys;

The planning phase
This phase includes, on the basis of what has been acquired in the preliminary phase, the construction of a taxonomy that illustrates the overall list of the information to be acquired. The development of the information taxonomy has to be integrated by some activities, such as:

- acquisition and organization of the available existing documents, with verification of their state of completeness and updating, in relation to the need for knowledge and objectives assumed;
- development of the system of supports (Chap. 3), that is the assumption of a classification and coding system concerning spaces and technical elements, the development of a system of procedures to guide survey activities, collection, organization and storage of information;
- assumption of priority criteria for the information collection, namely the identification of both basic information reckoned to be immediately necessary in relation to the service management and subordinate information, that can be collected over time in a further phase of acquisition;
- definition of: human and financial resources necessary for developing the inventory activities; methods of organization of the several types of activities; competences required for each of them; methods of organization and returning of information;

The programming phase
This phase should include the scheduling of the activities to be carried out in relation to the available resources and (concerning the geometric and dimensional surveys) to the possibility to visit the buildings;

The implementation phase
In this phase all the scheduled activities will be carried out, as well as many other activities have to be planned, such as: periodic checks of the progress of the scheduled activities, tests of correct implementation and procedures effectiveness, verification of usability of the collected data. In the implementation phase, the collected information are stored according to the provided tools and supports (i.e. paper sheets, database, information system, etc.).

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Chapter 3
The Building Registry

Abstract The aim of the chapter is to analyse the building registry, interpreted as a data base, supported by appropriate methods for the breakdown and the classification of the building and its parts, containing the information necessary to describe the consistency, the functional and the technical characteristics. The chapter highlights the role of the registry within FM services, its contents and relation with the inventory and the information system. Considering the risks of inefficiency, connected with the absence of a pre-determined framework for the collection and organization of information, first of all, some key concepts are introduced: the registry must be able to collect and connect documents and information, both on spaces and technical elements; the registry should be drawn according to the principle of gradualism and it should grow over time starting from a minimum information set; the structure of the registry depends on the "registry system", that can be considered as a framework of criteria useful for the classification and coding of spatial and technical elements and of an apparatus of data sheets, useful for collecting information. Starting from these assumptions, some subjects are analysed: the role of documents review for the collection of a large amount of information, developed and used in the building life cycle; the criteria for breaking down, classifying and coding the building and its parts. Starting from the prevailing logical breakdown scheme, consisting in the representation of the building as a hierarchical open structure applicable both to spaces and technical elements, several international standard references are introduced and analyzed; the contents and the structure of the system of data sheets, listing, with the support of international standards, the information that can be acquired over time.

Keywords Building registry · Registry system · Classification and coding · Data sheets

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3.1 Role, Basic Logic and Purpose of a Registry System

The processes of information collection, developed through the inventory, are preliminary and supportive to the subsequent activities, that are fundamental for the design and supply of services, such as: the organization of knowledge and the management of information flows.

It is well known that the *conditio sine qua non* for an efficient Facility Management service is the development and management of a system of information concerning the dimensional, functional and technical characteristics of the Real Estate [1–4]. This information platform must be able to grow gradually over time and collect information about the operating status and the events concerning spaces and technical elements constituting the buildings (i.e. faults, interventions, renovations, transformations, etc.).

It is a knowledge base, which must be considered as a system:

- characterized by different information categories;
- dynamic, as in constant growth;
- properly structured, since it must be able to collect data coming from different sources and to make them available to be aggregated, compared, verified and elaborated.

Although most of the operators in the field of FM are aware of the fundamental importance of information management, the analysis of the current practices shows that the operation and maintenance phase, considered as the terminal of the whole construction process, is that one most influenced by the poor organization of information occurred in the previous stages (Chap. 1).

The development of a knowledge base is, in fact, one of the most expensive and complex tasks in the setting of a management (operation and maintenance) service. Strong inefficiencies are possible if, as it often happens, the activities that require the information collection are carried out without an adequate preparatory stage and appropriate coordination [5–7]. Facility managers should consider a framework of information quality attributes (Table 3.1).

The cases of not positive experiences in building inventory activities are many and well known. For example, inventories may result excessively expensive and difficult to bring to completion since excessive amounts of data have been collected, or they may be not efficient because they have not been preliminarily oriented to a selective information acquisition. These situations are usually due to operations carried out in absence of an adequate phase of proactive analysis of the information coming from the design and construction phases and with deficiencies in the preliminary preparation of support tools (i.e. coding schemes, data, procedures and instructions for recording, inspection plans, etc.). It should also be noted that the absence of a "design of the information" to be used as a basis for the realization of

Table 3.1 Framework of information quality attributes [5]

Attribute	Component	Key questions
Accessibility	Mode and media	What is the information format? How is information distributed? How can information be accessed? Is information accessible when needed? Is information access restricted?
	Traceability	Can the data source be identified? Can original data be traced?
	Reliability	Is the information available when promised? Is the mode and media as promised?
Contents	Accuracy	Is the information error-free? Is the information content reliable?
	Uniqueness	Is the information the same for everyone? Is it possible to get customized information? Is it possible to benefit from being the only one having certain information?
	Relevance	Is the information really needed by the user? Does the information help to solve the problem at hand?
	Completeness	How complete is the information? Is it deficient?
Availability	Coverage	How wide is the area covered by the information? Does the information reach all relevant users?
	Volume	How much information is available? Are there multiple sources of information? How frequently is the information updated?
	Consistency	Is the information coherent and logical?
Timeliness	Real-time	Is the information provided in real-time?
	History	Is the provided information based on collected data of past events?
Validity	Unambiguous	Does the information include obscurities?
	Objectivity	Can the information be considered objective?
Effectiveness		Can the information affect its users' choices? Can the information make its user change his or her way of working? Does the information benefit its user? How?
Cost		Is the information free? How much does the information cost? Are the benefits of the information greater than its cost?

complex processes (i.e. public works) is itself a symptom of two typical discomforts of the sector:

- the first one due to the inability to define a vision of the overall work;
- the second one that can be attributed to a lack of leadership in the process/project management.

Still focusing on the subject of inefficiency in collecting information, it should be noted that situations in which different operators collect, independently and not co-ordinately, information on the same building with various purposes, are frequent. It is possible to find many cases in which, besides the realization of a building inventory, it is ongoing the development of other processes that require an information collection (i.e. due diligence, diagnostic, analysis for energy performance assessment, risk assessments, etc.).

In the absence of a standardized scheme for the identification of spatial components and building elements, the various operators may collect information often redundantly or, in some cases, coming to conclusions that are not in accordance one to each other. In other cases, information is used only for a specific analysis but it is not recorded in the knowledge base of the building. It can be considered, for example, the investigation that leads to determine the constructive features of a building envelope, which should be assumed to determine the energy performance of a building. The information, if there is a scheme identifying building elements and a catalogue describing technical characteristics, can be directly included in the knowledge base. Furthermore, such information can also be associated to the concerned technical element, together with information coming from other sources concerning, for example, the state of degradation observed in a process of due diligence or during a diagnostic procedure.

The acquisition of this information, according to a pre-determined framework, may avoid expensive documental research and survey during the design and development of FM services. Assuming a pre-determined framework for the collection and organization of information means to develop a registry system.

3.2 The Registry System

First of all, in this context, a registry can be interpreted as a data base—supported by appropriate methods for the classification[1] of the buildings and their technical components and spaces—containing the information needed to describe consistency, functional and technical characteristics of the built assets. In particular, the registry collects and organizes information on buildings regarding identification, location, destination, sizes, legal and administrative conditions, technological characteristics and performances. Moreover, the task of the registry is to contain

[1]According to the standard ISO 15489-1:2004, "Information And Documentation—Records Management—Part 1: General", classification is: systematic identification and arrangement of business activities and/or records into categories according to logically structured conventions, methods, and procedural rules represented in a classification system.

The standard underlines the importance of coding for indexing. According to the standard indexing is a process of establishing access points to facilitate retrieval of records and/or information. Besides classification and indexing allow appropriate linking, grouping, naming, security protection, user permissions and retrieval, disposition, and identifying fundamental records. Guidance on indexing can be found in the standard ISO 5963:1985, "Documentation—Methods for examining documents, determining their subjects, and selecting indexing terms".

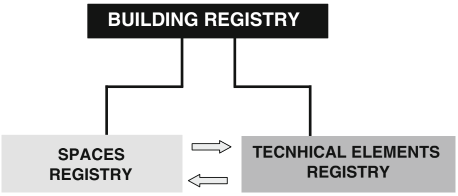

Fig. 3.1 The partition of the building registry

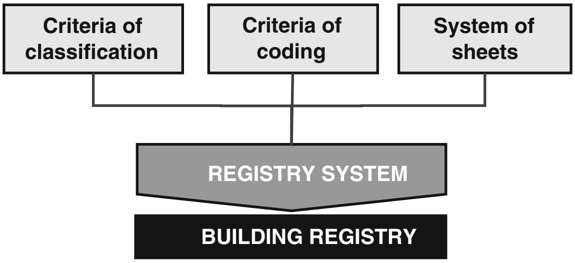

Fig. 3.2 The registry system

and make available information regarding the history of the buildings and their current state of operation.[2]

In order to better clarify the meaning of the building registry, some key issues must be highlighted:

- the registry collects information, both on spaces and technical elements, which need to be related one to each other. In this sense it is appropriate to consider the registry as subdivided in a registry for spaces and a registry for technical elements (Fig. 3.1);
- the registry should be drawn according to the principle of gradualism and it should grow over time starting from a minimum information set, essential to the basic requirements related to the management of the service considering aspects such as characteristics of the elements, their criticality, types of services, etc. This growth must be possible both vertically, i.e. by inserting additional levels of detail, and horizontally, that means, having the possibility to add new cataloged items;
- the structure of the registry depends on what we could call "registry system" (Fig. 3.2). It can be considered as a framework of criteria useful for the classification and coding[3] of spatial and technical elements and of an apparatus of data sheets, useful for collecting information always according to the same formalized scheme.

[2]See the standard UNI 10951:2001, "Systems of information for the maintenance management of buildings. Guidelines" and the standard UNI 11447:2012, "Urban Facility Management Services. Guidelines to set and program contracts".

[3]According to the standard ISO 15489-1:2001, the purpose of coding is associated with a location function, where the number or code indicates the "address" of the record, so that the record may be retrieved by specifying the residence within the records system.

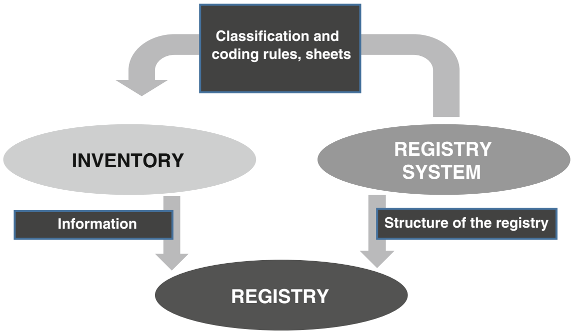

Fig. 3.3 The link between the registry system and the inventory process

A strong and fundamental relation links the registry system to the inventory process (Fig. 3.3) (Chap. 2). Before starting the inventory process, it is important to have acquired the rules for collecting and archiving correctly information (Fig. 3.4). Therefore, it is important to give priority to the development of a registry system, accurately drawn according to the specific characteristics of the real estate and Client's organization and requirements. On the contrary, it is common to observe, by analysing technical specifications of FM contracts, the request of inventory services without any specification neither about criteria and requirements to be considered, nor about roles and responsibilities in the development of a registry system.

For better organizing the various categories of collected information, the registry of a building may be further divided into sections, that are "sub-registries" (i.e. identification registry, technical registry, functional registry, administrative registry, etc.).

3.3 The Building Registry and the Documents Review

As already mentioned (Chap. 2), before developing survey activities, in setting the inventory plan, documents[4] should be gathered, analysed and reviewed. On the contrary, by analysing technical specifications of FM services, it often happens to observe that no mention is made by the client to the collection of documents, nor

[4]According to the standard ISO 15489-1:2004, "Information and documentation—Records management—Part 1: General", document is: recorded information or object which can be treated as a unit. Moreover, according to the standard EN 13460:2009, "Maintenance. Documentation for maintenance", the document is: the physical support of the information in a specific form. This may take the form of a paper sheet, the screen of a video monitor of a computer system, an electronic board, a blackboard, etc. and the figures, type, size and distribution on the available surface may vary without affecting the main purpose of the information system. A document is permanent. Program results displayed on a screen do not make any document unless it is stored. Document can be information stored in a database which can be shown on a screen or printed out.

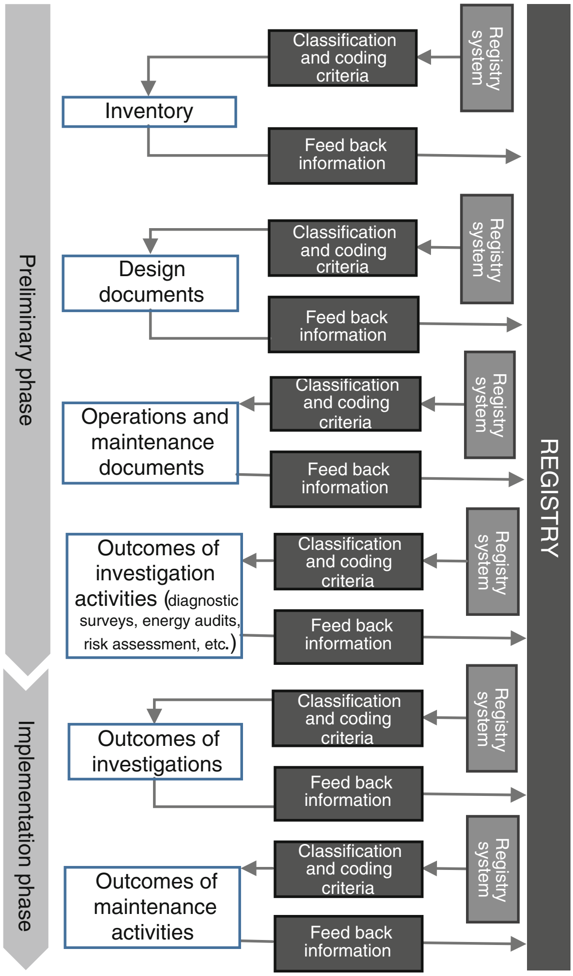

Fig. 3.4 The registry and the sources of information

criteria are given about the ways of gathering them. In this way, a very important source of information is reduced to a mere acquisition of papers and files. Vice versa, documents review is a very important and demanding activity aimed at searching, selecting, analysing, gathering and organizing the various and heterogeneous documents [8] coming from the design, construction, operations and maintenance phases (Tables 3.2, 3.3 and 3.4). These documents are valuable sources of information, useful to describe both the characteristics and the conditions (degradations, compliance and operating states) of the buildings and the significant events occurred during their life cycles.

According to this vision and pursuing the improvement of the effectiveness of the service, in the planning of the document review, at least three viewpoints should be considered.

Table 3.2 Criteria for the organization of building managerial files [33]

Section A (building registry)
Collects documents concerning:
– Establishment and management of the registry
– Identification of a building system (break down structure)
– Identification of operators responsible for the building systems
– Description of the building systems
– Graphic documents
Section B (mandatory requirements)
Collects documents concerning:
– Environmental protection
– Reduction of energy consumption
– Hygiene and safety in the building
– Conformity to standards
– Fire prevention
– References to the land register
– Constraints
Etc.
Section C (operating and maintenance)
Collects documents concerning:
– Economics and finance
– Real estate values
– Context, performance and needs
– Renewal works
– Maintenance programmes and works

First of all, document review is fundamental for extracting orientations useful to plan the activities of information collection. It allows to draw a list, distinguishing information already available within the documents, those ones to be verified through an on-field survey and the absent ones that, if necessary, should be acquired.

Secondly, document review can be considered within a broader programme of audit.[5] Therefore, it can be useful not only for searching information inside documents, but also for setting up documented evaluation processes about the

[5]According to standard EN ISO 19011: 2011, "Guidelines for auditing management systems" within internal or external audits of management systems, an audit is a: systematic, independent and documented process for obtaining audit evidence and evaluating it objectively to determine the extent to which the audit criteria are fulfilled. For the same standard two other terms and definition are important. Audit evidence are records, statements of fact or other information, which are relevant to the audit criteria and verifiable. Audit evidence can be qualitative or quantitative. Audit criteria are: set of policies, procedures or requirements used as a reference against which audit evidence. If the audit criteria are legal (including statutory or regulatory) requirements, the terms "compliant" or "non-compliant" are often used in an audit finding.

Table 3.3 List of documents and data sources [8]

Categories	Documents and sources of data
Title/insurance/real estate tax/mortgages	Original deeds, as recorded
	Matters of record of which the title is subject, including trust and partnership agreements
	Insurance policies (property insurance, general liability, etc.)
	Real estate tax bill
	Mortgage financing, including amendments
	Plot or site plan showing boundaries, casements, and major ground features and topography
	Bonds (performance/completion, labour and materials, and local government surety) presently in effect
Operations—income and expenses	Data referring to income and expenses
	Existing leases and amendments, and projected leases already received
	Chart of accounts
	Market studies conducted by or otherwise available to seller used in project development or any other market information
	All office buildings deemed competitive, their rent and level of concessions
	Pre-opening budget
	Pre-opening service contracts
	Pre-opening activities and schedule milestones
	Resumes of proposed general manager, resident manager and other key personnel
	Proposed inventory of initial operating supplies
	Proposed initial working capital budget
	Permits, licenses or pending applications
	Revenue histories and projections for all tenants paying percentage rents
Management contracts	Existing or proposed property management, marketing and leasing contracts and associated fee structures
	Existing or proposed vendor or service contracts
	Agreements affecting site
	Marketing, leasing and other related agreements and associated fee structures
Master plan documents—all master plan related drawings and documents	Site plan and documents to verify planning board or similar agency approval
	Documents related to clearance of environmental impact
	Other master plan related documents, if any
Zoning, building permits, inspections, and certificates of occupancy	Zoning:
	– Attorney's zoning opinion and certifications from architects and engineers regarding zoning
	– Zoning applications, zoning analysis (height, setback, and average calculations), annual report, and decisions rendered
	– Zoning ordinance and internal design standards, etc.

(continued)

Table 3.3 (continued)

Categories	Documents and sources of data
	Building permits:
	– Building permits for base building
	– Building permits for infrastructure
	– Other building department records
	– Building permits for tenant space renovations
	– Exceptions from building and zoning code
	Building inspections for base building and tenant work, including violations:
	– Base building
	– Elevators
	– Fire alarms
	– Electrical
	– Plumbing
	– Violations
	Certificates of occupancy:
	– Base building
	– All tenant spaces
Building documents (contracts presently in effect in the building, all amendments and correspondence from contractors, architects, engineers, attorneys, brokers, and management)	Design and construction contracts and correspondence for base building:
	– Architectural and engineering design contracts for ongoing improvements
	– Interior design contracts
	– Other design contracts and/or consulting agreements
	– Performance and payment bonds
	– Insurance
	– Finishes, furnishing, and equipment, including handling and installation contracts and proposed inventory
	– Construction contracts for ongoing improvements
	– Developer's agreement
	– Construction contract
	– List of subcontracts and costs
	– Job meeting notes for ongoing improvements
	– Contractors' requisitions for payment
	Construction contracts and correspondence, including development agreement for tenant spaces
	Contracts for related work not included in general contract, including infrastructure:
	– Landscaping
	– Telephone
	– Computer
	– Interiors
	– Furniture

(continued)

Table 3.3 (continued)

Categories	Documents and sources of data
	– Infrastructure
	Architects' and engineers' certifications:
	– Certificate of substantial and final completion
	– Structural engineers' acceptance of work
	– Structural design criteria
	– Mechanical and electrical engineers' acceptance of the work
	– Release of liens from contractor for base building
	– Release of liens from contractors for tenant improvement work
	– Certificates by architects to owner, financial institutions, building commissioner, or building inspector
	– Certificates by engineers to owner, financial institutions, building commissioner, or building inspector
	– Daily logs from on-site field representatives
	Building plans and specifications
	As-built with addenda, bulletins, and change orders
	Testing reports:
	– Soils compaction, concrete, compression and structural steel inspections
	– Freeze/thaw test procedures and results
	Fire safety plan
	Fire security system manual
	Acceptances by insurance carriers of fire suppression system
	Method and calculation of gross and net building areas
	Elevator control sequence
	Escalator control sequence
	Emergency elevator control sequence
	Emergency generator controls
	Roof guarantees
	Certification that building is not in flood plain and history of flooding on the site
	Survey of wetlands
	Site utility plan
	Building tenant standards and sample tenant agreement
Building Operations and Maintenance	Service contracts and warranties:
	– HVAC
	– Control systems
	– Filters
	– Pest control
	– Alarm system testing
	– Water treatment
	– Radio service

(continued)

Table 3.3 (continued)

Categories	Documents and sources of data
	– Artwork rental
	– Sprinkler and standpipes
	– Elevators
	– Escalators
	– Cleaning
	– Plants
	– Security
	– Parking lot maintenance
	– Landscape lot maintenance
	– Window washing
	– Roof guarantee
	– Trash
	– Water coolers
	– Garage maintenance
	– Plaza maintenance, other equipment/service
	– Telephone
	– Electric service
	– Interior design service
	– Automatic door equipment
	– Towel and uniform cleaning
	Contracts for work in progress
	Building management contract
	List of warranty expiration dates
	Maintenance schedules for equipment
	Inspection records
	List of stored materials
	Energy usage
	Breakdown of operation and maintenance budget
Building/capital cost data	Operating capital and building cost since opening
	Capital budgets for future years
	Budget of committed capital items
	Chart of accounts for capitals items
	Project budget and requisitions from lender
	References for operating expenditures
Miscellaneous	Seller's package
	Project appraisals conducted by owner
	Promotional brochure for project
	Brochures from architect, construction manager, and other key professionals involved with the project

Table 3.4 Information and documents in operations and maintenance phase [27]

Documents from the preparatory phase		
Document name	Document description	Information
Technical data	Manufacturer's specification of the item	Manufacturer; date of manufacture; Model/type/serial number; size; weight; capacity; power and service requirements; interfaces specifications; other: referring physical nature, assembly details and operation data
Operation manual	Technical instructions to reach a proper item function performance according to its technical specifications and safety conditions	Model/type; manual date (edition); technical details of the item; functional description of the item; functional capabilities and performances; design, safety and operation margin; procedures (commissioning/start-up, warning-up, steady operation, controlled shutdown, incidental and emergency); operation limitations/precautions; laws and regulations to be abided to
Maintenance manuals	Technical instructions intended to preserve an item in, or restore it to, a state in which it can perform a required function	Model/type; manual date (edition); technical details of the item; preventive maintenance operations/actions (inspections, calibration/adjustment, parts replacements, lubrication); procedures (troubleshooting, dismantling/assembly, repair, adjustment); Cause and effect diagrams; special tools required; spare parts recommendations; Safety requirements (signals, dressing, power source control, etc.)
Components list and spare parts list	Comprehensive list of items which constitute part of another one	Equipment breakdown description; upper level item (heading); (model/type/serial number); item number; item description; Item quantity
Arrangements	Drawing showing replacement components layout for an item	Drawing code and identification; date (issue/revision); dimensions; item components location and identification; necessary space for disassembly and maintenance; relevant information about connection details; etc.
Detail	Drawing with part list to ensure dismantling, repair and assembly of items	Code identifying the item which is detailed; Assembly drawing showing positions of parts; Identification of each part on the drawing (part number, description, number of units); Any other relevant information for assembly and disassembly operations
(…)		
Logic diagram	System control diagram to clarify the overall system logic	Diagram code and identification; date (issue/revision); logic functions (symbols, internetworking and control flow); modes of operation (e.g. starting, shutdown, alarm, trip functions)
(…)		

(continued)

Table 3.4 (continued)

Document name	Document description	Information
Documents from the preparatory phase		
Location	Drawing showing the position of all field items within the considered area	Drawing code and identification; date (issue/revision); area identification (code and name); item identification and location code; items drawings or symbols, without dimensional details
Layout	Drawing showing all areas of a particular plant	Drawing code and identification; date (issue/revision); plant name (and code, when necessary); areas (relative position, dimensions, names and codes)
Test program report	Commissioning report which demonstrates that an item is in compliance with specification.	Manufacturer; model/type/serial number; date of manufacture; date of commissioning; warranty period and conditions; fulfilment of the technical details (size, weight, power and service requirements, capacity/performance, referring physical nature, assembly details and operation data); name and signature of the end user of the item, accepting previous data
Certificates	Specific safety and statutory regulations certificates	Manufacturer; model/type/serial number, date of manufacture; subject to be certified; date of certificate; certification body/office and signature/stamp
Documents from the operational phase		
Assets register (equipment basic data)	Item basic information coming from either the preparatory or the operational phase. This information is related to technical, contractual, administrative, spatial and operational aspects of an item, in order to define it within the company	Location code; item name; acquisition price of the item; manufacturer; model/type/serial number; date of manufacture; date of installation; warranty period; accounting number for cost charging; responsible maintenance department; standard estimated maintenance time(preventive and corrective); family (in case of comparisons among similar items); opportunity cost/production loss cost; basic item maintenance data (direct maintenance cost, lost production cost, MTBF, MTTR, availability and use, criticality; Other: cross-references to technical documentation, spare-part list, etc.
Item history record of maintenance operations	List of work orders of a particular item. The list will be for a given period of time	Item code and name; date (issue); period of time analyzed (since/to); List of work orders chronologically ordered (number, date, complaint/cause, failing part, running hours of the item, registration/open/closure dates, cost of job covered by the work order)

(continued)

Table 3.4 (continued)

Documents from the preparatory phase		
Document name	Document description	Information
Work order	Main document to release, to follow and to manage each maintenance operation	
Spare parts cross reference list	Catalogue of spare parts and articles stored and/or needed	Article code; name; description; stock location; main supplier; lead time; price; unit of measure; unit of purchase; minimum level; order quantity; supplier article code
Cause and effect diagram	Diagram showing, by order of importance, the different causes which produce a given effect (failure)	Effect description and code; analyzed item/s code/population; diagram date (issue date); period of time analyzed (since/to); List of causes in descendent order, including for each cause: cause code, cause description, relative cause importance % (in cost, downtime, number of failures, etc.), total importance (cost or downtime or number of failures produced, etc.)
Parameter history record	Set of values given by any item inspected/monitored parameter during a certain period of time	Item code and name; parameter description and measure units; measurement point identification; date (issue); period of time analyzed (since/to) For each record: time, parameter value, measurement point identification; cross-reference to technical procedure(when required)
MTBF-MTTR control chart	Statistical information document. Contains the referred values for items considered of major interest	Item code and identification; date (issue); cause of failure analyzed and code; MTTR—MTBF
Planning sheet	List of work orders according to a given priority	Date (issue); Item code and identification; Planning period (from/to) List of work orders sorted including: number, expected date, complaint/cause, item (lower level)
Scheduling sheet	Work orders planning and time schedule assignment for a given period. It is obtained by assigning the available resources to the work orders backlog	Date (issue); item code and identification; planning period (since/to); list of work orders sorted including number, start date, due time, complaint/cause, item (lower level), resources required by the work order

(continued)

Table 3.4 (continued)

Documents from the preparatory phase		
Document name	Document description	Information
Production planning	Planning of the use of production resources (installations, personnel), defining availability window for maintenance operations implying complete or partial shutdown	Annual production program; monthly production program; weekly/daily production program
Item availability and use data sheet	Document which shows how the item availability is used	Item code identification; date(issue); period (since/to); scheduled time, downtime, uptime, availability; time of item use
(…)		
Maintenance cost history record	Maintenance expenses classified according to the maintenance and business cost structure, for a given period of time	Date issued; period of time analyzed (since/to); cost structure element
(…)		
Maintenance contracts and their amendments	Set of updated maintenance contracts in force, including amendments	According to EN 13269
Procedure to review causes of critical failures	Instructions regarding the periodic review of causes for critical failures	History recording of critical failures per machine/element (item); failure cost; causes of failure; work carried out; distribution list of results
(…)		
Maintenance information system manual	Guide and instructions to properly operate the maintenance information system and authorized access levels to the maintenance information system	Functions, operations and procedures to be followed; list of system error; access level code; list of authorised operations

(continued)

Table 3.4 (continued)

Documents from the preparatory phase		
Document name	Document description	Information
Acceptable maintenance suppliers	List of qualified maintenance suppliers	Address; ownership; size; occupancy; financial situation; references; expertise; proximity; appraisal
Procedure for maintenance suppliers evaluation	Check list for investigating/ evaluating maintenance suppliers	Ownership; years established; size; turn over; staff strength; equipment and facilities; occupancy degree; financial situation; contract forms; references; expertise; appraisal; proximity; copyright european
(…)		
Procedure to control customer supplied items	Procedure to control customer supplied items	Purchase orders; supplier's catalogue; machine card; maintenance instructions; catalogue of articles stored
(…)		
Procedure for items identification.	Guidelines for item codification, plant location codification and how to link the item code and the plant location code	Item code format; location code format; Item—location code format; Store/installation location; Supplier's catalogue cross reference format
Procedure for traceability	Guidelines for recording the different locations of an item in the plant, during the time	Guidelines for recording the different locations of an item in the plant, during the time
Procedure to control maintenance activities	List and form of maintenance reports	Elements for planning maintenance activities, among others: Priority assessment backlog, Schedule compliance, Labour efficiency, Material cost, Percent downtime maintenance cost, Recommendations and action plan
(…)		
Procedure for items monitoring and testing (during downtime and operation)	Guidelines for carrying out monitoring and testing	Nature and sequence of sub-activities; Precautions to be taken; means; tools and resources required; objective to be met
(…)		
Procedure for preventive and corrective actions	Maintenance instructions describing preventive and corrective actions to be undertaken	Item number and name; location; maintenance work description; responsibility/trade; standard man-hours required
(…)		

(continued)

Table 3.4 (continued)

Documents from the preparatory phase		
Document name	Document description	Information
Procedure to identify training requirements	Action plan with periodic progress review	Actions to be taken on the basis of observations and/or audits in the field of personnel training
(…)		
Laws and regulations abiding procedures	Guidelines to laws and regulations abiding procedures	Laws and/or regulation reference; relevant issues; responsibility; what to do, when, where

conditions of the documents. This activity allows, for instance, to draw a description of the compliance degree, to find gaps in the authorization requirements and to check deadlines (formalities required or documents to be renewed). Pursuing these aims, according to the standard EN ISO 19011:2011, auditors should consider if the information provided by the documents are complete, correct, consistent (the document is consistent in itself and with related documents), current (the content is up to date). Moreover, this evaluation of the state of documentation can be considered as a first step within due diligence[6] processes, in which audit activities[7] [9] are developed for evaluating[8] the fulfilment level of assigned criteria (set of policies, procedures or requirements used as a reference).

Thirdly, it is advisable to take advantage of the documents review by developing a data room. The data room may be considered as a physical location (PDR for physical data room), where information (in the form of files and documents placed in binders, folders and boxes) are temporarily maintained and available for viewing. Data rooms contain primarily documents such as drawings, files, letters, records, transcripts, etc. An evolution of the physical data room is the virtual data room (VDR), where

[6]According to the standard EN 15221-2:2007, "Facility Management—Part 2: Guidance on how to prepare Facility Management agreements", due diligence is: compilation, comprehensive appraisal and validation of information of an organisation at the appropriate stage of the Facility Management agreement required for assessing accuracy and integrity at the appropriate stage of the agreement process.

[7]Although due diligence processes differ significantly, each process has the same basic purpose of assisting a buyer in determining whether to acquire a target, and if so, how much it should be paid for the target. Through the due diligence process, a buyer is able to evaluate the risks related to the transaction and how much to pay for a potential target. If the diligence process reveals that the target is too risky for a buyer, the buyer will either decline to make an offer or offer to purchase the target at a lower price than what he was initially willing to pay. Due diligence, therefore, is a tool to assist buyers in assessing realistic values of target companies by evaluating their strengths, weaknesses, risks, synergies and overall fit within the buyer's strategic plan. For this reason, during the process of due diligence a large amount of information can be collected [9].

[8]See the standards: ISO/DIS 37500 "Guidance on outsourcing- Lignes directrices sur le management de sous-traitance; ASTM E 2018-08 "Standard Guide for Property Condition Assessments: Baseline Property Condition Assessment".

documents are presented more efficiently and effectively in digital format, in contrast with physical documents in a PDR. Operating both through Website on the Internet and Stand alone application, VDR[9] have many advantages, such as: multiple teams may access the same data at the same time; users can search documents for specific words and phrases, similar to the Internet search engines; it allows document tracking; it enhances transparency of the data room process; it allows to upload "late" documents by efficiently placing them in their appropriate position in the VDR index; it allows to quickly reorder documents in the index and inform users through email or SMS about changes of the index and data room contents; digital documents may be flagged with respect to copying, printing, downloading or viewing.

The Italian standard UNI 10998:2007, "Building managerial files. Appointed and care general criteria" suggests general criteria for the organization of building managerial files. The standard suggests to arrange documents according to sections (Table 3.2).

More in detail, Rowe [8] provides a wide list of documents (Table 3.3) to be collected that contain a large amount of information developed and used throughout the building life cycle.

Furthermore, by considering the specific field of maintenance services, the standard EN 13460:2009, "Maintenance—Documentation for Maintenance" provides an useful guideline about the large amount of information that may be collected for managing maintenance of technical items. The standard defines the whole set of documents and information (Table 3.4) according to the various phases of the maintenance process by listing and describing the documents and, for each one, by stating the minimum information set to be included.[10]

A more extended and open taxonomy of general reference information and information types within a project, is provided, classified and codified, by the OmniClass Table 36.[11]

On the basis of these viewpoints, it is evident that building registry and documents review should be developed according to an integrated and shared approach in order to get synergies and improve effectiveness in the processes of information management (Fig. 3.5). So, it is advisable to acquire criteria for the classification and application of codes to the documents coherently with those ones assumed for the buildings and their parts. Developing a unique registry system for information and documents allows also to easily:

- trace and map information that can be find within documents;
- outline documents useful for deepening specific information;
- make more efficient the operations of survey, searching, updating and documents storage, that will be developed over time.

[9]VDRs should store files of varying formats, including PDF, Excel, PowerPoint, Word, GIF, MPEG, JPEG, and TIFF, so eliminating the need to convert files to a specific file type [9].

[10]The standard points out that in some cases, some of the information listed for a document should not be used because of their lack of relevance or the nature of the item to which it is related.

[11]For an in-depth analysis of the OmniClass Tables see the next paragraph.

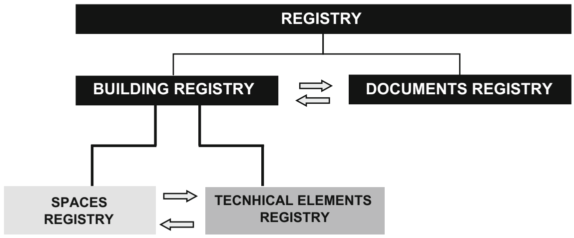

Fig. 3.5 The building registry and the documents registry

3.4 Developing the Building Registry: Classification and Coding Criteria

A registry system should be based on criteria of breaking down, classifying and coding that have to be unique for the whole building process.

So, before the development of the inventory process and building registry, the fundamental tasks to be carried out consist in identifying and acquiring criteria for the classification and application of codes to the buildings and their construction entity parts.

In the current practice, the prevailing logical breakdown scheme, assumed for the description of the building, consists in the representation of the building as an hierarchical open structure.[12] It is a tree structure, starting from a level of maximum aggregation (real estate, compound or building) that can be organized in underlying layers, each one having a lower degree of complexity, to the simplest elements, not further decomposable.

This hierarchical open structure is applicable both to spaces[13] and technical elements (Fig. 3.6) and it has many advantages for the cognitive tasks associated with Facility Management services. In fact it allows to:

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[12]According to standard EN 15221-4:2011, "Facility Management—Part 4: Taxonomy, Classification and Structures in Facility Management", hierarchy is: structure of levels in which each level includes its lower levels. Taxonomies are frequently arranged in a hierarchical structure. Typically they are related by supertype-subtype, also called parent-child relationships.

[13]Considering the subject of the building registry, appropriate definitions for space and element are provided by the standard ISO 12006-2:2001, " Building construction—Organization of information about construction works. Part 2: Framework for classification of information" (at present this standard is under revision).

Space is: three-dimensional, material construction result contained within, or otherwise associated with, a building or other construction entity. A space may be bounded physically or notionally (i.e. room, corridor, atrium, cleared zone (at an airport), roadway, square, working space around a machine, swimming pool, etc.). A key property of a space is the function or user activity it is intended to serve.

Element: construction entity part which, in itself or in combination with other such parts, fulfils a predominating function of the construction entity (i.e. elements are: external wall, floor, roof, foundation, column, lighting system, ventilation system, culinary furnishings, sanitary equipment) (i.e. predominating functions are: space enclosing, supporting, servicing, furnishing).

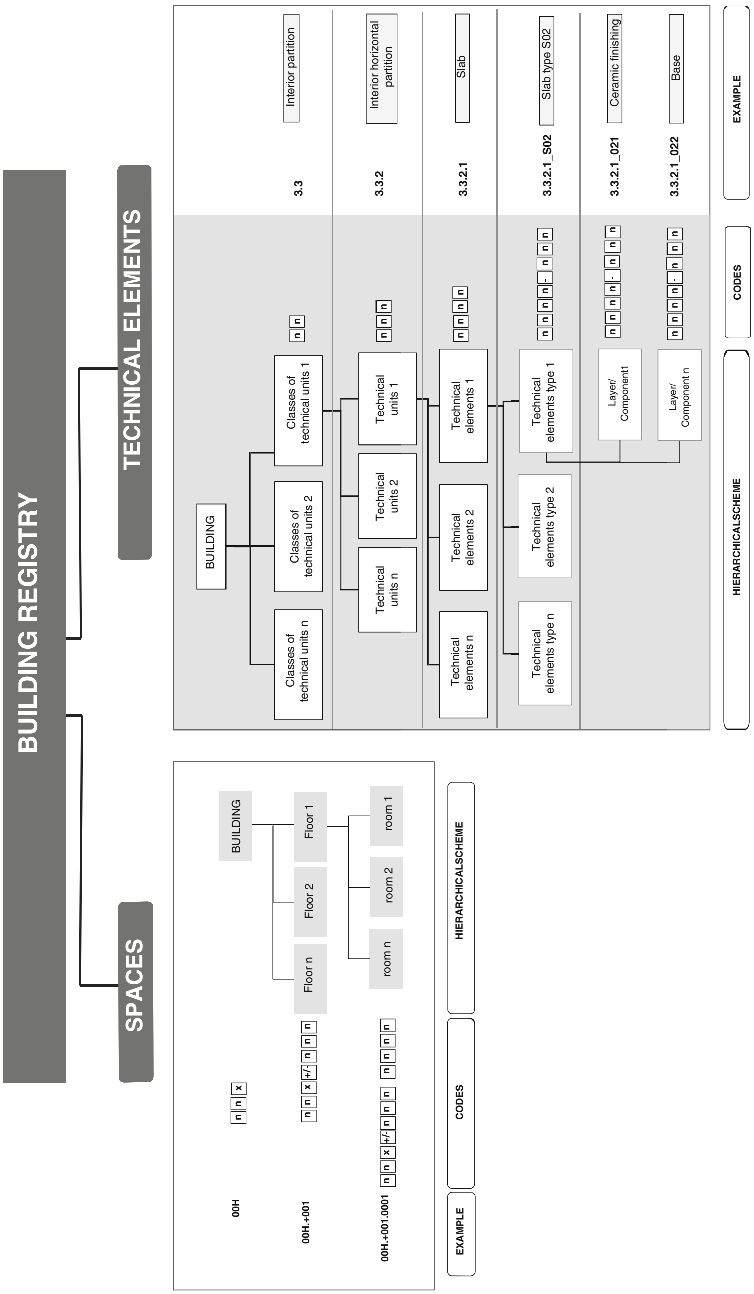

Fig. 3.6 Example of hierarchical open structure applied both to spaces and technical elements

– allocate information at different hierarchical levels;
– organize and extend the hierarchy to further levels, if necessary (vertical extension);
– add new elements at the same hierarchical level, if necessary (horizontal extension);
– aggregate information with respect to different hierarchical levels (i.e. for classes of technical elements, typologies of technical elements, typologies of spaces, etc.).

On the basis of the assumed hierarchical structure, all the items[14] constituting the physical system can be identified by assigning to them a unique code for recognition.

The code may be composed in many ways (it can be done manually or automatically generated), but, in general, the code should:

– lead to the unambiguous identification of each entity (spatial, technical or documentary);
– be as "speaking" as possible, i.e. explicit with respect to the type of entity and level of hierarchy organization;
– be coherent with the criterion of the assumed hierarchical structure.

At the present time, it is possible to find several references for the assumption of classification and coding criteria.

First of all, a basic reference may be found in the standard ISO[15] 12006-2:2001, "Building construction—Organization of information about construction works. Part 2: Framework for classification of information", that defines a very general framework and set of recommended table titles, supported by definitions, but not by a detailed content of these tables. In fact, it is intended to be used by organizations developing and publishing classification systems and tables on a national or regional basis.

The standard considers the whole life cycle of the construction process by including design, production, maintenance and demolition, in relation to both building and civil engineering. It identifies classes for information organization and it indicates how these classes are related one to each other, but it does not provide a

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[14]According to the standard EN 60300-3-14:2004, "Dependability management. Part 3–14: Application guide -Maintenance and maintenance support" an item is: any part, component, device, subsystem, functional unit, equipment or system that can be individually considered. In particular an item may consist of hardware, software or both, and may also, in particular cases, include people. Besides a number of items, i.e. a population of items or a sample, may itself be considered as an item.

[15]ISO (International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

complete operational classification system. Details of these classification tables may vary in order to satisfy local needs.

Although the standard does not give any operative instruction for classifying and coding, anyway it may be interesting to consider the proposed general view.

The standard aims at giving a general basic model of the construction process by linking resources (construction products/aids, agents, information) with results (designed construction entities, produced construction entities, maintained construction entities, demolished construction entities) in relation to the various phases (inception/design, production, use and maintenance, decommissioning and demolition). This model allows to establish classes that are reference categories for the organization of information. These classes may be split up in deeper levels of detail. The general scheme for listing classes and contents of some classification tables is proposed below (Fig. 3.7).

The main classes of construction results are:

- construction entity[16];
- construction complex[17];
- space[18];
- construction entity part.[19]

According to a hierarchical vision, the main classes related to construction entity parts are:

- element;
- designed element;
- work result.

Each class can be divided into subclasses by a principle of specialization and thus resulting in a classification table. The standard proposes seventeen basic tables organized according to the schema proposed in the Table 3.5.

[16]According to the standard, construction entity is: independent material construction result of significant scale serving at least one user activity or function (i.e. building, bridge, road, dam, tower, sewer, museum (if a single structure), sports field, sewage settlement tank, cycleway, etc.).

[17]According to the standard, construction complex is two or more adjacent construction entities collectively serving one or more user activity or function (i.e. airport, sewage treatment works, business park, port, motorway, shopping and sports complexes, etc.).

[18]See note 13.

[19]According to the standard, construction entity part is: solid (as distinct from liquid or gaseous), material part of a construction entity, having physically delineated boundaries (i.e. wall, door, door handle, wash basin, road surface, bridge pier, pipeline valve, light switch, roof, heating system, sluice gates, etc.).

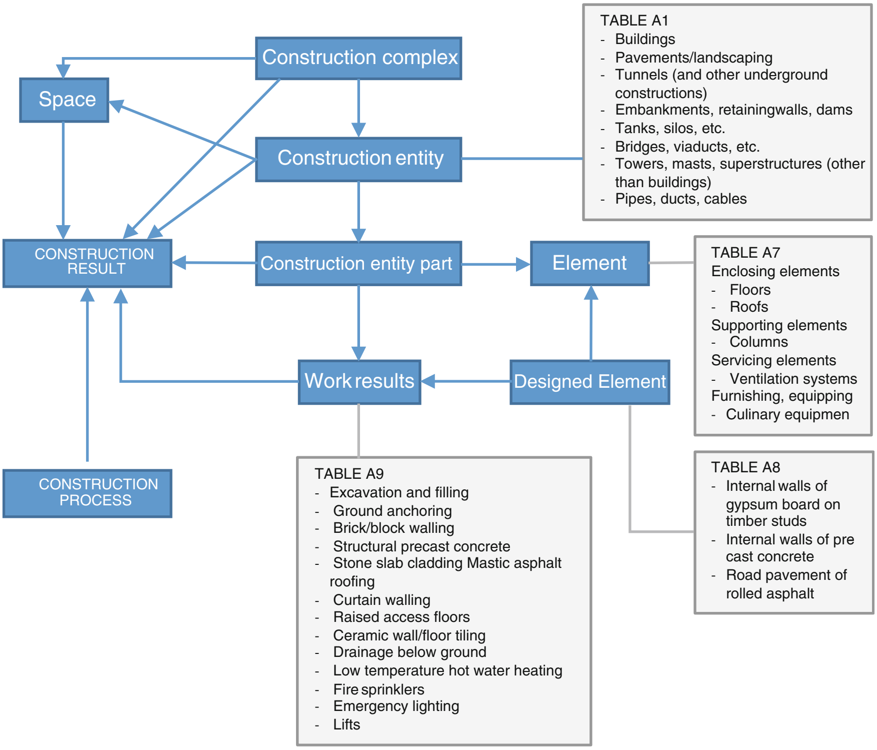

Fig. 3.7 Part of the scheme of classes and of the general relationships between them and summary of some classification tables [38]

Going on, a further and useful reference is surely the E 1557-09, "Standard Classification for Building Elements and Related Site work"—UNIFORMAT II[20] by ASTM.[21] This standard establishes a classification of building elements and related site works. The standard considers as elements the major components common to most buildings, defined in relation to their given functions, regardless of the design specification, construction method or materials used. The proposed

[20]The original UNIFORMAT classification was developed jointly by the General Services Administration (GSA) and the American Institute of Architects (AIA). UNIFORMAT II is an elemental format similar to the original UNIFORMAT. UNIFORMAT II differs from the original UNIFORMAT, since it takes into consideration a broader range of building types and it has been updated to categorize building elements as they are in current building practice.

[21]ASTM International, formerly known as the American Society for Testing and Materials (ASTM), operates in the development and delivery of international voluntary consensus standards. Today, some 12,000 ASTM standards are used around the world to improve product quality, enhance safety, facilitate market access and trade, and build consumer confidence. ASTM serves diverse industries—ranging from metals to construction, petroleum to consumer products, and many more—through 143 technical standards-writing committees.

Table 3.5 List of classes and possible ways of specializing the classes with examples of application of the system of classification [38]

Class	Principle of specialization	Examples of possible headings	Table reference
Construction entity	Form	Buildings, pavements/landscaping, bridges, viaducts, etc.	A1
	Function or user activity	Hospital buildings, health centre buildings, footbridges, etc.	A2, A6
Construction complex	Function or user activity	Transport complexes, public health complexes, etc.	A.3, A.6
Space	Degree of enclosure	Open space (with a floor, pavement or ground surface; not covered; no or limited horizontal physical boundaries), not covered, enclosed space, etc.	A.4
	Function or user activity	Health, welfare spaces; administrative spaces, etc.	A.5, A.6
Construction entity part	Classified by related tables for elements, designed elements and work results	Health, welfare facilities: hospital buildings, operating theatres, hospital wards, health centre buildings, consulting rooms, sick bays, etc.	A.7, A.8, A.9
Element	Characteristic predominating function of the construction entity	Enclosing elements (floors, roofs, supporting elements, columns); servicing elements (ventilation systems), etc.	A.7
Designed element	Element by type of work	Internal walls of gypsum board on timber studs; internal walls of pre-cast concrete	A.8
Work result	Type of work	Excavation and filling, ground anchoring, brick/block walling, structural precast concrete, etc.	A.9
Management process	Type of process	Personnel management, Marketing/sales management, project management, etc.	A.10
Work process	Classified by related table for work results	Excavation and filling, ground anchoring, brick/block walling, structural precast concrete, etc.	A.9
Construction entity lifecycle stage	Overall character of processes during the stage	Origination, design, production, use/maintenance, etc.	A.11
Project stage	Overall character of processes during the stage	Inception/procurement, feasibility, outline proposals, programme preparation, scheme design/costing, etc.	A.12

(continued)

Table 3.5 (continued)

Class	Principle of specialization	Examples of possible headings	Table reference
Construction product	Function	Ground treatments and retention, construction works, structural and space divisions, accesses, barriers, circulation equipment, coverings, claddings, linings, etc.	A.13
Construction aid	Function	Ground water lowering plant, contractor's pumps, steel reinforcement cutting and bending plant and equipment, formwork and scaffolding, etc.	A.14
Construction agent	Discipline	Clients, architects, etc.	A.15
Construction information	Type of medium	Drawings, photographs, etc.	A.16
Property/characteristic	Type	Composition, methods of assembly, shape, size, weight, density, etc.	A.17

classification is related to a hierarchical structure and it allows different levels of aggregation and summarization. The UNIFORMAT II[22] classification of building elements comprises three hierarchical levels:

- Major Group Elements for Level 1;
- Group Elements for Level 2;
- Individual Elements for Level 3.

For each level the standard proposes an alphanumeric designation for the classification: a single character letter code for Level 1 Major Group Elements, a three character alphanumeric code for Level 2 Group Elements and a five character alphanumeric code for Level 3 Individual Elements (Table 3.6)

Starting from the third level, it is possible to list less and less complex items. The standard proposes open and detailed lists of specific items, defining those ones included and excluded under each individual element listed in the Level 3 category.

[22]UNIFORMAT classification has been developed in relation to several uses: structuring costs on an elemental basis for economic evaluations early in the design process; estimating and controlling costs during planning, design, and construction (i.e. UNIFORMAT II may support in preparing budgets and establishing elemental cost plans before design begins); conducting value engineering workshops (i.e. UNIFORMAT may be used as a checklist to ensure that alternatives for all elements of significant cost in the building project are analysed in the creativity phase); developing initial project master schedules; performing risk analyses (i.e. by developing probability distributions of building costs applied on individual elements and group elements when evaluating the economic risk in undertaking a building project); structuring cost manuals and recording construction, operating and maintenance costs in a database; structuring preliminary project descriptions during the conceptual design phase; coding and referencing standard details in computer aided design systems.

Table 3.6 Standard classification for building elements and related site work [40]

	Level 1 Major group elements		Level 2 Group elements		Level 3 Individual elements
A	Substructure	A10	Foundations	A1010	Standard foundations
				A1020	Special foundations
				A1030	Slab on grade
		A20	Basement construction	A2010	Basement excavation
				A2020	Basement walls
B	Shell	B10	Superstructure	B1010	Floor construction
				B1020	Roof construction
		B20	Exterior enclosure	B2010	Exterior walls
				B2020	Exterior windows
				B2030	Exterior doors
		B30	Roofing	B3010	Roof coverings
				B3020	Roof openings
C	Interiors	C10	Interior construction	C1010	Partitions
				C1020	Interior doors
				C1030	Fittings
		C20	Stairs	C2010	Stair construction
				C2020	Stair finishes
		C30	Interior finishes	C3010	Wall finishes
				C3020	Floor finishes
				C3030	Ceiling finishes
D	Services	D10	Conveying	D1010	Elevator and lift
				D1020	Escalators and moving walks
				D1030	Other conveying systems
		D20	Plumbing	D2010	Plumbing fixtures
				D2020	Domestic water distribution
				D2030	Sanitary waste
				D2040	Rain water drainage
				D2050	Other plumbing systems
		D30	HVAC	D3010	Energy supply
				D3020	Heat generating systems
				D3030	Cooling generating systems
				D3040	Distribution systems
				D3050	Terminal & package units
				D3060	Controls and instrumentation
				D3070	Systems testing and balancing
				D3090	Other HVAC systems and equipments

(continued)

Table 3.6 (continued)

	Level 1 Major group elements		Level 2 Group elements		Level 3 Individual elements
		D40	Fire protection	D4010	Sprinklers
				D4020	Standpipes
				D4030	Fire protection specialties
				D4090	Other Fire protection systems
		D50	Electrical	D5010	Electrical service and distribution
				D5020	Lighting and branch wiring
				D5030	Communications and security
				D5090	Other electrical systems
E	Equipment and furnishings	E10	Equipment	E1010	Commercial equipment
				E1020	Institutional equipment
				E1030	Vehicular equipment
				E1090	Other equipment
		E20	Furnishings	E2010	Fixed furnishings
				E2020	Movable Furnishings
F	Special construction and demolition	F10	Special construction	F1010	Special structures
				F1020	Integrated construction
				F1030	Special construction systems
				F1040	Special facilities
				F1050	Special controls and instrumentation
		F20	Selective building demolition	F2010	Building elements demolition
				F2020	Hazardous components abatement

The listings of inclusions and exclusions proposed by the standard are not intended to be exhaustive. Rather, they provide a general outline of what expecting in a particular element. In the Table 3.7 it is proposed an example of the Level 4 Sub-Elements.

Sharing the same approach of UNIFORMAT II, the Italian UNI standard 8290-1:1981, "Residential building. Building elements. Classification and terminology" proposes a classification and coding of the building elements based on a typical breakdown scheme, organized in three hierarchical levels that may be further split up in lower levels (Table 3.8). Each level contains items characterized by the same degree of complexity. The three levels are:

Table 3.7 Example of the proposed Level 4 sub-elements [40]

Code	Level 1 Major group elements	Code	Level 2 Group elements	Code	Level 3 Individual elements	Level 4 Sub-elements	
						Included	Excluded
B	SHELL	B10	Superstructure	B1010	Floor construction	(a) Floor structural frame (b) Interior structural walls (c) Floor slabs and decks (d) Inclined and stepped floors (e) Expansion and contraction joints (f) Balcony construction (g) Suspended ramps (h) Exterior stairs and fire escapes (i) Other floor construction (i.e. catwalks, space frames, etc.)	(a) Exterior load bearing walls (b) Applied and suspended ceiling and floor finishes (c) Stair construction (d) Balcony walls and railings
				B1020	Roof construction	(a) Roof structural frame (b) Structural interior walls supporting roof (c) Roof decks, slabs and sheathing (d) Canopies (e) Other roof construction	(a) Roof coverings (b) Skylights and roof openings (c) Stair construction
		B20	Exterior enclosure	B2010	Exterior walls	(a) Exterior wall construction with facing materials, exterior applied finishes, back-up construction, framing, sheathing, wallboard, parapets, insulation, and vapour retarders (b) Exterior load-bearing wall construction (c) Exterior louvers and screens (d) Exterior sun control devices (e) Balcony walls and railings (f) Exterior soffits	(a) Applied finishes to interior faces of exterior walls (b) Columns and beams in exterior walls (c) Venetian blinds (d) Other interior sun control devices (e) Roof eaves and eaves soffits

(continued)

Table 3.7 (continued)

Code	Level 1 Major group elements	Code	Level 2 Group elements	Code	Level 3 Individual elements	Level 4 Sub-elements	
						Included	Excluded
							(f) Glazed curtain walls
				B2020	Exterior windows	(a) Windows (b) Storefronts (c) Curtain walls (d) Exterior painting of windows (e) Wall opening elements such as lintels, sills, flashings, etc.	(a) Window treatments
				B2030	Exterior doors	(a) Personnel doors (b) Revolving doors (c) Overhead doors (d) Other doors (i.e. hanger doors, blast-resistant doors, etc.)	
		B30	Roofing	B3010	Roof coverings	(a) Roofing membranes, shingles and tiles (b) Traffic coatings (c) Waterproof membranes below paving (d) Expansion joints (e) Vapour retarders (f) Roof and deck insulation (g) Roof fill (h) Flashings and trim (i) Gutters and downspouts (j) Eaves and eaves soffits	(a) Roof openings (b) Roof drains (c) Parapets
				B3020	Roof openings	(a) Skylights (b) Area glazing (c) Roof hatches (d) Gravity roof ventilators (e) Smoke vents	(a) Powered and ducted ventilators

Table 3.8 Classification for building elements [41]

Level 1 Classes of technological units	Level 2 Technological units	Level 3 Classes of technical elements
Loadbearing structure	Foundation structure	Direct foundation structure
		Indirect foundation structure
	Above ground structure	Vertical above ground structure
		Horizontal and tilted above ground structure
		Spatial above ground structure
	Containment structure	Vertical containment structure
		Horizontal containment structure
Closing	Vertical closing	External vertical walls
		External vertical windows/frames
	Lower horizontal closing	Slab on grade
		Horizontal windows/frames
	Horizontal closing on outdoor spaces	Slab on open areas
	Upper closing	Roofing
		External horizontal windows/frames
Internal partition	Vertical internal partition	Internal vertical walls
		Internal vertical frames
		Protective elements
	Horizontal internal partition	Floor slabs
		Intermediate floors
		Internal horizontal frames
	Tilted internal partition	Internal stairs
		Internal ramps
Outside partition	Vertical outside partition	Protecting elements
		Separating elements
	Horizontal outside partition	Balconies and loggias
		Walkways
	Tilted outside partition	External stairs
		External ramps
Services	Climate control system	Feed
		Thermal units
		Fluids treatment plants
		Distribution piping/network and terminals
		Condensate drain network
		Exhaust and vents

(continued)

Table 3.8 (continued)

Level 1 Classes of technological units	Level 2 Technological units	Level 3 Classes of technical elements
	Domestic water system	Connections
		Hydraulic machines
		Storage systems
		Boilers
		Domestic cold water distribution and terminals
		Domestic hot water distribution and terminals
		Hot water re-circulating networks
		Fixtures (plumbing fixtures)
	Liquid disposal system	
	Gaseous disposal system	
	Solid disposal system	
	Gas distribution system	
	Electrical system	
	Telecommunication system	
	Fixed conveying system	
Safety system	Fire fighting system	
	Grounding system	
	Lighting protection system	
	Anti-theft and anti-intrusion system	
Internal equipment	Domestic furnishing	
External equipment	Outdoor collective furnishing	
	External fittings	

– classes of technological units;
– technological units;
– classes of technological elements.

The hierarchical structure proposed by the standard UNI 8290-1 may be split up, for example, in a fourth level represented by the various types of a technical element. This level may be further split up in a fifth level represented by the various components/layers that may compose each type of technical element (Fig. 3.8).

Finally a recent and very interesting proposal for the classification of the built environment is represented by the OmniClass Construction Classification System (OCCS). OmniClass is useful for many fields of application: organizing library

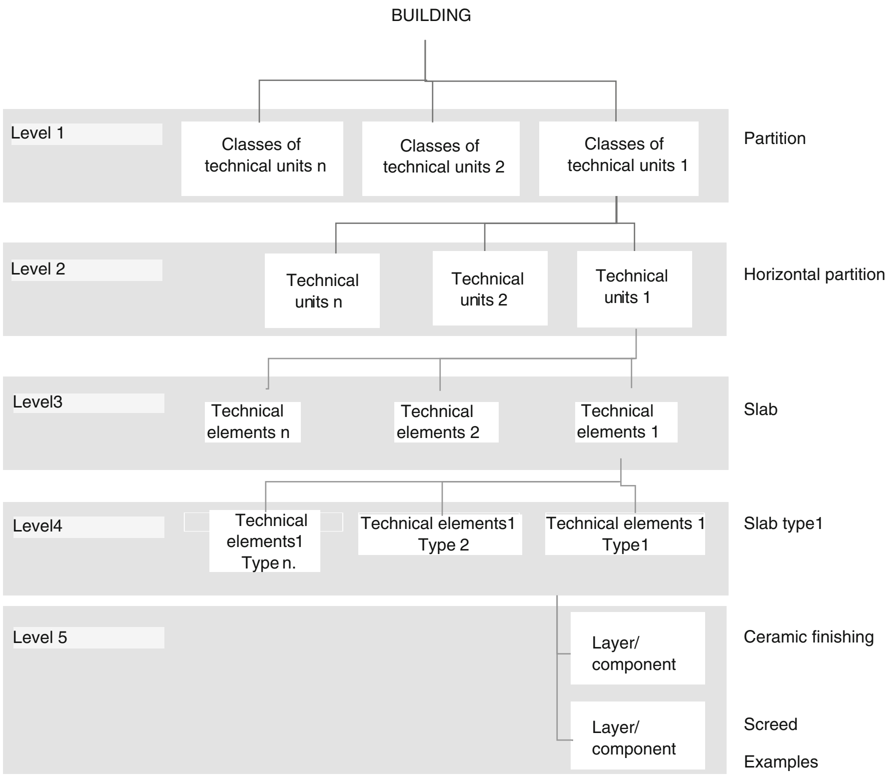

Fig. 3.8 Example of application of the classification system [41]

materials, product literature, project information, electronic databases. OCCS[23] is intended to be the global mean for organizing, sorting and retrieving information, as well as deriving relational computer applications considering the whole life cycle of a facility, from its conception to its deconstruction or recycling. OmniClass is a support tool for organizing many different forms of information (electronic and hard copy, libraries and archives) and preparing project information, communication exchange information, cost information, specification information and other information that is generated during the services carried out throughout the project life cycle. Moreover, OmniClass is compatible with information stored in computerized databases and most existing databases can simply have a field added to accept OmniClass codes. Therefore, the codes, that can be assigned to each item in databases and reports produced according to OmniClass codes, allow information to be sorted and retrieved for a variety of purposes.

[23]OmniClass has been designed in order to provide a standardized basis for classifying information created and used in the field of North American architectural, engineering and construction (AEC) industry, throughout the facility life cycle, from conception to demolition or reuse, in relation to all the different types of constructions making up the built environment.

Table 3.9 The tables proposed by the OmniClass construction classification system

Class	Table	Title
Construction results	11	Construction entities by function
	12	Construction entities by form
	13	Spaces by function
	14	Spaces by form
	21	Elements (includes designed elements)
	22	Work results
Construction resources	23	Products
	33	Disciplines
	34	Organizational roles
	35	Tools
	36	Information
	41	Materials
Construction processes	31	Phases
	32	Services
	49	Properties

OmniClass derives classification and coding criteria from internationally accepted standards developed by the ISO organization and, in particular, from the above mentioned standard ISO 12006-2.[24] Following the framework for information classification proposed by ISO 12006-2, OmniClass accepts the basic structure of information about construction grouped into three primary categories composing the model of the process (construction resources, construction processes and construction results). Then, these categories are further subdivided into fifteen suggested “Tables” (Table 3.9) organizing construction information. Each table represents a different aspect of construction information. Each table can be independently used to classify a particular type of information, or it can be combined with entries on other tables to classify more complex subjects.

OCCS incorporates other existent systems currently used as a basis for these tables. These systems are: MasterFormat (for work results), UniFormat (for elements), EPIC (Electronic Product Information Cooperation) (for products).

In particular, in this context it may be interesting to report the framework of contents of some tables:

[24]OCCS derives its contents from the standard ISO 12006-2 as well as Uniclass (Unified Classification for the Construction Industry). Uniclass is the UK’s equivalent of OmniClass. The OCCS Development Committee has been in contact with the developers of Uniclass, and from an early point in the OmniClass development effort, received permission to freely adapt and use portions of the content and structure of Uniclass as needed in the development of OmniClass. This cross-referencing allows the Uniclass maintenance team to, in turn, use OmniClass as a resource for further refining their document, thereby moving both documents closer to a harmonized international standard.

Table 3.10 Example of Table 21 [47]

OCCS number	Level 1	Level 2	Level 3	Level 4	Table 22 reference
21-02 00 00	Shell				
21-02 20		Exterior vertical enclosures			
21-02 20 10			Exterior walls		
21-02 20 10 10				Exterior wall veneer	
21-02 20 10 20				Exterior wall construction	
21-02 20 10 30				Exterior wall interior skin	
21-02 20 10 40				Fabricated exterior wall assemblies	
21-02 20 10 50				Parapets	
21-02 20 10 60				Equipment screens	
21-02 20 10 80				Exterior wall supplementary components	
21-02 20 10 90				Exterior wall opening supplementary components	
21-02 20 20			Exterior windows		
21-02 20 20 10				Exterior operating windows	22-08 50 00
21-02 20 20 20				Exterior fixed windows	22-08 50 00
21-02 20 20 30				Exterior window wall	
21-02 20 20 50				Exterior special function windows	22-08 56 00

- Table 21—Elements

It is organized by elements' implied functions. Major elements may be composed of several sub-elements. The Table proposes four levels[25] of elements. For example, a shell enclosure might be composed of superstructure, exterior closure and roofing. Currently, elements are most frequently used during early project phases for identifying project's physical, operational or aesthetic characteristics. Elements are considered without regard to a material or technical solution of the function. For each element, there may be several technical solutions able to accomplish the elemental function and more than one may be selected for a project. These solutions are the designed elements. Furthermore, it is possible to describe an element by using the three levels of the Table 21 (Table 3.10) integrated by the reference to the Table 22 (Table 3.11).

- Table 22—Work Results[26]

A work result represents a complete entity existing after all the required raw materials, human or machine efforts and processes which have been provided to achieve a complete condition. It represents a construction result achieved in

[25]The first one is composed of the seven levels proposed in UNIformat II: substructures, shell, interiors, services, equipments and furnishings, special construction and demolition.

[26]Table 22 is based almost entirely on an existing Construction Specifications Institute/Construction Specifications Canada publication called MasterFormat.

Table 3.11 Example of the Table 22 [47]

OCCS number	Level 1	Level 2	Level 3	Level 4
22-08 00 00	Openings			
22-08 50 00		Windows		
22-08 51 00			Metal windows	
22-08 51 13				Aluminum windows
22-08 51 16				Bronze windows
22-08 51 19				Stainless-steel windows
22-08 51 23				Steel windows
22-08 51 66				Metal window screens
22-08 51 69				Metal storm windows

production stage, maintenance or demolition processes and it is identified by various features (skill or trade involved, construction resources used, the part of the construction entity which results, the work which results). A work result may pertain to several manufactured products (assembly), such as exterior insulation and finish system, or to a single product such as a framed marker board. A work result could also involve only labor and equipment used to achieve the desired result, such as trenching (Table 3.11).

- Table 23—Products

This Table provides a basis for identifying products categorized by number and name in a unique location. Products are components or assemblies of components for permanent incorporation into construction entities. A product may be a single manufactured item, a manufactured assembly of many parts or a manufactured operational stand-alone system. Basic materials are also considered products when they are used in their original form as a component to achieve a construction work result. An example is sand used as a sub-base cushion for brick paving. Sand is also a constituent material of other products such as items made from precast concrete. Therefore, base materials like sand occur both in this Table and in Table 41—Materials. The contents of the Table 23 may be related to the classifications and codes of Table 41—Materials,[27] such as to the ones of Table 22—Work Results that provides multiple classifications for any given product dependent upon the application (or work result) the product is used for. An example is a glass panel, which can have many work result locations such as in a window, as cabinet shelving, or in an interior door opening (Table 3.12).

[27]It is possible to use codes from one other table as modifiers for the base numbers (i.e. entries from Table 41 could be used as qualifiers where necessary, i.e. aluminium windows could be classified as 23 − 30, 20 + 41 − 10, 20 13).

Table 3.12 Example of Table 23 [47]

OCCS number	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Definition
23-13 00 00	Structural and exterior enclosure products							
23-13 33 00		Envelope enclosure products						
23-13 33 27			Glazed facade and roof structures					
23-13 33 27 11				Curtain walls				
23-13 33 27 11 11					Curtain wall components			
23-13 33 27 11 11 11						Curtain Wall Frames		
23-13 33 27 11 11 13						Curtain wall sections		
23-13 33 27 11 11 15						Curtain wall infill panels		
23-13 33 27 11 13					Metal framed curtain wall			
23-13 33 27 11 15					Translucent curtain wall assemblies			
23-13 33 27 13				Structural glazing				
23-13 33 27 13 11					Structural glass curtain walls			

- Table 41—Materials

This table provides a classification and description of the substances from which construction resources are made of. These substances may be raw materials or refined compounds (i.e. metallic compounds, rocks, soils, timber, glass, plastics, rubbers, etc.). Material means any composition that can be described without implicitly or explicitly defining its form.[28] For example, "aluminum" is a material, since it is a chemical composition. Although aluminum products come in bars, sheets and other forms, the term aluminum describes the "material" each of those products is made of. Other types of materials included in this Table are raw material names, that usually encompass both chemical composition and form, because they are found in nature in certain forms. For example, the chemical composition "sand" is a silicon dioxide, but, since it is a naturally occurring form of silicon dioxide and it is used as a constituent material of other products, it is included it in this Table[29] (Table 3.13).

- Table 49—Properties

Properties are the various characteristics of the construction entities. The Table (Table 3.14) lists, classifies and codes seven main categories of properties, that may be further split up in three lower levels:

- identification properties, that identify objects, provide or enhance metadata about objects (i.e. indications about facility, space, occupancy, proprietary etc.);
- location properties that describe positions or points in physical space that an object occupies on the earth surface such as geographic location;
- properties of time and money related to scheduling, durations and cost (i.e. time, scheduling, cost properties, etc.);

[28]Forms are characteristics like "board", "bar", "sheet", "block", etc.

[29]Since sand is also a product used in its original form, it will also show up in Table 23—Products.

Table 3.13 Example of Table 41 [47]

OCCS number	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Definition
41-30 00 00	Solid compounds						
41-30 50 00		Synthetic compounds					
41-30 50 24			Rubbers				Any type of artificial elastomer, invariably a polymer
41-30 50 24 11				Butyl rubber			Impermeable to air and used in many applications requiring an airtight rubber
41-30 50 24 14				Neoprene			Good chemical stability and maintains flexibility over a wide temperature range
41-30 50 24 17				Silicone			Typically heat-resistant, used in sealants, adhesives, lubricants, medical applications and insulation
41-30 50 24 21				Polysulfide			A class of chemical compound containing chains of sulfur atoms
41-30 50 27			Petrochemical compounds				Compounds originating from Petroleum-based substances mixed with other sources
41-30 50 27 11				Asphalts			Compounds consisting of a sticky, black and highly viscous liquid or semi-solid present in most petroleum and natural deposits
41-30 50 27 11 11					Asphalt		Primarily used in road construction
41-30 50 27 11 13					Polymer modified asphalt		An asphalt with greater elastic and durability properties and greater temperature stability

– source properties dealing with the attributes, that can describe creation, distribution or installation of objects, chiefly products or work results (i.e. manufacturer, product, warranty properties, etc.);
– physical properties (i.e. quantity, shape, dimensions, relational measurements, sustainability properties, chemical composition properties, etc.);
– performance properties expressing the behavior of an object in reaction to physical properties and forces (i.e. tolerance, durability, acoustic, combustion properties, permeability and moisture resistance, etc.);
– properties of facility services (i.e. properties of fire protection, plumbing, HVAC, lighting, energy systems, etc.).

The listed properties may be usefully related to the entities listed in Tables 21, 22 and 23 in order to describe their requirements and performances (Table 3.14).

Table 49 is useful for: describing the characteristics of objects by identifying a classification defined in one of the other tables and modifying it using properties identified in this Table; defining requirements for construction objects; comparing the characteristics of similar objects; classifying information resources on subjects relating to factors and properties.

The various classification systems show the worldwide interest for developing breakdown structures to be used and shared as a framework for the organization of information concerning the building in all its aspects and processes during the whole life cycle, from conception to demolition or reuse, and encompassing all the different types of construction, that make up the built environment.

Despite the availability of these classification and coding systems, most operators working in the FM market (both clients and suppliers) are still late in considering these references. Analysing general conditions and technical specifications of FM contracts and agreements, it is uncommon to find precise requests about the breakdown structure to be assumed as a base for the building registry and the management of the services. Generally, the registry structure is defined by the client and the supplier only during the mobilisation phase of the service, otherwise its development is delegated to the supplier that operates more or less autonomously.

Instead, during the preliminary phase of the Facility Management agreements, the client should perform a comprehensive analysis of the state of consistency and characteristics of the real estate assets, as well as of his specific needs, organizational models and strategies for the services. In this way the client could outline basic criteria or (if he has enough skills) prescribe rules for the development and management of the building registry (also in relation to the implementation of an information system). Nevertheless, as the standard EN 15221-2:2007 advises, these criteria or rules should concern not only the framework of the registry system, but also modalities and responsibilities for the information management. According to this standard, both the parties should ensure that the responsibilities for designing, updating and reporting information are fully understood and articulated in the Facility Management agreement and procedures for the issue of reports and performance indicators are available for each stakeholder, especially if financial penalties or inducements must be paid.

Table 3.14 Example of Table 49 [47]

OCCS Number	Level 1	Level 2	Level 3	Level 4	Definition
49-81 00 00	Performance properties				Properties that express the behaviour of an object in reaction to physical properties and forces
49-81 61 00		Properties of the envelope			Properties between inside and outside environment. refer to other categories for structural, moisture/permeability, combustion and fire resistance, acoustics, impact resistance
49-81 61 11			Absorbance		Measurement of the ability of an object to absorb radiation
49-81 61 13			Air Infiltration		Measurement of the ability of air to permeate a given area
49-81 61 15			Air Tightness		Not allowing air to pass through or permeate
49-81 61 17			Air Leakage		Measurement of the amount of air seeping out of a given area
49-81 61 19			Water Penetration		Measurement of the ability of water to permeate a given area
49-81 61 21			Condensation resistance factor (CRF)		Determined by the manufacturer and expressed in values from 0 to 100
49-81 61 23			R-value		Related to one component, relative but not specific to an assembly. Ratio of the temperature difference across an insulator and the heat flux (heat flow per unit area,) through it
49-81 61 25			R-value système international (RSI)		A measure of thermal resistance in SI units

(continued)

Table 3.14 (continued)

OCCS Number	Level 1	Level 2	Level 3	Level 4	Definition
49-81 61 27			U-value		Overall conductance. Thermal resistance of entire assembly including outside and inside, fenestration, and percentage of openings. Sometimes called U-factor
49-81 61 29			USI		Metric U-value. Inverse of RSI
49-81 61 31			Insulation density		Measurement of the substantiality of insulation. This relates heavily to the R-value of the insulation
49-81 61 33			Insulation profile		Refers to the general shape of a piece of insulation or insulation assembly
49-81 61 33 11				Tapered	Shaped in such a way as to gradually narrow or become smaller
49-81 61 33 13				Flat	Shaped in such a way as to provide the most consistent R-value across a given area
49-81 61 35			Properties of openings		Descriptors that provide information about various access points and holes
49-81 61 35 11				Opening Type	Generally identifies a basic opening and how attached hardware may interact with surrounding elements
49-81 61 35 13				Opening Number	Numerical identifier used to refer to a certain type of opening
49-81 61 35 15				Opening Transmittance	Measurement of how far an opening extends in all directions
49-81 61 35 17				Opening Reflectance	Measurement of the light bouncing off of an opening
49-81 61 35 19				Opening Emittance	The ability of an opening to reduce absorbed heat
49-81 61 35 21				Opening Conductivity	Measurement of how well the opening conducts electricity

(continued)

Table 3.14 (continued)

OCCS Number	Level 1	Level 2	Level 3	Level 4	Definition
49-81 61 37			Solar heat gain coefficient (SHGC)		Visual Transmission of solar radiation (visual light admitted vs. rejected) is calculated using SHGC
49-81 61 39			Shading coefficient		The ratio of total solar transmittance for the specified glazing system to the total solar transmittance for the standard reference glazing (1/8″ clear)
49-81 61 41			Heat transfer coefficient		Heat transfer coefficient is the inverse of thermal insulation
49-81 61 43			Specific heat		Percentage of higher or lower value based on the proportion of solid versus openings. The ratio of the amount of heat required to raise the temperature of a unit mass of a substance by one unit of temperature to the amount of heat required to raise the temperature of a similar mass of a reference material, usually water, by the same amount
49-81 61 45			Internal thermal energy		Is the part of the total internal energy of a thermodynamic system or sample of matter that results in the system's temperature
49-81 61 47			Linear thermal expansion coefficient		Relates the change in a material's linear dimensions to a change in temperature
49-81 61 49			Long-term thermal resistance (LTTR)		Refers to the rating given to an object with regard to its R-value based on a 15 year time-weighted average

(continued)

Table 3.14 (continued)

OCCS Number	Level 1	Level 2	Level 3	Level 4	Definition
49-81 61 51			Specific heat input		A measured amount of heat energy going into a system
49-81 61 53			Thermal break		An element of low thermal conductivity placed in an assembly to reduce or prevent the flow of thermal energy between conductive materials
49-81 61 55			Thermal conductance		The act and measurement of continuous heat transfer
49-81 61 57			Thermal conductivity		Refers to the capability of a material or object to transfer heat
49-81 61 59			Thermal diffusivity		Is the thermal conductivity divided by density and specific heat capacity at constant pressure
49-81 61 61			Thermal insulation		Measure of the ability of a material to contain and not transfer heat
49-81 61 63			Wind uplift resistance		The ability to resist a net upward force on the roofing system

Coherently with these indications, the Italian standard UNI 11136:2004, “Global service for maintenance of buildings—Guidelines” suggests to systematically collect information related to the outcomes of the crucial preparatory phase of analysis and assessment of needs. The standard suggests to report this information in a special document named “Document of Preliminary Orientation” in order to support the following phase of tender preparation and service request.[30]

[30]The standard UNI 11136:2004 suggests that the basic subjects for the Document of Preliminary Orientation should be:

- analysis of the state of consistency and of the characteristics of the real estate;
- orientations of the FM service in relation to the Client’s real estate management strategies;
- examination of the characteristics of the internal organizational structures;
- analysis and evaluation of the information system (if already existing);
- identification of activities to be outsourced through FM service;
- definition of the gradual process of implementation of the building registry and information system;
- definition of the criteria for determining and monitoring performance levels of the various services.

3.5 The System of Data Sheets

As already stated (Chap. 3), besides classification and coding criteria, a further element that composes the registry system is what could be named “system of data sheets” (Fig. 3.2).

Setting preliminarily a system of data sheets means planning a framework of possible information to be acquired over time in order to know and develop management activities on real estate assets.

Considering the requirements listed in the Table 3.1, it can be stated that if information is collected during the inventory process according to the indications included in the data sheets, it can be traceable, consistent and unique over time. Moreover, it can be reliable in real time if, during the process of gradual implementation of the registry, it is recorded and allocated to different spatial and technical entities represented according to the classification and coding system.

In this way, data will be collected on the basis of the system of data sheets and, in accordance with management strategies, carried out in relation to the size and complexity of the building stock. In the process of gathering data, in relation to specific contextual goals and registry systems, data become information useful to support the various activities (Plan, Do, Check and Act) of FM services (Chap. 1) and to implement the knowledge base.

Once they have been collected, data can implement the registry according to various ways:

- they can be stored in a paper data sheet. Of course this is an “archaic” mode, acceptable only in presence of one or few buildings characterized by a very low complexity and it shall be considered as a transitional situation, waiting for more advanced forms of data storage;
- they can be transferred in tables, managed by electronic spread sheets (for example in the case of small real estate for which it is not considered appropriate to invest in the acquisition and management of an information system);
- they can finally be included within an information system.

Regardless of the method used for gathering information, any collected data must be allocated within a formalized framework and referred to a classified and codified item.

Information regarding identification and description of space and technical elements constitutes the basis of the building registry (Fig. 3.1). Building registry is fundamental as it represents the basic platform of knowledge that may support several management activities (i.e. space management, maintenance and operation, administration, energy management, etc.).

In particular, considering FM services, maintenance and operation activities are those ones engaged with the main amount of technical information about the buildings. So it may be helpful to analyse maintenance [10–20] and operation activities in order to outline an open list of technical information useful for defining some of the main contents of the data sheets.

A significant contribution to establish the data sheets framework referring to technical information about maintenance activities can be extracted from a large number of standards[31] (Tables 3.15, 3.16 and 3.17). A basic reference can be found in the EN 15331:2011, "Criteria for design, management and control of maintenance services for buildings". In particular, a wide list of information can be extracted from the Italian standards UNI 10874:2000, "Maintenance of buildings. Criteria in order to write maintenance and use manuals", UNI 10951:2001 "Systems of information for the maintenance management of buildings Guidelines" and UNI 11257:2007, "Maintenance of buildings. Criteria for the drafting of plan and programme of maintenance of buildings. Guidelines" (Table 3.17). These three standards, in a coherent and coordinated way, set the framework of possible information to be acquired in order to know and develop management activities on real estate assets.

[31]It is interesting to highlight the work of the Technical Committee TC 319 "Maintenance" within the CEN "European Committee for Standardization". TC 319 is bringing together the contribution and the needs of the sector of the building maintenance, characterized by some peculiarities compared the more general discipline of maintenance.

The Technical Committee TC/319, whose President and Secretary are assigned to Italy, is divided into 13 working groups, as detailed in Table 3.15.

The working groups have developed over time a series of standards (Table 3.16) that could be defined as "horizontal" (that is applicable to different production sectors) with the exception of a standard specifically developed for building sector, that is the standard EN 15331:2011 "Criteria for design, management and control of maintenance services for buildings". Furthermore, the groups are now working on three interesting projects that relate to the themes of "condition assessment", "risk based inspection" and "maintenance process".

The Technical Committee TC/319 has also established links ("formal liaisons") with other committees both at European and at international level, that deal with issues related to or associated to maintenance. In particular with regard to the issue of building maintenance the following connections are particularly important:

- CEN TC 348 "Facility Management" is a technical committee of the CEN activated in 2006 to offer to the FM sector a harmonized framework of reference, useful to support the great and rapid developments in the field of services. The TC/348 has produced several standards on the subject, but actually it has now completed its work when the topic of facility management has been shared internationally and ISO "International Organization for Standardization" has created a specific technical committee ISO TC/267 "Facilities management" (under the coordination of BSI standardization). The TC/267 is currently working on three new draft standards;
- ISO TC 251 "Asset management" is a ISO technical committee (born as PC project committee and later formalized as TC technical committee) that deals with the general topic of asset management, considering any asset, material or immaterial, related to organizations. TC/251 has produced three standards till now and has provided to TC/319 an opportunity to develop a specific standard (EN 16646:2014, "Maintenance—Maintenance within physical asset management";
- ISO PC 259 "Outsourcing": it is a Project Committee (under the coordination of the Dutch NEN for standardization) that has produced the standard ISO 37500:2014 "Guidance on outsourcing" with the aim of standardizing and proposing principles and a common vocabulary about the subject of outsourcing.

Table 3.15 List of working groups of the CEN/TC/319 with indication of the WG with Italian convenorship

CEN/TC/319 Working groups
WG1 Classification[a]
WG2 Maintenance documentation
WG3 Maintenance agreements (Italian convenorship)
WG4 Terminology
WG5 Quality[a]
WG6 Maintenance performance and indicators (Italian convenorship)
WG7 Maintenance of buildings (Italian convenorship)
WG8 Maintenance management
WG9 Qualification of personnel
WG10 Maintenance within physical asset management
WG11 Condition assessment methodologies
WG12 Risk Based Inspection Framework (RBIF)
WG13 Maintenance process

[a]For workgroups no longer active

Table 3.16 List of technical standards developed by the CEN TC/319

Standard Title
EN 13269:2006, "Maintenance—Guideline on preparation of maintenance contracts (standard under review process)"
EN 13460:2009, "Maintenance—Documentation for maintenance"
EN 13306:2010, "Maintenance—Maintenance terminology (standard under review process)"
EN 15331:2011, "Criteria for design, management and control of maintenance services for buildings"
EN 15431:2007, "Maintenance—Maintenance key performance indicators (standard under review process)"
EN 15628:2014, "Maintenance—Qualification of maintenance personnel"
EN 16646:2014, "Maintenance—Maintenance within physical asset management"

A synoptic, extrapolated from the three standards, is shown in the Table 3.18. It sums up the complex information that may be collected for the construction of a building registry. The listed information is useful both for the management of technical services and the preparation of maintenance manuals. Of course, in the various management situations, not all this information will be necessary and/or available. In fact, not necessarily all the information listed in the Table 3.18 for the data sheets must be collected. Considering the principle of gradualism, information not available have not to be necessarily searched. A criticality assessment of the item and its layers/components, as well as the need for the missed information, will influence the decision to seek this information. Information not relevant will never

Table 3.17 The Italian standards UNI in the field of maintenance

UNI Standard	Goals
UNI 10604:1997 (*replaced by the standard EN 15331:2011 Criteria for design, management and control of maintenance services for buildings*) Maintenance Criteria for design, management and control of the maintenance Services of building	Outline the overall framework of the references necessary for the development of the maintenance service, establish the basic criteria, identify key issues and relationships between them
UNI 10831-1:1999 Documentation and basic information for maintenance services of projects approved and executed Structure, contents and levels of documentation **UNI 10831-2:2001** Maintenance of buildings Documentation and basic information for maintenance services of projects approved and executed Details of content of technical documentation and lay-out models	Definition of project documentation for the proper setting of the maintenance service
UNI 10874:2000 Maintenance of buildings Criteria in order to write maintenance and use manuals	Definition of the information to be collected in order to develop maintenance manuals
UNI 10951:2001 Systems of information for the maintenance management of buildings Guidelines	Provide methodological and operational guidelines for the design, construction, operation and upgrading of information systems for maintenance management of real estate assets and for the relative computerization
UNI 11136:2004 Global service for maintenance of buildings—Guidelines	Guidelines for some basic steps in the process of developing a Global Service contract, namely: – setting the stage preliminary on the customer's side – setting the stage of request of offer on the customer's side – setting the stage of draft offer on the supplier's side
UNI 11257:2007 Maintenance of buildings Criteria for the drafting of plan and programme of maintenance of buildings. Guidelines	Provide the criteria for drawing up plans and programs of maintenance applicable to existing buildings and buildings under construction
UNI 11447:2012 Urban facility management services Guidelines to set and program contracts	Provide guidelines to customers for setting and programming procurement processes of Facility Management Urban services (FMU), in order to standardize the approach based on common methodological references and to classify urban assets and services

Table 3.18 Data sheets and synopsis of the information that can be acquired for the implementation of the building registry

Data sheet	Goals	Information contents	Allocation level of the information
Identification card of the built asset	To collect information useful to describe the real estate property in its general characteristics	• Localization data: territorial coordinates and location (i.e. address, number of floors, number of building units, address, etc.) • Dimensional data (i.e. gross volume above ground and basement, gross areas, total net and gross floor areas, etc.) • Cadastral data • Functional data: intended use of the real estate property	Building
		• Dimensional data (gross and net floor area)	Floor
		• Dimensional data (gross and net floor areas for the rooms) • Functional data: intended use of the real estate property and its parts • Main activities and instructions for use, requirements of use, etc.	Room
Administrative data sheet	To collect information useful to describe the legal and administrative status of the real estate asset	• Data relating to lease contracts (i.e. contracting party, type, contract number, date of execution, duration, expiry, base fees, etc.) • Information relating to documentation (i.e. document type, location code documents, code recognition, etc.) • Information relating to sale and purchase agreements (i.e. contracting party, contract type, contract number, date of signing, amount, etc.) • Data relating to the legal status purchase agreements (i.e. owner, etc.) • Data for constraints and servitude (i.e. type,	Building Floor Room

(continued)

Table 3.18 (continued)

Data sheet	Goals	Information contents	Allocation level of the information
		stakeholders, possible duration, reference (normative/contractual), etc.) • Data for supply contracts: information relating to contracts for the supply of products, works and services (i.e. contractor, date, amount, subject of the contract, method of delivery, contract number, duration, date of signing, amount basis, subsequent revisions, etc.)	
Technical data sheet	To collect technical data and identification data regarding the various classes of technical elements and components counted in the building The data sheets may include information as drawings and diagrams	• Definition of materials and constituting elements • Identification of manufacturers and installers • Identification of the commercial name/brand of the product and/or reference to the specific descriptions contained in the design specifications (when available) • Characteristics and performances (i.e. fire resistance, colour, thermal resistance, etc.). • Dimensional characteristics (i.e. linear measures, surface measurements, volume, weight, etc.). • Functional characteristics, mode of operation, operation values (i.e. power, efficiency, power consumption, limits and constraints of use, etc.) • Reference Requirements indicating, wherever is possible to express it, the minimum level of required quality: (i.e. safety, well-being, usability, appearance, integrability, etc.)	Technical element

(continued)

Table 3.18 (continued)

Data sheet	Goals	Information contents	Allocation level of the information
		• Costs: cost of construction/acquisition *Due to the specific features or criticality of the technical element it is also possible to collect information on:* • Method of installation/erection • Methods of assembly/disassembly • Operating schemes • Ability to be inspected, that is how to access the item, and possible devices to be used in order to improve the accessibility • Requirements for compliance audits • Specifications for checks and inspections required by law • Requirements for monitoring safety risks associated to operation of the unit, activities related to its maintenance and finally its disposal • Information on possible emissions of toxic-noxious substances arising from problems or failures that may occur during and at the end of the life cycle of the technical element	
Diagnostic data sheet	**Section A** Describes the degradation phenomena and list the types of more likely failures that can be identified in the counted technical	• Typology of degradation processes • Typology of the more likely detectable faults • For each listed fault, where it is considered appropriate to provide a greater level of detail: a description of the failure modes, methods of investigation and applicable diagnostics	Technical element

(continued)

Table 3.18 (continued)

Data sheet	Goals	Information contents	Allocation level of the information
	elements and components The data sheets may include information as drawings, diagrams, and photographs	(visual and non-destructive/destructive tests), visible signs (when present) of the failure state, possible causes, hypothetical times of occurrence • As integration, wherever possible, information about: the criticality degree of each failure identified in relation to the involved function, the risk of fault propagation, the probability of occurrence, the frequency of occurrence, the probability of identifying the failure and the involved direct/indirect costs	
	Section B Describes the degradation phenomena and list the types of faults found, as a result of inspection, affecting the surveyed technical elements and components The data sheets may include information including drawings, diagrams, and photographs	• Description of the detected degradation phenomena (typology, location, extent, causes, effects) • Description of the detected faults (typology, location, extent, causes, effects) • Information on the degree of criticality of the degradations and faults detected in relation to: the function involved, the risk of fault propagation, the probability of occurrence, the frequency of occurrence, the probability of identifying the failure and the direct and indirect costs involved	Technical element
Intervention data sheet	In relation to the degradation phenomena and to the possible counted failures to report a description of the more	• Description of the interventions for each degradation or identified failure • For each identified intervention: operational guidance on how to carry out the activities of site	Technical element

(continued)

Table 3.18 (continued)

Data sheet	Goals	Information contents	Allocation level of the information
	appropriate corrective and preventive actions with indications regarding the methods of intervention, the resources and the frequencies	visit, monitoring and inspection with description of operations, methods, tools, the item to be inspected, evaluation criteria and control parameters, frequency • Information on operating procedures for work to be carried out with description of tasks and frequency • Information on environmentally acceptable limit for execution • Indications on the produced disturbances (i.e. noise, dust, etc.) • Description of the intervention area (i.e. area occupied by equipment and operations, procedures for reporting and requirements for the eventual fencing and protection of the intervention, etc.) • Indication of the average time of active maintenance, (i.e. the time during which maintenance is carried out, both manually and automatically, on an entity, with the exception of the logistics delays) • Expected costs. The reference to the costs may refer to an overall "lump sum" cost (including or not administrative costs), an average cost for example reported per square meter, or an analytical cost, articulated in the different cost items (breakdown elements: labour, means, materials replacement, energy) • Indication of the risks associated with the	

(continued)

Table 3.18 (continued)

Data sheet	Goals	Information contents	Allocation level of the information
		activities (if any, reference to the risk assessment document) • Requirements for the safe execution of activities (if present, reference to the file of the construction work requested by the Directive CEE/92/57 "Minimum safety and health requirements at temporary or mobile constructions sites" • Information about: specialization required to contractors, minimum number of workers and their appropriate qualification; means of work; materials; energy sources, expected average duration for the intervention • Information on possible assistance centres, specialized operators, suppliers of materials for replacements • Listing factors (check-list), ways, criteria and parameters for monitoring the activities	
Regulation data sheet	To give references for voluntary and mandatory standards	• Normative reference • Responsible for carrying out activities envisaged by provision of the law • If applicable: certifications, licenses, concessions, tests relating to the building and its appurtenances • Certifications by law to be periodically updated about the building and the activities that take place there • Declarations of conformity • Periodical permits related to functional units or technical	Building/room/technical element

(continued)

Table 3.18 (continued)

Data sheet	Goals	Information contents	Allocation level of the information
		elements (i.e. lifts, etc.), including the logging of any verification visits of the authority inspection body	
Feedback data sheet	To allow the accurate registration of "feedback information" on alerts, inspections, maintenance works (planned and unplanned, performed) Registration of work orders	• Data on maintenance works undergone by the technical element (repair works, planned preventive works): type, date of execution, execution mode, tasks • Reference to the cause Maintenance strategy adopted (on call, emergency, preventive scheduled, condition based, of opportunity) • Time (planned and used, opening and closing date) • Operational resources • Costs (expected and sustained)	Building/room/technical element

be included. Other information with a little relevance may be included in a second time, when available. Gradually over time, thanks to feedback information or development of new experiences, new data can be implemented.

3.6 The Registry and the Information System

The structure of the registry and the methods of storing and managing information should be consistent and in close relation one to each other, whatever are the strategies adopted for managing FM services. To sum up, it is possible to trace back all the cases to four paradigmatic situations:

- low consistency and complexity of the managed assets do not lead to the acquisition of a proper information system. In this case, in order to realize and update in an appropriate way the building registry, acquired data should be collected and maintained within the data sheets, each one traceable and manageable because connected with spatial and technical entities;
- management takes place without an information system, but it is planned to acquire it in the future. In this case, it is very important, in order not to loose important feedback information from management activities, to design, implement and update a registry to be later transferred to the information system.

If the information system will be part of a new service contract, the structure of the registry and the methods of acquisition and transfer of information, already available, should be properly defined, described and required in Technical Specifications;

- the objective is to develop an "in house" information system in order to realize a platform fully consistent with the enterprise management procedures. In this case, the analysis of the operational needs and the consequent definition of the structure and tools of the building registry assume the basic role of starting point steering the implementation of the information system;
- it is required a technical management service and, within it, it is prescribed the acquisition and implementation of an information system. In this case, the analysis of the management needs and the consequent definition of the structure and tools of the building registry are essential to manage the selection of the information system and indicate, in the tender, the implementation modalities. Regarding this situation, it is common to find two different positions within Technical Specifications. In some situations the client, basing on an analysis of his *modus operandi*, describes the elements to be counted and, in some cases—not so uncommon today—even details the minimum information to be acquired as a basic start up and that one to be implemented over time (applying the principle of gradualism). Other situations, instead, are characterized by the request to the contractor—in order to take advantage of its expertise and experience—of a proposal for the organization of the building registry and its levels of detail, in relation to the services covered by the contract and client's specific needs. In this case, if on one hand contractor's knowledge and skills about information management are rightly used; on the other hand, there is a risk of loss of control for the client. This risk is generated if it is not adopted a logic of effective partnership and if the client does not use—if necessary including the use of external consultants—a good ability to interact and express his needs and guidelines. In this case, the risk is that the registry is not set up in accordance with the specificity of the real estate, as well as present and future management needs, and that vice versa it fundamentally conditioned by the contractor's *modus operandi*. This last possibility determines, at the end of the period of services delivery taken over by a new contractor, the risk of not being able to fully use all the collected information, or even worse, having to review the setting of the building registry.

In all the described cases, it must be clear the importance of establishing a building registry, which must have within its structure adequate levels of flexibility in order to grow gradually. Such a building registry should remain valid over time and belong to the building property. This means that the owner will transfer the knowledge base to service suppliers, who will change over time, in order to learn about characteristics of the managed assets and, at the same time, expanding and updating the registry.

3.7 The Role of the Building Registry from the Design Phase

The building registry may play an important role in the improvement of the whole building process. Design deliverables (i.e. drawings, specifications, cost estimates, bill of quantities, etc.) can be issued according to a scheme for the identification of spatial and technical elements that is also valid for the operational phase. This scheme may directly represent the starting point for the construction of the basic knowledge for maintenance services.

Given these considerations, it is possible to identify two possible strategies, both underlining, in terms of information, the uniqueness of the building process and its outcomes.

1. Design documents, consisting of drawings and technical reports, are arranged keeping in mind cognitive needs related to maintenance processes. This is an important condition to start management processes since:
   - it allows, during the activities of design verification and validation, to carry out a set of compliance controls about maintenance and management requirements that should be made explicit within the brief document issued by the client;
   - it represents, appropriately updated and possibly supplemented at the end of the construction stage, an important and unambiguous basis to identify risks for health and safety of the operators who will carry out maintenance activities; at the same time it represents a source of unambiguous and continuously updated information;
   - it is the baseline according to documents needed for management (i.e. maintenance plan, emergency management plan for the safety or the environment, records of checks for firefighting, operating manuals, etc.) should be drawn;
   - it is the basic information that the operator assumes at the beginning of the building life cycle. It is important to emphasize that this basic information should be developed during the design and construction phases. In fact, in these phases, designers and operators involved in the construction process can integrate (in a coherent and comprehensive way) the design deliverables (drawings and technical documentation) with information useful for operations and maintenance activities. It is much more difficult and uncertain to find the same information at the end of the construction process and, moreover, consistency with already processed documents is not guaranteed.
2. The development of a unique building registry during the entire building process. This involves the setting, at the design stage, of a classification and coding system for space and technical elements according to assets, documents and information to be classified.

To develop a registry with these features it is necessary that all the actors involved in the design, construction and operation phases define together an adequate way to break down and classify the building, as well as assign a correct coding system to its components.

This means that, once the classification and coding system has been assumed, all the design deliverables (i.e. drawings at different scales, bill of quantities, special conditions, technical reports, etc.) shall contain spaces and technical elements uniquely identified and coded. This procedure allows:

– to perform checks for comprehensiveness and consistency about the contents of the design documents;
– to organize, from the beginning of the process, an archive of documents with appropriate categorizations and possibly to trace the reference to the parts of the building that are concerned;
– to start data collection about building space and technical elements from the first stages of the process;
– to set up a series of standardized documents (i.e. maintenance manual and plan, safety plan, building data book, etc.) that are consistent one to each other;
– to manage, during the construction stage, the update of the design documents with the production of as-built drawings and documents;
– to control the cataloguing and referencing of external documents (i.e. suppliers documentation, technical reports, inspection reports, tests, etc.).

The information traceability obtained through these strategies[32] allow to build, since the first stages of the process and almost in an automatic way, a first base registry that can be directly acquired by the operator and then updated over time.

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Chapter 4
Information Systems for the Information Management

Abstract The aim of the chapter is to highlight the main functions and specific requirements that should characterize an information system for real estate management. Given the consideration that the common practice is still late in maturing a full awareness of the close relationship existing between the specificity of the context (organizational model of FM services, characteristics of the real estate, client's requirements) and the structure and modes of use of the information system, the aim of the chapter is to propose some key concepts useful for the development of technical specifications within the service tender documents. By acquiring and developing the guidelines proposed by some standards, the chapter deals with some connected subjects: relation between the information system, the inventory and the building registry; modalities of use of data processed in the information system, in relation to the various activities constituting the FM service (aggregate data and single data); structure of the database, constituting the core of the information system (registries and archives); modular structure of the information system; key functions of an information system in relation to the supply of a FM service (building registry; monitoring; collection and processing of feedback information); role and functions of an information system in the services of maintenance management.

Keywords Information system · Data processing · Information tools · Work orders

4.1 The Diffusion of Information Systems

The process of collecting and organizing information, developed through the inventory activities and the construction of the building registry, finds its completion in the implementation of an information system (Fig. 4.1).

Information systems for real estate management—after several years of an almost complete indifference—are now becoming fundamental tools for the

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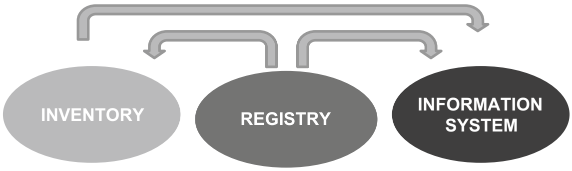


Fig. 4.1 From the inventory to the information system

organization, implementation and monitoring of facility management services. Several factors are at the basis of this acceleration.

A first factor is surely due to the fact that until few years ago, before the spread of Facility Management services, systematic ways of organizing knowledge were essentially absent in the practices of traditional managers of real estate assets. Data relating to technical characteristics of building elements and installations, operating status of assets, works executed or even only to consistency, were extremely incomplete and fragmented, if not completely absent, in both small and large real estate.

A second leverage factor for the spread of information systems is certainly due to the rapid and considerable growth of various forms of contracting the building management services [1, 2], from different models of multi-service agreement to forms of highly integrated FM services (Fig. 1.3). All these forms of contracting are anyway united by an overriding need for having available adequate information frameworks [3] shared both by clients and service suppliers [4], in order to work for the setting, planning and control of management activities [5].

A third factor of growth for information systems—but others may still be mentioned—is finally attributable to the spread of the culture and practice of planned maintenance [6], which, by its nature, has the need of reliable basis of knowledge to enable the development of proactive strategies and the rationalization of operations over time [7, 8].

It may be stated that today the various parties involved in the use of information systems for real estate management are sharing basic logics and common references. Such references could be summarized and linked to specific requirements that should characterize an information system for real estate management,[1] namely:

- ability to perform a breakdown of the real estate assets into individual components (spaces and technical elements). This breakdown must be achieved through a hierarchical process of splitting up the building into more and more detailed levels;

[1]See the Italian standards: UNI 10951:2001, "Systems of information for the maintenance management of buildings. Guidelines" and UNI 10584:1997, "Maintenance Systems of information of maintenance".

- ability to define elementary tasks, identifying for each of them the necessary resources, in terms of labour, materials, equipment and related costs;
- ability to manage and relate different forms of information (i.e. drawings, data in alphanumeric form, scanned documents, tables, charts, etc.);
- ability to regroup information in relation to various reading keys;
- ability to ensure feedback information in order to build historical series and statistics, necessary for the analysis of results (i.e. reliability analysis, failure modes, intervention time and costs, etc.);
- possibility to develop a database in a way that it is appropriate to the specific operational context by collecting and organizing only the necessary and sufficient data (by type and quantity) for appropriately describing the asset and its operating status. The definition of the information level to be reached is important because of the risk—normally involved in the set up of an information system—to accumulate, with a very high cost, large amounts of unuseful data. Therefore, it is necessary to distinguish limits and benefits resulting from type and quantity of data to be collected by identifying the most appropriate level of detail for the specific case (Chap. 3);
- the adequacy of the system to the methods of transmission and dissemination of information within the managerial structures.

These requirements should be valid in the same way for both the two main alternative strategies that can be implemented for developing an information system:

- the first one is the case of an information system specifically developed for a single user, in relation to the specificity of the context of use. This situation concerns basically two different types of user. On one hand, small management companies/clients that, due to the limited size of assets and resources that can be used, have few needs and thus they may choose for the most widespread platforms available on the market (for acquisition and operational costs). Therefore, the choice is to move towards the development of information systems focusing only on few simple functions. These systems are usually focused on the function of building registry management. On the other hand, there are large structures (both owners and integrated service providers) that, due to the size and/or specific nature of assets and investment capability, prefer to develop *ad hoc* systems, strictly adhering both to their organizational model and management procedures;
- the second one is the case of an information system purchased on the market. Currently, the market is characterized by a limited number of products, rather consolidated and suitable, constantly evolving and generally equipped with a plurality of functions. Therefore, they can be adopted, customized and integrated within a large variety of management situations.

4.2 Information System as a Decisional and Operational Support

An extremely useful and shared reference for setting up the logical structure of an information system is certainly the Italian standard UNI 10951:2001, "Information systems for maintenance management of real estate assets. Guidelines" (Table 3.17). The standard has the goal to compare experiences and tests developed in the construction industry with specific standards and more mature experiences coming from the industrial sector. The aim is to provide business operators with guiding criteria, guidelines and basic principles to define requirements of information systems adapted to the specificity of the building management and to orient clients and service suppliers' behaviours.

This standard has been often mentioned in technical specifications of services as a reference for tender documents. This fact demonstrates that, in the Italian context, the standard has probably contributed greatly to the spread first, and then to the consolidation, of a general and shared vision of information systems. This shared vision is confirmed by the fact that today the majority of the most significant information systems, both those ones developed within specific management cases and those ones dedicated to the commercialization and subsequent implementation, are referable to some features and operating modes as defined by the standard (Table 4.1).

First of all, it should be considered that the standard UNI 10951:2001 defines the information system as a "decisional and operational support tool, consisting of databases, procedures and functions to collect, store, process, use and update the information necessary for the setting, the implementation and management of the maintenance service".

The definition does not only list all the characteristic activities of an information system, but it also contains a number of keywords referring to some key concepts, namely:

- decisional and operational support;
- databases;
- functions.

The concepts related to the key words "decisional and operational support" are very important.

The reference to the two "extremes" of management activities (decisions and operations) emphasizes a fundamental characteristic of information systems: they should be a support tool for all the different operators involved in the context of a service [10].

Specifically, the emphasis on decision-making and operational roles indicates that the same information set included within an information system (the data base) must be able, through the activation of different functions and procedures, to provide two different categories of data, as the result of different processing modes: aggregated data and single data.

Table 4.1 Main functions of an information system [19]

Functions	Activities
Management of archive and registries	Gathering, storage, connection, extraction and control of basic and feedback data
Resource planning and drafting of the maintenance plan	Preparation and management of the maintenance programme and calendars of works
Statistical processing	Statistical analysis related to: performances and failures of technical elements and subsystems, logistics of the interventions, costs
Probabilistic evaluations	Construction, starting from the statistical data, of: forecasts of the behaviour over time of the elements and systems through indices of reliability, maintainability, durability, availability, cost, efficiency of logistics, risk, etc.
Management of the procedures for: inspections/monitoring, progress monitoring, quality control	On-going verification of the performances of technical elements and systems and the trend of maintenance activities compared to the programming, cost estimates and requests for intervention
Financial management of the contracts, expense reports	Programming, management and economic and financial control through: management of budget and management control, supplier management, budget analysis
Management of work orders, contracts and warehouse stock	Contract management for the supply of products, works and services; issuing of work orders
Interaction with other systems	Finding, connecting, checking the data processed by other systems (i.e. tenancy management, general accounting, remote databases, etc.) and provision of information for processing performed by other systems
Communication management	Acquisition, recording, storage, management and control of reports and requests for intervention; generation and management of information through multiple channels
Production of documents	Production on different media (i.e. paper, electronic, etc.) and in different forms (i.e. sheets, tables, graphs, etc.), of documents relevant to the presentation and reading of the information
Generation and updating of manuals	Generation, update and distribution of user manuals, technical operation manuals and maintenance manuals

- Aggregated data

Aggregated data can be interpretated as a plurality of data, selected on the basis of searching keys, and then processed. In the management process, different types of decision makers define strategies and action lines also by reading and interpretating summary data, which enable trend analyses, comparison between phenomena and situations, monitoring through indexes, etc.

In this sense, there is a large number of possible situations.

For example, in decisions about financial strategies, the measure of profitability per unit area of a certain amount of real estate assets—characterized by being composed of buildings similar for age and conditions—can lead, once an assumed threshold (benchmark) has been exceeded, to start disposal actions, value improvements or even renegotiations of rent.

The analysis of aggregated data is also essential for typical strategies of space management and space planning, where it is often used for reading the aggregate amount of homogeneous spaces by functions and types of users. In this case, for example, the reading of indexes of space occupancy in a commercial building may lead to start redesign projects of spaces.

Considering a different context, in the case of taking decisions about energy strategies, it is essential a correct consumption monitoring. This kind of monitoring is especially useful when carried out through performance indicators such as, for instance, energy consumption per unit of volume related to functions accommodated in buildings, typologies or portions of the building sharing the same construction techniques.

Furthermore, in planning maintenance for medium and long term periods, a great advantage comes from data processing which, through the collection of information from inspections and operations, allows the development of time series useful both to describe, in probabilistic terms, the behaviour over time of technically homogeneous elements and to determine maintenance cost indexes (Table 1.8). An example may be the processing in order to know the size, within a building stock, of a given family of technical elements (i.e. wood frames, aged between 15 and 20 years, which have never undergone maintenance work). Combining quantitative data with maintenance cost indexes and some databases concerning frequency and methods of intervention, it is possible to develop two different actions. First, it is possible to get a set of approximate technical and economic forecasting about the maximum residual service life, useful for deciding about rehabilitation and repair activities to be performed in the following years. Secondly, it is possible to define overall maintenance strategies by making comparisons with other categories of aggregated objects that need interventions.

In summary, with reference to the reading of aggregate data, it is possible to identify, in the management practice, some common and recurring requirements to which an information system is expected to give answers both in terms of data processing and standardized reporting. These requirements are related to:

– knowledge of all the real estate in terms of surfaces and rooms. This reading clearly represents the highest level of aggregation which must always be available to the property manager since it is the basis according to it is possible

to carry out more sophisticated readings about quantitative and qualitative characteristics of all the real estate;
- description of the building stock in relation to the different intended uses. For this type of analysis it can be useful to get some statistical processing about the areas and their different uses for person, business unit or tenant;
- description of the building stock in relation to its technical and typological features. Readings of quantitative data with regard to age or building construction techniques can be important reference bases. These bases may be combined with assessments, for instance about the service life, characteristics of the interventions in relation to the age of the buildings age and the maintenance costs. These assessments can support the definition of financial requirements for the management of the building and the decisions about the maintenance strategies to be undertaken;
- analysis through indicators (Chap. 1). This activity is extremely useful since it allows the decision maker to have synthetic views about a plurality of issues regarding the managed assets and to quickly identify critical areas and magnitude of the problems.

Within the processing of aggregated data, the issue of managing indicators deserves attention.[2]

As already stated (Chap. 1), a system of indicators (KPIs—Key Performance Indicators) may be used in order to [9]:

- measure the state of an item or process;
- compare performance and/or services levels (i.e. develop internal or external benchmarking processes);
- perform diagnosis;
- define objectives and targets;
- plan improvement actions;
- perform continuous monitoring.

Indicators can be used in different time dimensions:

- continuously, in the monitoring activities;
- periodically, for instance in performance assessments;
- only once (*una tantum*), for instance within an audit or specific studies or in benchmarking activities.

Within an information system, the management of a system of indicators can be successfully carried out through the implementation of a *tableau de bord*. By *tableau de bord* it can be meant a set of indicators, possibly linked together through a series of cause-effect relationships.

The *tableau de bord* is an application that, even through means of immediate interpretation such as bar graphs or pie charts, can provide different organizational levels of support information for process monitoring and achievement of company

[2]See the standard EN 15341:2007, "Maintenance—Maintenance Key Performance Indicators".

objectives. The *tableau de bord* operates by selecting and processing, according to defined procedures, information included in the database and it can be used in various ways by the different decision-making levels, depending on the position occupied in the hierarchy. At the highest levels (strategic decision makers), control is achieved through synthetic measures and is generally based on overall economic and financial indicators. Vice versa, at lower levels (technical decision makers), economic and financial measurements are not so important and thus the *tableau de bord* provides more usefully other indicators (i.e. concerning process, market, technical issues, etc.). Indicators may provide an overall view of general functioning (i.e. annual profitability of managed assets) or they may concern only individual aspects (i.e. average annual energy costs per unit area). The *tableau de bord* has various functions, such as:

- to support the various decision-making levels;
- to create a common information base useful for setting up a dialogue between managers at different levels;
- to empower managers for the achievement of specific objectives;
- to define the basis according to the reporting system has to be built.

- Single data

As already stated, information systems must be able to provide not only aggregated but also single data.

Single data are individual data that are selected, isolated and extracted according to specific search keywords. This reading level allows an accurate consultation of information and it can provide data for the creation of various documents, reports, programmes of the activities and operating procedures. For instance, the specific information relating to location, configuration and manufacturer of a component part, once extracted, can be used for compiling work orders, operations data sheets and schedules of activities. In the same way, it must be possible to extract information, from archived drawings (plans, sections, elevations), in a graphical form which is useful, for instance, to locate a specific building area in which the operating team must work.

In summary, it can be said that an information system should allow to retrieve any stored data in a simple and rapid way.

The methods of searching, extracting and using data may be various, depending on several management practices; for example, it should be possible to:

- obtain all available information, or only some specific one, about any object stored in the database; for instance to know, with respect to a specific room, user, size, frequency and cost of maintenance operations performed in a given time frame;
- select objects according to various searching criteria: for instance to obtain the list and the location of all the spaces in a building that are available for the same user or all the spaces, within a building stock, that have a same function;

- connect alphanumerical and graphical information, for instance, to obtain drawings (floor plans) from the selection of an object or vice versa to get the selection of an object, and the information related to it, from a plan concerning it or containing it;
- extract information in both graphical and alphanumerical form for the preparation of different documents, such as work orders, operating instructions, synthetic building files;
- select and connect different forms of graphical representation (drawings, pictures, videos) of a same object.

4.3 The Core of the Information System: the Database

The definition of information system, given by the standard UNI 10951:2001, highlights the fact that the core of an information system is the database.

In most cases, the database [11] of an information system is made by a set of tables, integrated and connectable, which allow to manage data relating to different areas of the management service. These tables represent different informative themes (i.e. localization and identification information, administrative information, functional and consistency information, etc.) and information is organized in rows and columns. Columns (fields) define the informative category (i.e. building name, space code, net surface of a room, etc.). Rows (records) contain information about individual objects (i.e. about a specific building, room, equipment, etc.).

From a logical point of view, the database, according to the indications proposed by the standard, must be considered as articulated in registry and archives (Fig. 4.2) that are two areas of information collection characterized by different tasks.

The building registry (Chap. 3), according to a hierarchical breakdown structure, contains and makes available data concerning space and technical elements, which constitute the building, in relation to their identity, location, features, consistency, configuration and technical characteristics. The main function of the building registry, within an information system, is to collect and make available only those data which are necessary to describe identity of the building or built asset.

The registry represents a database, permanently linked to the buildings and constantly growing through the implementation of feedback information coming from management activities. The standard defines four interconnected registry levels (Fig. 4.3):

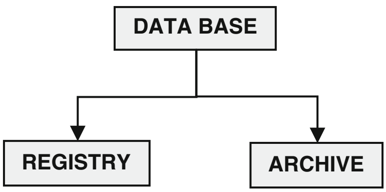


Fig. 4.2 The basic structure of the database

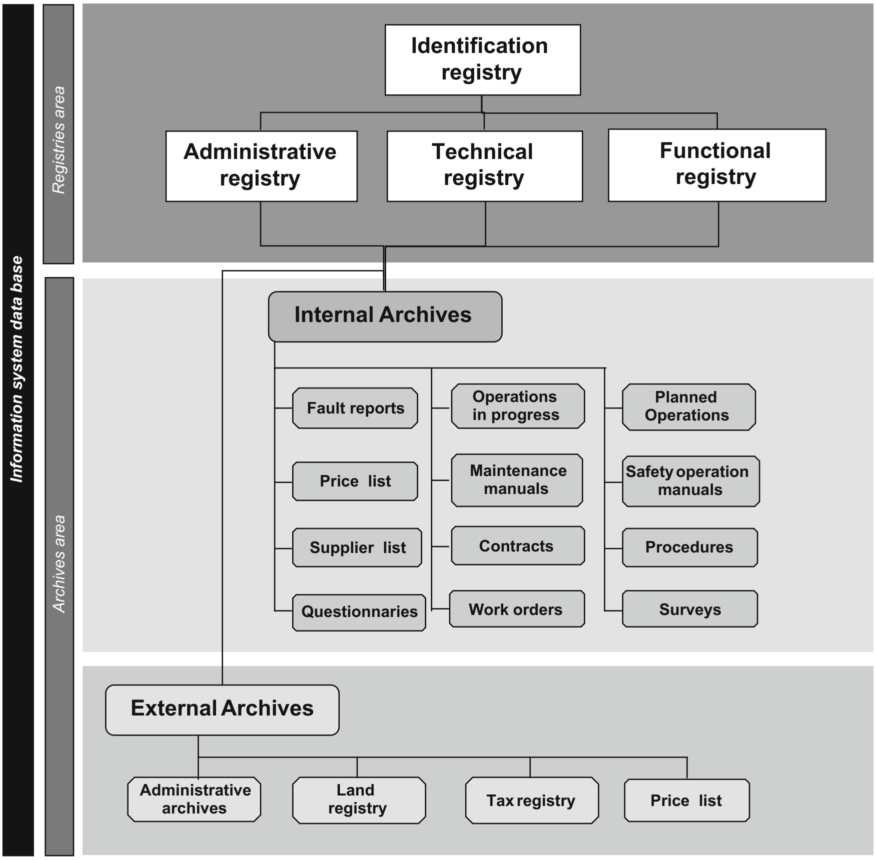


Fig. 4.3 Structure of the data base in an information system

- the identification registry, which collects and organizes basic data related, for instance, to nominal identification, location coordinates, state of consistency of the assets (i.e. net and gross surfaces, volumes, etc.);
- the functional registry, which collects and organizes data related, for instance, to intended uses, users of spaces, rights of use, ways of use, user's requirements, reference standards, etc.;
- the technical registry, which collects data about technical characteristics of building systems and plants (i.e. technical and commercial identification, physical characteristics, functions, expected requirements, metrics and reference values, performance indicators, description of installation or construction method, etc.);
- the administrative registry, which collects data about rentals and purchase contracts, contracts for the supply of products, works and services related to the building, legal status of the buildings, obligations and constraints.

On the other hand, archives can be considered as data containers collecting various types of information from multiple sources and they can be used for different purposes. Archives can include:

– accurate information extracted from various types of documents, as, for instance, information about frequencies and intervention methods derived from databases, fault reports from call centres, operations in progress or planned;
– full documents such as contracts, complete maintenance manuals or parts of them, price lists, supplier lists, intervention procedures, safety operation manuals, etc.;
– information coming from external archives such as: administrative information systems, accounting, land register, tax register, price lists, etc.

To clarify the relationship between registries and archives, it can be considered an example concerning the processing of information about a possible environmental assessment, including the measurement of temperature and humidity conditions within the various building spaces (Fig. 4.4). The archive can contain, and refer to the codes of the specific rooms, all the data related to the survey (i.e. air temperatures and mean radiant temperatures measured at different observation points, as well as procedures for implementing the survey, running conditions, etc.).

It means storing all the information useful to keep records of the survey and support actions, such as comparative quality assessment of space in connection with identification of places in which corrective actions should be implemented. In the

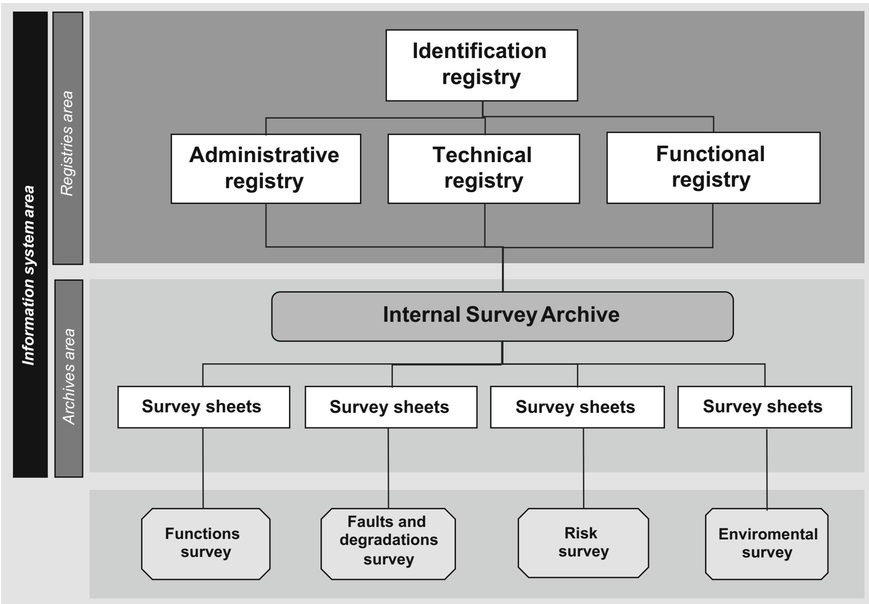


Fig. 4.4 Example of relationship between registries and archives

registry building, spaces (rooms) are stored, coded and monitored through the survey, which records for each of them, data about location, surface and intended use. Through the key of a room code, it is possible to associate to a specific space (or group of spaces associated, for instance, since they have a similar destination) information collected in the registry regarding, for instance, room dimensions and information, collected in the archive, related to the survey. This association allows multiple elaborations, as, for instance, the calculation of the total floor area of spaces in the building characterized by thermo-hygrometric conditions that are below predetermined thresholds.

As regards treatment and characteristics of data contained in the registry and archives, two further clarifications should be made.

The first clarification regards the modular structure of information systems. In general, information systems for real estate management are platforms structured according to an architecture organized in a database and a set of specialized modules (Fig. 4.9), generally related to the different application areas of Facility Management (Table 1.3). Information contained in the database can be extracted and processed in the different specialized modules integrated within the information system. The modules can be activated in various ways and according to the specific needs related to the FM service. In the same way, information can be extracted and transferred for further processing to external processing environments (i.e. spreadsheets, specialized programs, other information systems).

The second clarification regards the coexistence of information in alphanumeric and graphical form. In many information systems, available on the market, it is possible, according to different methods, to connect CAD (Computer Aided Design) drawings and alphanumeric data concerning the building. This feature allows to manage information both in alphanumeric and graphics form through the connection of a record, contained in the tables of the database, to a drawing element (i.e. floor plan, specific space, single component, etc.). This is possible because floor plans, drawing of specific objects contained in the rooms (i.e. building components, furnishing elements, etc.), can be associated to every information level of the hierarchy representing the breakdown of the buildings and their parts. Therefore, it is possible to carry out some fundamental activities in the building management, such as:

- obtaining graphic printouts from queries on data tables (i.e. selecting all the rooms occupied by a specific department within an organization or with the same intended use or characterized by a too high space occupancy index or internal comfort conditions below predetermined parameters, etc.);
- obtaining various information from the drawings (i.e. gross and net floor area, number of reported faults, etc.);
- obtaining thematic plans in which, for instance, different uses, user's categories, types of space (i.e. space that can be equipped, service space, horizontal circulation, etc.) are distinguished, for example, with diverse colours. Then, these thematic plans can be associated to the automatic calculation of surfaces.

4.4 Key Functions of the Information Systems

Information systems should ensure a variety of functions in relation to building management and planning and operation of maintenance activities (Fig. 4.5).

Although the complex framework of these functions (Fig. 4.5), it is possible to recognize three main key functions characterizing an information system:

– the building registry;
– the monitoring;
– the collection and processing of feedback information.

• The building registry function

The building registry function is basic and fundamental. The basic need for knowing, whatever the level of detail may be, the characteristics of the real estate is fulfilled by the presence of a registry function (Chap. 3), whose objective is the collection, storage and immediate retrieval of all information necessary to unambiguously describe the identity of the buildings (Table 3.2).

The building registry function concerns the information storage about both the quantitative, functional and localization aspects of the buildings, and the basic information describing technical configurations of the different parts of the building.

The data contained in the register, once extracted, can be used for the two levels previously described, namely the level of aggregated data and the level of single data (this chapter).

Besides the basic collection and organization of data about localization and descriptive characteristics of the buildings, the registry function can be extended—with coding criteria similar to those ones described for the building registry (Chap. 3)—to other categories of data, such as data related to contract or companies providing goods and services, whether they are individuals or organizations.

In technical and administrative management, it is important to be able to link together different categories of data (i.e. specific service providers with their identity and contract data to the spaces they manage). Similarly, in space management, it is important to match data about specific areas (i.e. location, size, level of equipment, etc.) with those ones related to the staff hosted in the corresponding areas (i.e. identification data, department membership, qualifications, equipments, etc.).

• The monitoring function

The monitoring function represents the second basic key function. In fact, an information system should provide a constantly updated vision of different situations concerning the real estate: i.e. the state of consistency, the operating status of the building components and plants, the status of regulatory compliance, the progress of the planned management activities, the invoicing of the executed maintenance activities, the situation of the assets to be leased, etc. Therefore, an

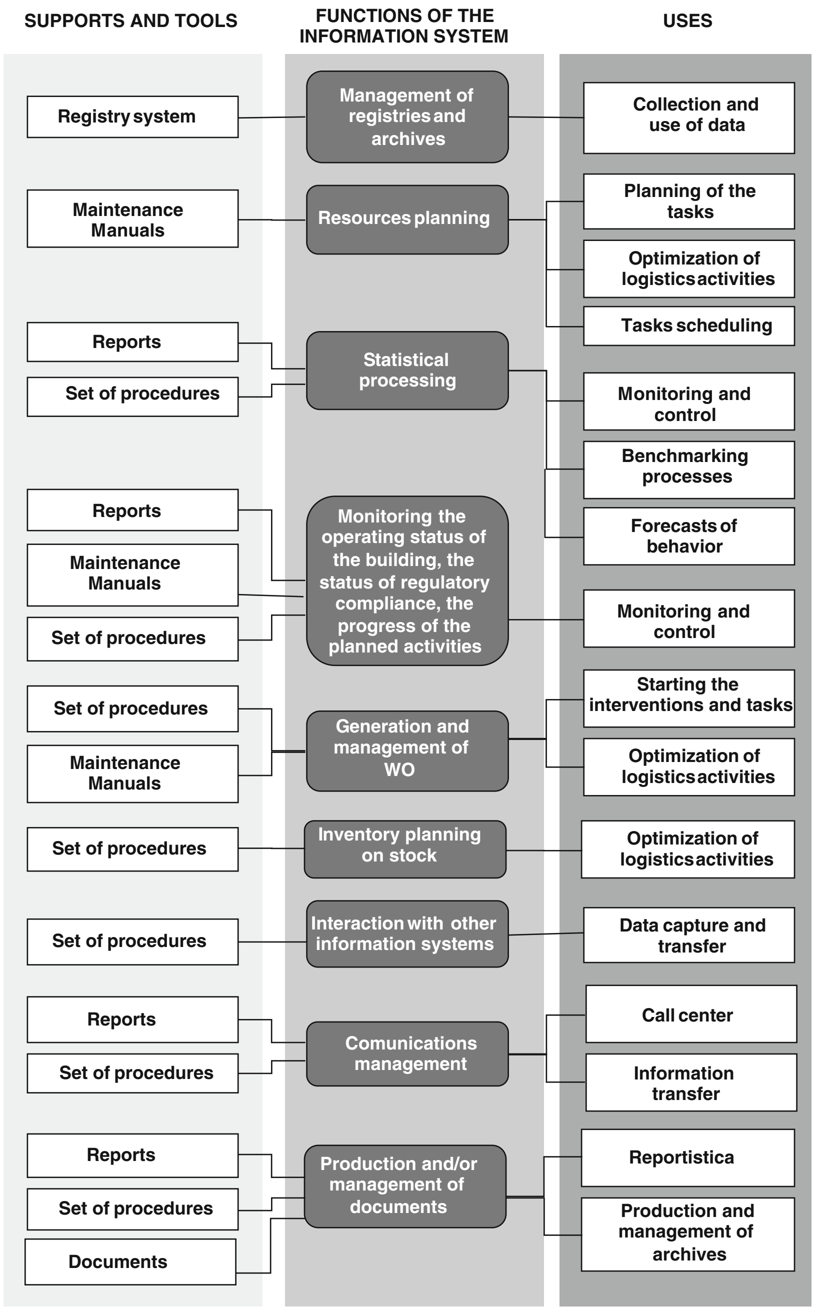


Fig. 4.5 Framework of the main functions of an information system

information system should manage the information flow in relation to at least two primary categories of knowledge.

The first category is the state of consistency. It is the knowledge concerning quantities of the real estate in terms of surfaces, volumes, numbers of technical elements and equipments. In particular, the analysis of the spaces should be carried out in relation to various categories of areas, such the ones (Table 4.2) proposed by the standard EN 15221-6:2011, "Facility Management—Part 6: Area and Space Measurement in Facility Management".

Monitoring the state of consistency should be considered as a sort of supervision, that presupposes the existence of appropriate procedures, since information and documents must be constantly updated according to standardized protocols and any change concerning the buildings should be immediately transmitted and received by the information system.

Table 4.2 Hierarchy of floor areas [21]

<table>
<tr><td colspan="6">Non-functional level area (NLA)</td><td rowspan="12">Level area (LA)</td></tr>
<tr><td colspan="5">Exterior construction area (ECA)</td><td rowspan="11">Gross floor area (GFA)</td></tr>
<tr><td colspan="4">Interior construction area (ICA)</td><td rowspan="10">Internal floor area (IFA)</td></tr>
<tr><td colspan="3">Partition wall area (PWA)</td><td rowspan="9">Net floor area (NFA)</td></tr>
<tr><td>Unrestricted technical area (UTA)</td><td rowspan="2">Technical area (TA)</td><td rowspan="8">NET room area (NRA)</td></tr>
<tr><td>Restricted technical area (RTA)</td></tr>
<tr><td>Unrestricted circulation area (UCA)</td><td rowspan="2">Circulation area (CA)</td></tr>
<tr><td>Restricted circulation area (RCA)</td></tr>
<tr><td>Unrestricted amenity area (UAA)</td><td rowspan="2">Amenity area (AA)</td></tr>
<tr><td>Restricted amenity area (RAA)</td></tr>
<tr><td>Unrestricted primary area (UPA)</td><td rowspan="2">Primary area (PA)</td></tr>
<tr><td>Restricted primary area (RPA)</td></tr>
</table>

The second category concerns the monitoring of the state of the operations. It is important that an information system is able to receive, store, process and return data coming from all those investigations, inspection and controls that aim at constantly checking conditions and compliance degree of the buildings in relation to assumed quality levels.

- The collection and processing of feedback information

Finally, the third key function of an information system concerns the possibility of a progressive growth of knowledge throughout the lifecycle of assets by continuously collecting feedback information from maintenance activities.

If we consider the scope of maintenance management, the "historicizing" function allows to increase over time a forecasting ability about three main aspects.

The first aspect concerns the behaviour over time of materials and components. The collection, chronologically ordered, of information about features, location and frequency of anomalies, degradations, failures and pathologies observed in the building, allows to obtain all the data necessary for a gradual improvement of knowledge about behaviour of the building components and plants [12, 13]. For the most critical elements, these data may allow to develop forecasts of the behaviours, based on statistical processing. Such processes may allow to estimate failure rate, reliability and durability of building systems and plants.

The second aspect concerns operational activities. The collection of data relating to operational and organizational aspects—such as execution modes, means of work, materials, human resources, competencies, time spent on a task activity—allows to define an operational planning of the activities thanks to a gradually growing and consolidated knowledge base. Such knowledge can support some activities, for instance: monitoring the efficiency of operating procedures; identifying resource needs; setting inventory planning on the real estate; task scheduling, etc.

The third aspect concerns the costs of actions. Collecting data about costs [14] of the performed actions allows, over time, to gradually increase the ability to forecast maintenance costs on medium-long time scales, in relation to different strategies [15, 16]. The more detailed is the detection of the cost components (i.e. labour, materials, equipment, etc.), the more sophisticated are the investigations that can be carried out to assess the impacts of expenditures and their evolution over time in relation to different aspects (i.e. organizational models, age of buildings, types of contract, etc.). In any case the most significant aspect for the development of programming policies is the ability of aggregating and statistically processing data about costs in order to define tools such as profiles of maintenance costs, maintenance cost indexes, etc. [17].

4.5 Information Systems and Maintenance Management Process

With specific reference to the scope of technical management services, it should be underlined that planned maintenance requires information supports for its implementation. These supports can be identified in the maintenance manual and information system (Fig. 4.6) and they are developed to collect different types of building information.

As stated by the standard UNI 11257:2007—"Maintenance of buildings. Criteria for the drafting of plan and programme of maintenance of buildings. Guidelines", (Table 3.17), maintenance manual and information system have to be considered essential elements for the development and implementation of a maintenance plan, since:

- when drafting a maintenance plan, information tools gather information (i.e. descriptions, localization, administrative, technical, and operational information, etc.) related to the building and its parts. This information represents the knowledge base needed to define strategies, organize the maintenance service and define the operational planning of the tasks to be carried out over time;
- during the implementation of the activities planned in the maintenance plan, there must be a continuous and progressive collection of feedback information (Fig. 4.6), which must be collected in the information system and thus increasing knowledge included in the manuals. This collection is an essential condition for a gradual improvement of knowledge about behaviour over time of technical elements, reliability of the forecasts, effectiveness and efficiency of maintenance.

Furthermore, during the development of a maintenance process, it is also important the continuous monitoring of the state of implementation of the planned activities. In fact, during the implementation phase, based on the results of monitoring and contents of feedback information, the maintenance plan and programme

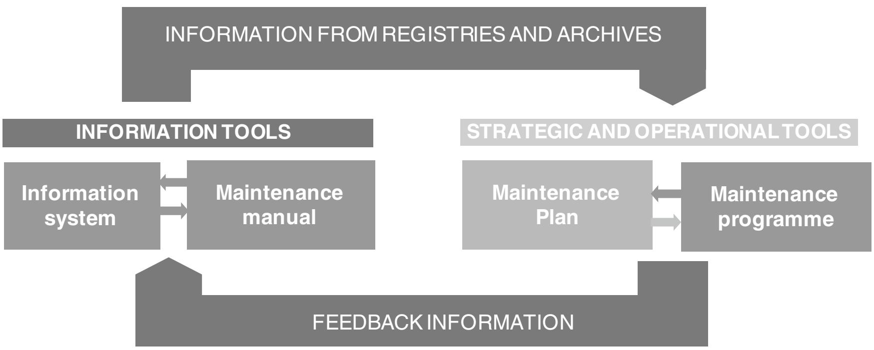


Fig. 4.6 Information tools for maintenance services

should be able to be subjected to revisions and updates. Therefore, it is evident the importance of implementing procedures for collecting feedback information concerning performed operations, both the planned and unplanned ones.

About the relationship between maintenance manuals and information system, some clarifications should be made.

First of all, the standard UNI 10874:2000, "Maintenance of buildings Criteria in order to write maintenance and use manuals" (Table 3.16) defines maintenance manuals for maintenance technicians, as a comprehensive and systematic information collection concerning the building and related to three main characteristics: first, information that identifies and describes the different technical elements constituting the building; secondly, information concerning all the methods of maintenance, inspection and checking that are necessary to maintain those elements under operating conditions; thirdly, feedback information concerning the various types of performed activities (inspections, monitoring, corrective actions due to failures, planned scheduled activities, replacements).

In this logic, an information system should be the collector of information gathered in the maintenance manuals for the different buildings of the real estate that are managed. In fact, talking about maintenance management within a service approach, the presence of an information system is a condition which is almost unavoidable. The absence of an information system is an event that should exist only when management activities are applied at one or few buildings characterized by low levels of technical complexity.

In presence of an information system, which manages the knowledge base of real estate assets, some situations are possible:

- maintenance manuals relating to different buildings and their parts can be considered as part of the information system. Therefore, all the information regarding the managed buildings is resident within the information system, where it is collected, updated and processed. In this case, the manuals for each building are derived from a selection of various categories of information resident in the information system;
- the maintenance manual is a stand-alone document for collecting information about each building and it exchanges information with the information system. The manual sends to the information system only some information, for instance useful for the general inventory of real estate or for statistical processing. At the same time, it receives from the information system some data coming from processing (i.e. failure rate of a particular category of technical elements, average maintenance cost index linked to a certain type of intervention or class of technical elements, etc.).

In both cases, it is clear that between the instruments of maintenance planning and scheduling (maintenance plan and maintenance programme) and the information tools (maintenance manuals and information systems) there must be an interactive relationship. Information flows can cover different aspects:

- technical (i.e. number and types of most frequent faults, conditions detected during inspections or interventions on request, etc.);
- organizational (i.e. intervention times, times of non-availability, operational and overall durations of interventions, etc.) (Table 1.8);
- operational (i.e. competences involved in carrying out activities, etc.);
- economical (i.e. actual costs of maintenance).

The considerations, arising from the analysis of feedback information during the phase of plan implementation, can lead to a revision of the maintenance programme, searching for an operational optimization, or to a revision of the intervention strategies and frequencies.

The goal of this process is the constant management of the information flow and the review of the forecasts in order to continuously improve the overall maintenance management process towards a progressive reduction of faults and organizational optimization of the activities.

It should be added that information systems are fundamental support tools for maintenance plans, not only for the management of information flows but also for operational activities.

In fact, in order to enable an efficient maintenance management in the execution phase of the maintenance plan, an information system must allow two actions:

- managing and optimizing the schedule of planned maintenance activities (Fig. 4.7);
- managing the issuing of work orders[3] (WO) and their subsequent return after fulfilling and processing (Fig. 4.8; Table 4.3).

Regarding the management of the interventions, it should be noted that the provisions contained in the maintenance plan (splitted over a period of years) can be implemented only through the creation of a yearly program.

The programme includes a time schedule, which contains a list of tasks ordered according to a timetable. In each of these tasks included in the timetable, the information system must allow to combine a range of information, some from time schedule, others found in maintenance manuals or other informative sources (i.e. lists of operating procedures, standards and regulations, contract requirements, etc.).

This information collection converges in the work order (WO), which can be considered as an instruction activating maintenance tasks through a document (paper or electronic) or verbal request (Table 4.3).

Therefore, an information system for building management should support the generation and management of work orders.

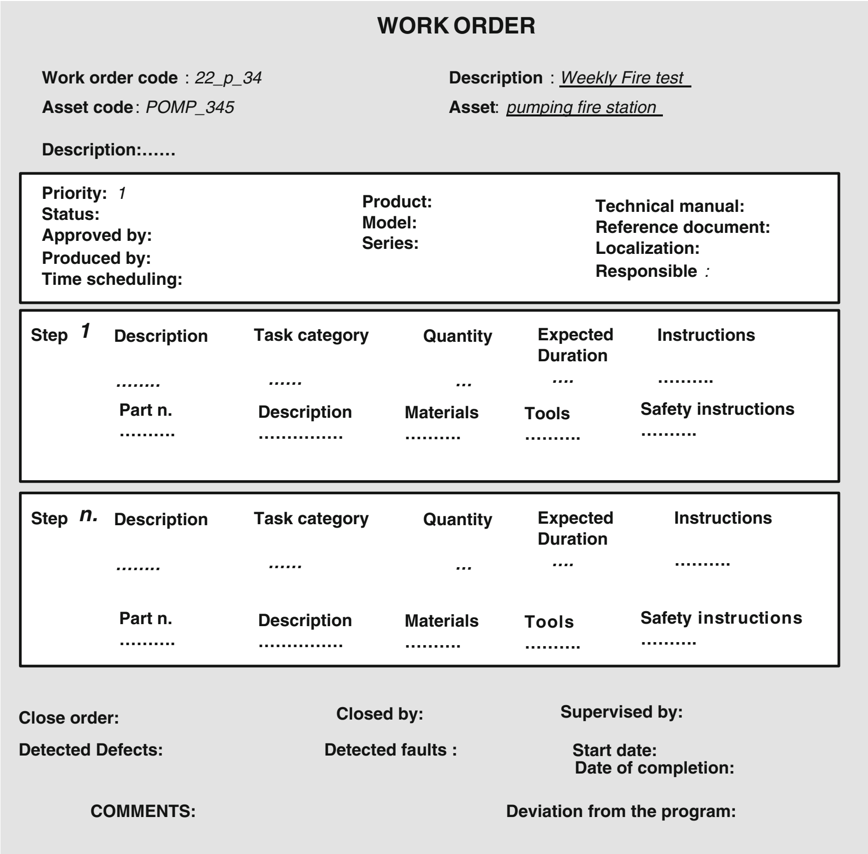
The work order (Table 4.3; Fig. 4.8) is a very important document, since it has different meanings:

- it represents the interface between the forecasting phase of the maintenance tasks and their execution;

[3]See the standard EN 13460:2009, “Maintenance—Documentation for maintenance”.

Element code	Activity code	Intervention	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	N. Int.	Quantity (sqm)	Duration (h\man\sqm)	Cost (€ h)	Total €
3.1.1.11	3.1.1.ISP.1	Visual inspection of the wall (indoor and outdoor)	1												1	84,75	0,01	22	18,64
	3.1.1.ISP.3	Examination of the superficial alterations																	
	3.1.1.PUL.1	Cleaning of the superficial surface of the wall	1		1		1		1		1		1		6	84,75	0,01	12,50	31,78
	year 1	Total																	50,42

Fig. 4.7 Example of a schedule of planned maintenance activities



WORK ORDER

Work order code : *22_p_34* — Description : *Weekly Fire test*
Asset code: *POMP_345* — Asset: *pumping fire station*

Description:......

Priority: *1*
Status:
Approved by:
Produced by:
Time scheduling:

Product:
Model:
Series:

Technical manual:
Reference document:
Localization:
Responsible :

Step *1*	Description	Task category	Quantity	Expected Duration	Instructions
	....	......	...	....	....
	Part n.	Description	Materials	Tools	Safety instructions
	....	....	....	....	....

Step *n.*	Description	Task category	Quantity	Expected Duration	Instructions
	....	......	...	....	....
	Part n.	Description	Materials	Tools	Safety instructions
	....	....	....	....	....

Close order: — Closed by: — Supervised by:
Detected Defects: — Detected faults : — Start date: — Date of completion:

COMMENTS: — Deviation from the program:

Fig. 4.8 Example of a work order (WO)

- it defines the conditions according to operate in accordance with the guidelines developed in the system plan-programme;
- it provides unified and unambiguous information, that makes the activities to be performed consistent with the programme and verifiable in their technical and economic outcomes;
- it allows to trace the whole development process of a maintenance activity.

In particular, it should be noted the central role, in terms of information, of the work order with respect to two purposes:

- to manage operations by sending information to operators in order to start maintenance interventions;
- to manage feedback information coming from maintenance activities by receiving information from the completed maintenance tasks (Fig. 4.6).

Table 4.3 Work order information items [24]

Information	Information description
B.1 Number	Code assigned to a W.O. This code is unique for each W.O.
B.2 Petitioner	Name of the authorized person requesting the maintenance service
B.3 Registration date	Date when the W.O. is issued
B.4 Open date	Date when the W.O. is activated
B.5 Close date	Date when the W.O. is completed. The corresponding work is finished
B.6 Item code	Code assigned to the item within the physical structure of the plant. This code is unique for each piece of equipment
B.7 Item location	Code corresponding to the geographical location of the item within the plant. It is normally attached to or is included in the item code
B.8 Item running hours	Parameter by means of which, the utilization of the item can be recorded. The parameter can be different, such as number of operations, pieces, natural calendar
B.9 Type of maintenance	Code referring to the nature of the maintenance activity (i.e. preventive, electrical, new installation, etc.). Usually, it is linked to the cost structure
B.10 Priority	Code to give information about the necessary precedence among the W.O.s for its activation. Priority has in some cases to do with criticality
B.11 Safety and environmental regulations	Link to the possible safety and environmental requirements to perform the maintenance work, either mandatory or recommendations
B.12 Retention justification	The reason why an open W.O. is not running at the moment. Downtime for each retention should also be included
B.13 Frequency	Time between maintenance services within cyclic operations
B.14 Last operation time	Last date when a particular cyclic maintenance operation was performed
B.15 Resources estimation	Amount of the different resources intended to be used to accomplish the W.O. in a cyclic operation
B.16 Check list	Relation of points to inspect within a cyclic maintenance operation. Normally these should be first line maintenance activities
B.17 Complaint	Reason why a W.O. is issued. Symptom of the failure, normally detected by the user of the item
B.18 Failing part	Malfunctioned component of the item. The repair or substitution of this part in addition to the description of the actuation is the solution of the problem
B.19 Cause of failure	Reason which determined the failure of the part, according to the maintenance technician criteria
B.20 Technical procedure code	Link to the technical documentation which holds the information about the right actuation way. Tools required should be also included in that documentation
B.21 Actuation description	Explanation of the carried out operations

(continued)

Table 4.3 (continued)

Information	Information description
B.22 Labour amount	Working hours spent in carrying out the W.O; the sort of hours: normal, shift, night, extra, etc. should be specified
B.23 Labour type	Personnel category or skills of those who carried out the W.O.
B.24 Personnel	List of all maintenance workers, who participated in carrying out the W.O.
B.25 Spare-parts reference	Code list of all spare-parts used within the W.O.
B.26 Spare-parts amount	Number of each spare-part type used within the W.O.
B.27 External labour	In the case of a contract with an external supplier of service for the W.O., list of all external workers, who participated in carrying out the W.O.
B.28 External spare-parts	In the case of a contract with an external supplier of service for the W.O., code list of all spare-parts used within the W.O.
B.29 Other external services	Services description, in the case of a contract with an external supplier of service for the W.O.
B.30 Acceptance	Maintenance work reception

The information system should generate the WO through the selection of information coming from the maintenance programme and the information developed to support it (i.e. instructions and operating procedures, maintenance manuals, etc.).

The WO should be automatically produced by the information system, according to the expected schedule and then directly transmitted, if necessary through web portals, to operators. The responsible operators, after the fulfilment of the activities carried out in accordance with the instructions contained in the work order, must send to the information system the filled work order through several possible procedures (i.e. via tablet, smartphone and web, completing and returning WO on paper, etc.).

Regarding the management of feedback information, it must be underlined that the WO, besides containing information to be transmitted to operators about when and how to carry out the maintenance activity, should include also a part, to be filled out by executors and/or their supervisors, in which is reported information, important for the control of execution and possible revision of the programme, such as: start date of the activity, duration of the activity, end date of the activity, used resources, unexpected events during execution, etc.

The information set gathered through the completion of the WO, and its subsequent integration and processing by the information system, allows to use feedback information for important goals, such as:

- modification of time schedule in case of deviations;
- revision of operational guidelines;
- revision of expenditure forecasts;
- monitoring of operational teams' skills, organization of activities, efficiency of logistic support, accuracy of the adopted estimates (i.e. durations of interventions, resources, etc.);
- updating of the maintenance manuals.

In summary, it can be stated that processing feedback information within the information system involves a gradual growth of knowledge about behaviour of materials and systems, methods of intervention and costs. Consequently, collecting feedback information is fundamental to the gradual improvement of the forecasting and planning abilities of the organization responsible for the building management.

The WO concerns activities planned in the maintenance plan, but it must be kept in mind that, in building management, it constantly occurs the need to perform non planned interventions due to many causes, such as: occurrence of not foreseen faults, specific user's requirements, outcomes of inspections and monitoring activities carried out according to the programme, etc.

Therefore, an information system must be able to handle even the WO related to unplanned tasks.

4.6 Information Systems Within Management Services

Within FM services an important issue, which still deserves investigation and testing in current practice, is the role of information systems in relation to the so-called "command centre" [18] (Chap. 5). The command centre is the entity, within a service, that oversees a number of organizational activities in relation to: management of building registry and information flows, coordination and optimization of logistics activities both planned and on request, control of the activities, measurement and monitoring of the degree of achievement of the quality levels of the service established through KPIs (Key Performance Indicators) and SLA (Service Level Agreement) (Chap. 1), collection of feedback information.

The command centre can refer to different organizational models (Chap. 5), but, in any case, the presence of an information system is crucial to implement the different functions necessary for steering the service.

An information system represents a fundamental support tool since, due to the presence of different integrated modules (Fig. 4.9) and functions (Fig. 4.4), it allows the development of a large number of management activities.

A typical model of an information system for real estate management may be represented (Fig. 4.9) as a "constellation" of possible modules, mutually independent, which may be present or not, depending on the specific management requirements, and they can be progressively acquired over time in relation to the evolution of the organization (criterion of gradualism). These modules are all fed by the database, according to specific procedures for data extraction and processing.

With reference to typical activities concerning real estate technical management, an information system, considering its modular configuration, offers multiple uses, such as:

- management of the registry data. The information system allows the identification of technical (building and plant parts) and spatial (rooms) components of buildings and the storage of feedback information coming from maintenance activities;

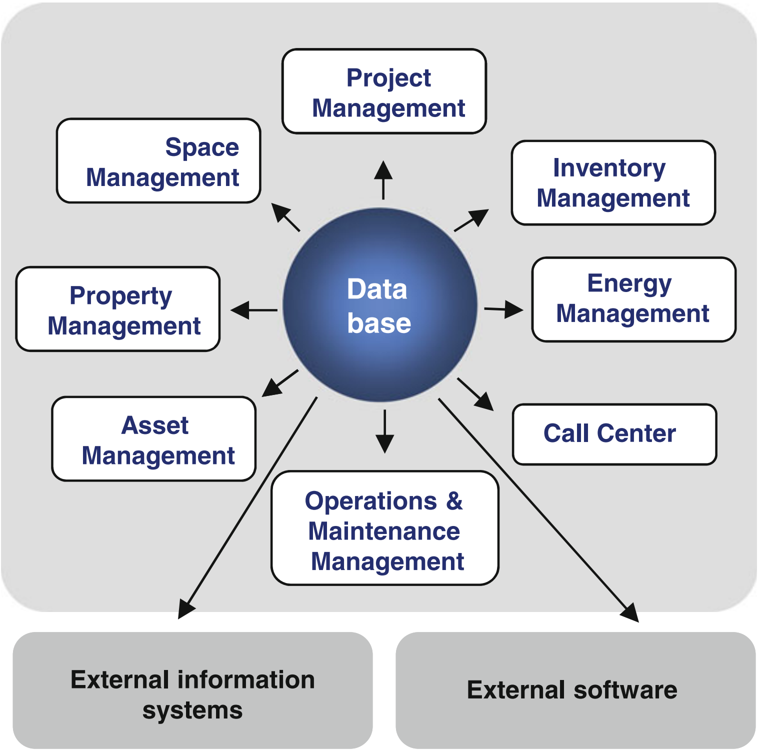


Fig. 4.9 Some of the integrated modules that can constitute an information system

– management of the “on call interventions”. The management module of the Call Center represents a fundamental support since, it allows: as a first step, the immediate locationing of site and involved technical objects; the retrieval of data sheets and maintenance manuals useful for the definition of the intervention to be carried out; the activation of operational procedures. In addition, the recording of all the reports received by the Call Center, allows the creation of an “historic knowledge”, useful for statistical analysis about the most common faults and their frequency. At the same time, it plays an important role in order to monitor activities in relation to the time spent for the problem resolution (Table 1.8);
– management of planned maintenance. The information system can support, through the module of Maintenance Management, the preparation of manuals and maintenance plans. It can also support the preparation of the maintenance program and the management of its time schedule, optimizing the calendars of activities, assigning operating skills and possibly their costs. The module can support the automatic issuance of the work orders needed to start the interventions (this chapter).

– logistic management of the tasks. It also allows, in addition to the WO management, a number of features aimed at optimizing operations, such as control of any overlap of activities, availability of spaces and equipments, activation of procedures (i.e. security, permits, etc.);
– management of the inventory about available stock and equipment;
– monitoring and quality control of the integrated services. The information system plays a key role when, through the implementation of feedback information coming from the various activities, it is able to develop various processing, that can go from the simplest standardized and periodic reporting to statistic processing of various nature (i.e. number of failures, response times, number of operations performed and not scheduled, non-compliance detected, etc.) (Table 1.8) to modalities of automatic alarms when thresholds defined by quality indicators are overcome.

Although these important functions, from the reading and comparison of several tender documents (both public and private) it arise that the common practice is still late in maturing a full awareness of the close relationship existing between organizational methods of the command centre and structure and modes of use of information systems. In fact:

– in many tenders, it is totally absent a systematic listing of the activities of the command centre and thus there is a lack of an accurate definition of the functions of the information system which should support such activities;
– in other cases, there are not indications about the characteristics of the information system and its mode of use, merely including a generic demand for supply.

Vice versa, it is very important to consider the guidelines of the standard UNI 11136:2004, "Global service for maintenance of buildings—Guidelines" (Table 3.17), that suggests to the client engaged in the acquisition of a FM service, to start an investigation stage, preliminary to the setting of the service and the subsequent drafting of the tender. This investigation phase is crucial in order to clarify some key points that can make clearer the requirements to be provided to the information system, intended as a support to the steering activities of the service. In particular:

– selection of the activities that can be outsourced and careful and articulated analysis of the characteristics of such activities, as well as of information used and produced, involved roles and needed supports. The analysis of all these subjects allows to bring out the "minimum" information required for the functioning and use of the information system;
– definition of the gradual implementation of the service over time (also depending on the initial information about the state of quantitative consistence of the real estate assets) allows to trace different steps of implementation of the information system, so that functions offered by the service and supported information may grow together, thereby avoiding situations of misalignment and relative inefficiency (i.e. activities that are not supported by the information

system or functions of the information system unused because they do not support any activity);

– description of results to be achieved by the service—qualitative and, when it is possible, quantitative (Tables 1.8 and 1.9)—and of the modality to carry out checks, so that it is possible to define key aspects of the information system such as: storage and data processing modes, procedures for the collection of feedback information, characteristics and forms of the reporting, management and processing of questionnaires ("cold and hot"), automatic alarms when exceeding service quality thresholds (i.e. exceeding the maximum waiting time for the resolution of a failure, delays in the execution of planned interventions, exceeding the number of faults over a predetermined threshold, etc.).

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Chapter 5
The Command Centre

Abstract The aim of the chapter is to investigate and highlight characteristics and key functions of the core structure of a FM service, here named "command centre" (CC), which is the structure responsible for the planning and coordination of interventions, the monitoring of the outcomes and the management of information flows. Starting from a framework of the key functions, the main activities of the CC have been analyzed in order to point out information needs and supporting tools. This analysis has been developed in relation to four theoretical models of CC, proposed as representative of some various approach that nowadays are observable in the field of FM services: command centre internal to the client of the service; command centre internal to the service supplier; command centre managed by a third party; control command centre jointly managed by client and supplier.

Keywords Command centre · Planning and coordination · Monitoring · Information flow · Information system

5.1 The Control of the Integrated Services

The high complexity and the competences involved in the organization of the activities in a FM service require the presence of a structure responsible for the planning and coordination of interventions, the monitoring of the outcomes and the management of information flows. This structure, crucial for the process efficiency and effectiveness, may be defined as "command centre" (CC).

The command centre represents a key condition in order to pursue simultaneously at least two basic objectives of the management services: firstly, the client monitoring and control of the compliance with the contract requirements; secondly, the effective integration of the different services included in the contract.

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Table 5.1 Framework of the possible main tasks of the command centre developed through the analysis of several case studies of FM agreements

Areas	Main activities
Information system	Design of the information system for the control of services
	Implementation of the information system for the control of services
	Operation and management of the information system
Registry	Setting up and management of technical registry
	Population and updating of the database
	Information management
Planning and scheduling	Planning and scheduling of the tasks
	Budgeting and management of the work orders
	Coordination and supervision of the operations
Operation centre	Management of the call centre
	Management of the corrective tasks
	Management of the operational unit
Management of third parties	Management of the building files
	Management of the construction documents
	Management of the previous contracts
	Management of the utilities supply
	Insurances
	Administration
Communication	Support to the internal information
	Communication plan
	Training plan
Monitoring and checks	Coordination of the general monitoring activities
	Management of the inspections and technical checks
	Management of the set of indicators

Although all the operators in the FM industry now agree on these objectives, it should be emphasized that the characteristics of this "centre" have not been explicitly and unambiguously defined yet.

Taking into account different case studies, it is fair to assert that neither in the literature, nor in regulations or contract practices, it can be found a univocal, shared and consolidated interpretation of the command centre, despite numerous reminders to its different typical functions (Table 5.1).

Summarizing the results of a long term analysis[1] on case studies in the field of maintenance management services, it is possible to assert that the client, in defining the request for FM services, should consider a series of coordinated and integrated

[1]In Politecnico di Milano, the authors of this book have been developing studies for several years, analyzing the contract specifications of public and private clients. The aim is to describe models of the command centre through the analysis of the requests elaborated in the contract documents [1–5].

key activities referred to the CC, such as: registry, information systems, call centers, planning and management of the operations, administration, checking (Table 5.1).

These categories draw a framework of functions that should be taken in charge by a command centre, but, at the same time, they allow some reflections. The supply of integrated services requires the presence of a unique and centralized structure characterized by a multiplicity of support activities. Considering growing demands expressed by clients (Chap. 1), management services are now more and more gradually expanding their scope of work and expertise towards different directions (Fig. 1.3). This process involves certainly the improvement of competences for supporting coordination activities and operations planning. In response to this request, today it is not still present a widespread awareness about what may be the model of CC for a best integration and control of the various areas of the services which, in some cases, are still considered autonomous.

In the analysis of specifications and contract documents, the CC activities are often not explicitly mentioned. So, it cannot be easily understood if these activities have to be carried out by the client or by another structure external to the service contract or, vice versa, if demands are not expressed because these activities are implicitly considered as natural supports to other services listed in the contract, or, lastly, if they are not considered due to inattention about these issues.

5.2 Key Functions and Role of the Command Centre

Given these considerations, a possible designation of the command centre may be the one that identifies it as a set of activities supporting the delivery of operational services with a particular reference to planning and coordination functions, management of information flows, monitoring and checking. The objective of these activities is to pursue efficiency and full achievement of performance and service levels predetermined by the client, as well as sharing information between the client and supplier.

According to this definition, it is possible to identify, for the specific scope of technical services, some basic functions of the command centre (Fig. 5.1). These functions can then assume different variations depending on the adopted organizational model[2] (Fig. 5.2) [6, 7].

[2]The model of CC may be considered in relation to the various organizational models of FM [6]. IFMA Italy (International Facility Management Association) [8] proposes a possible classification based on the activities integration level and the facilities management outsourcing level, defining three macro cases. The first one is characterized by the absence of a unique subject or facility department independent from the other company functions and the service management is divided into different structures. The second model is characterized by the presence of a facility manager, that heads the FM department, and the services are internally managed and provided through internal and/or external employees. In the third model, there is a FM department that is operated by external resources. Beside these models, many other criteria of classification have been proposed, such as the one presented by Cotts [9] and based on the type of location and sites of the FM structure. Ancarania and Capaldo [10] propose a model based on the progression of services to be

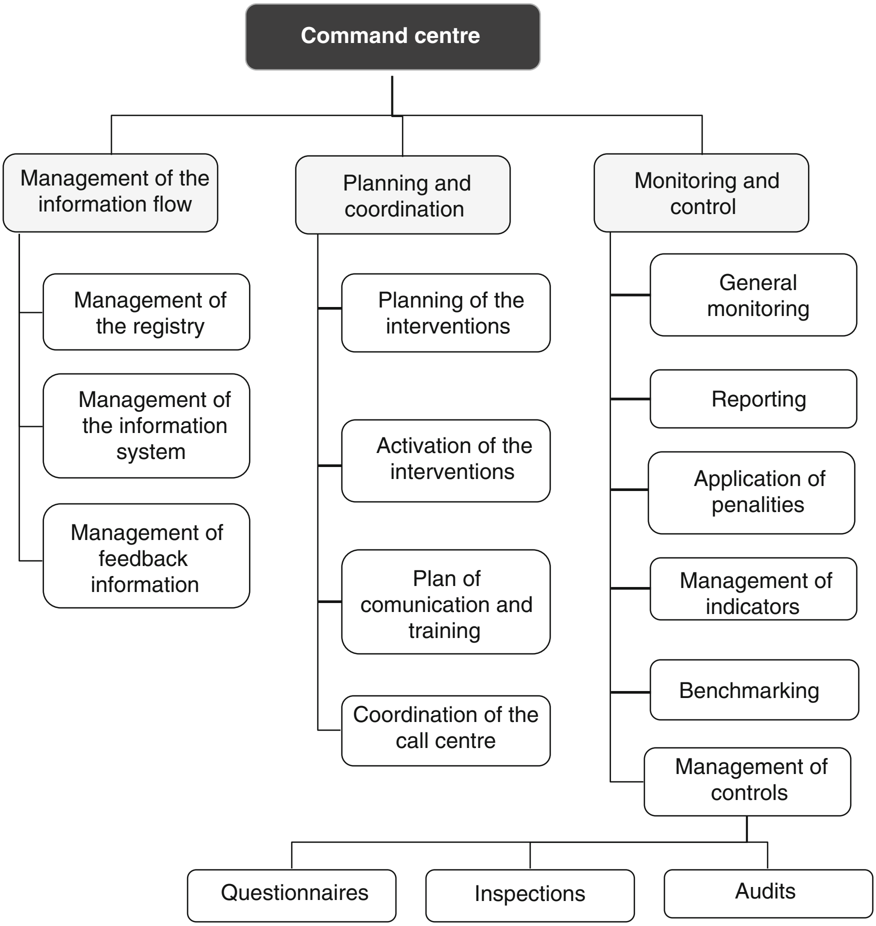

Fig. 5.1 Main key functions of a command centre

- Planning and coordination

First of all, a command centre should carry out planning and coordinating activities in different areas (Fig. 5.1).

Concerning the strategic scope of the integrated service, an important activity is the development of a masterplan of the service. It should be developed a general strategy, depending on the specific nature of the management contract, able both to

(Footnote 2 continued)

outsourced, starting from a situation of one service, evolving in contracts collecting together groups of operational separate services, up to forms of integrated services provided by only one supplier [10]. An overview of the progression of outsourcing in facilities management is proposed by Kurdia et al. [11].

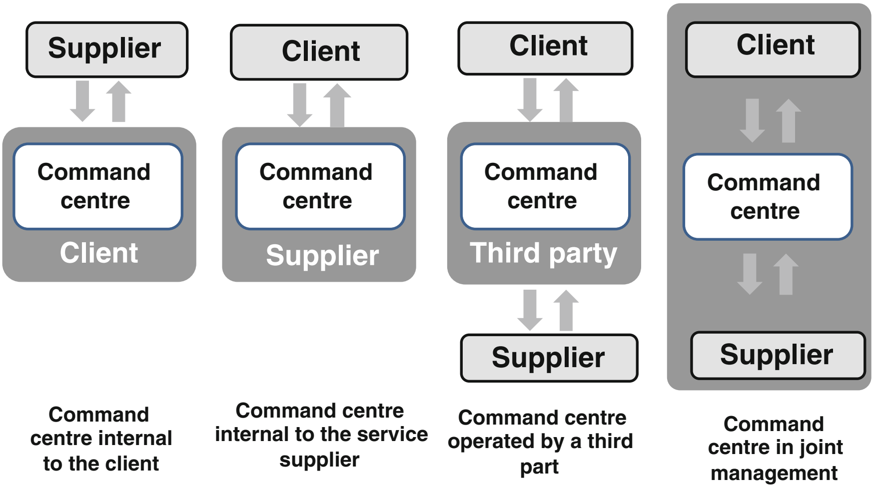

Fig. 5.2 The main models of command centre

direct and standardize the entire value chain of the different services up to the operating terminals (supply chain management) [5, 12–14] and to direct the definition of common management support tools.[3]

Concerning the logistic tasks, it is possible to identify many typical activities of the command centre, such as the management of: call centre, warehouse stocks, set of equipment, execution of activities, etc.

Concerning the administrative scope, the coordination supported by the CC may be developed towards different directions aimed at improving efficiency and pursuing scale economies, such as: the realization of a single central procurement office, the realization of procedures for automatic chargeback of costs for different utilities, the rationalization of insurance policies, etc.

Within the operating area, the coordination supported by the CC may concern the collection of intervention plans of the various service providers in order to

[3]Several authors underline [5, 12–14] the importance of information sharing in supply chain management. In particular, the study developed by Kembro and Selviaridis [14] empirically explores demand-related information sharing in the extended supply chain [14]. The study suggests different approaches to information sharing depending on the type and intensity of interdependence between supply chain partners and it identifies key barriers to extend information sharing: demand information disaggregation; risk of demand information misinterpretation; and risk of making production and distribution decisions based on incomplete information. The study proposed by Molinari et al. [5] analyzes three main strategies that represent different behaviors in supply chain management and that, at the same time, can be considered the steps of a progressive maturation of buildings services organizations, from a "simple addition" of services towards the creation of an organized system: aggregation, integration, homogenizing. For each of these strategies, the study proposes possible models concerning relationships between the components of the supply chain and the ways for information sharing [5].

achieve only a unique optimized schedule, based on at least two aspects. One aspect concerns compatibility checks in the case of overlap (i.e. between the calendars of core activities and those ones of maintenance activities, or in the case of assessment of the effects of the concurrence of different maintenance activities). The other aspect concerns the search for possible synergies (i.e. sharing of working equipments, concentration of shutdown of the activities in the same period, optimization of functions of logistic support and monitoring, etc.).

This coordination is useful not only in order to rationalize planned tasks, but also to deploy unplanned tasks in the most appropriate time frame.

Based on the time schedule, the coordination can then be implemented through centralized activities of preparation and issue of the work orders (WO) (Chap. 4).

Therefore, the coordination carried out by the command centre can be based on a single plan (i.e. general plan of services, maintenance plan, cleaning service plan, etc.) developed at the central level. Starting from this plan, the work program can be developed and transmitted to the various operating entities.

At more advanced levels, the coordination activity may involve other aspects, which could also have been omitted from the contract specifications, but whose presence can be an important contribution to improve quality and efficiency of the services. These issues may include:

- preparation of standardized reference schemes to draft manuals and maintenance plans to be developed at sectorial level (i.e. at the level of the building envelope system, heating system, etc.);
- preparation of standardized procedures to be shared between different service providers (i.e. procedures related to: safety, preparation of working areas, tasks in critical condition and emergency, communication mode between different operators, etc.);
- development of general rules for the approval of intervention requests;
- realization of supporting activities able to improve the interaction between different service providers and to make more homogeneous their operating modes (i.e. specific actions of training and communication) [5, 13].

• Monitoring and checking

The monitoring and checking process (Fig. 5.1), as well known, represents a central node in the management of services.

In this sense, there are basic actions that a CC can perform in a unified way, such as:

- collection and processing of data relating to: progress of the planned activities, compliance with the pre-established parameters (i.e. schedule requirements for the operations), quality of the tasks carried out;
- monitoring of the response time to the requests for intervention;
- setup, integration and improvement of the system of indicators for the monitoring of the service quality (if absent or inadequate at the level of contract specification) (Table 1.8);
- management of the system of indicators (i.e. collection and processing of data with the purpose of processing and distributing summary indexes to stakeholders,

producing reports, constant monitoring with reports of non-conformities, realization of *tableau de bord*/dashboards, etc.) (Chap. 4);
- analysis of non-conformities and suggestions for improvement;
- identification of problems arising from interference between services;
- identification and management of benchmarks to be used as references for the internal monitoring of services and suppliers (Chap. 1);
- implementation of "report cards" for different suppliers.

• Management of the information flows

The key functions of coordination and control (Fig. 5.1) are made possible by the basic function of management of information flows.

The function of centralized management of information requires different tasks, which can be performed by the CC:

- defining standardized rules and procedures to gather and store information in both graphical and alphanumerical form (i.e. inventory procedures, cards, classification system registry, etc.) (Chaps. 2–4);
- developing appropriate support tools to collect and store information (Chaps. 3 and 4);
- creating and managing the building registry (Chap. 3);
- coordinating the collection and storage of information coming from different sources (i.e. census, audit records, surveys, diagnostic investigations, due diligence, etc.) (Chap. 3);
- defining different modes of using information and setting up appropriate supports for output (i.e. reports, indices, charts, tables, etc.);
- processing the stored information and distributing them both in direct form (i.e. simply through search and selection of data) and in the form of elaboration (i.e. as an index);
- collecting and storing information concerning the performed tasks.

Benefits of a centralized management of information flows are many and include the possibility of:

- having a single knowledge base, able to grow gradually and consistently over time;
- acquiring and storing feedback information from the executed tasks; as already stated, this kind of information is useful both for the checking and the growth of knowledge about the behavior of the building systems and the operational modes. This knowledge growth, as recurrently stated, is a key factor for the gradual improvement of the forecasting and planning capacities of the whole management system;
- knowing, at any time, and comparing over time, with respect to unique and standardized parameters, the status of the assets, service levels and activities performed by the different service providers;

– providing a single support tool, updated and reliable, to the people working with different roles in the management of the buildings, avoiding duplication and overlap in gathering and producing information.

5.3 Models of Command Centre

From the analysis, carried out through case studies (Table 5.1), of the activities that may be attributed to the CC it clearly emerges—at least above a certain level related both to the size of the real estate and the complexity of the services—that an information system (Chap. 4) represents an essential support for the activation, coordination and integration of the various FM services (Fig. 5.3).

The activities of the command centre, within individual cases, may be carried out in various ways by the different parties involved in the service contract. For this reason, in the construction of a service contract, the CC should be preliminarily outlined by defining:

– the overall system of the functions, activities and tools that are required for making the services as much efficient and integrated as possible;
– the role of the information system as support to all the planned activities;

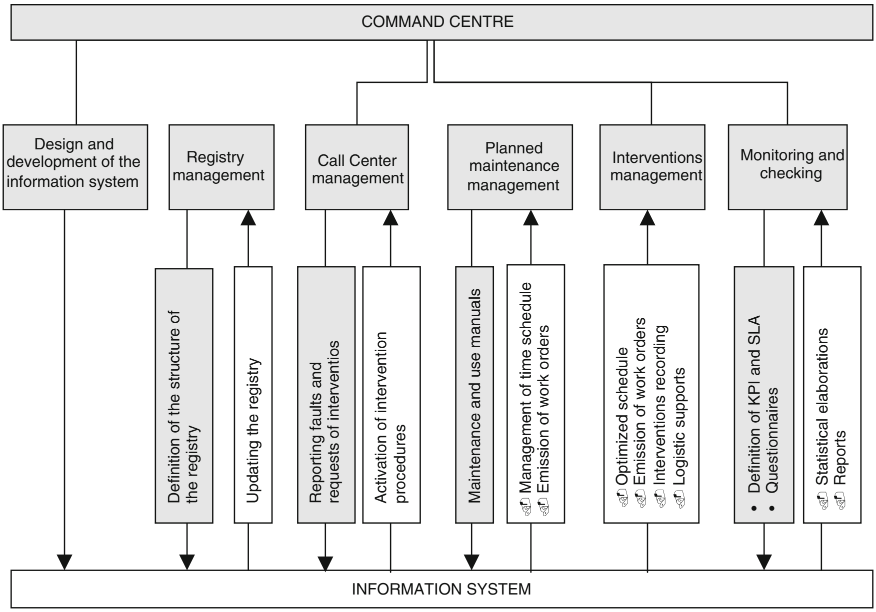

Fig. 5.3 Information system supporting the functions of the command centre

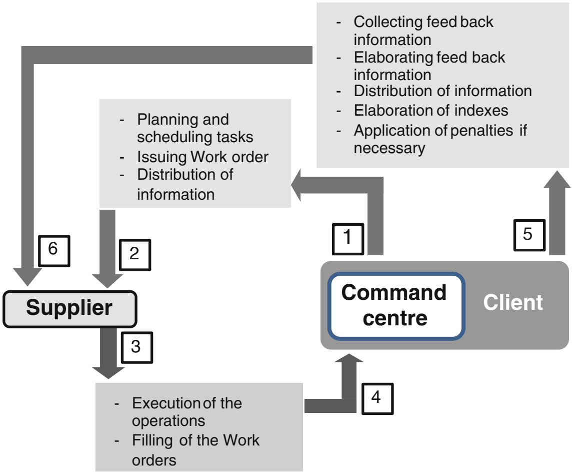

Fig. 5.4 Model of command centre managed by the client

– the organizational model of the CC, according to it is possible to establish tasks and tools, which may be focused on a single subject or variously distributed between different players (i.e. customer, the sole supplier of the service, contractors of individual services, consultants, etc.).

Whatever the organizational model is, it is essential, through a proper description of the tender requirements, to maintain a uniform vision of the CC.

The models, according to it is possible to implement the CC, can be arranged assuming some different basic structures.

Some possible models are (Fig. 5.2):

– command centre internal to the client of the service;
– command centre internal to the service supplier;
– command centre managed by a third party;
– command centre jointly managed by client and supplier.

• Command centre managed by the client

The client, working with its structures, keeps the functions of planning, coordination and control with the support of an information system (Fig. 5.4).

Supplier of works and services, according to established procedures, shall transmit to the CC the information (i.e. maintenance manuals, operating instructions, plans of the operations, etc.) necessary for the growth of the common knowledge base and for the optimization, at a central level, of planning and scheduling activities. The CC implements the centralized program of the service by issuing work orders (WO) to be sent to the suppliers of works and services. The filled WO will then be transmitted to the CC. Feedback information, appropriately archived, allows to increase the knowledge base and, at the same time, implement a series of checks at the service levels. From these checks, indications for corrective actions and/or application of penalties may be derived.

This model can be indicated in the presence of one or more characteristics of the client:

– ownership of an operating information system;
– gradual process of partial outsourcing (i.e. "mixed" situations, with contracts of Facility Management only for mechanical and safety systems and in-house management of the remaining areas);
– presence of an internal managerial know-how that the client does not want to loose;
– peculiar characteristics related to the specific type of building stock and/or hosted functions;

It is clear that this model safeguards the client, especially about the control of activities and protection and growth of the information; however, it should not be ignored that the client is burdened by several functions that often require the strengthening of his management structures.

- Command centre managed by the service supplier

This solution is now quite common, even if sometimes it is adopted by clients with a little attention for all those efforts and requirements that could guarantee them an actual control over the management process, the outcomes and the information flows.

In this case (Fig. 5.5), the client entrusts the management of the assets to the supplier of the FM services, which is often also involved both in the inventory activities and the coordination and management of information flows.

The client, for the purpose of monitoring and controlling, can obtain periodic reports (i.e. on the state of execution of the activities, the state of conservation of buildings, etc.) from the supplier. The client may eventually integrate these reports with his monitoring activities, such as audits or management of questionnaires

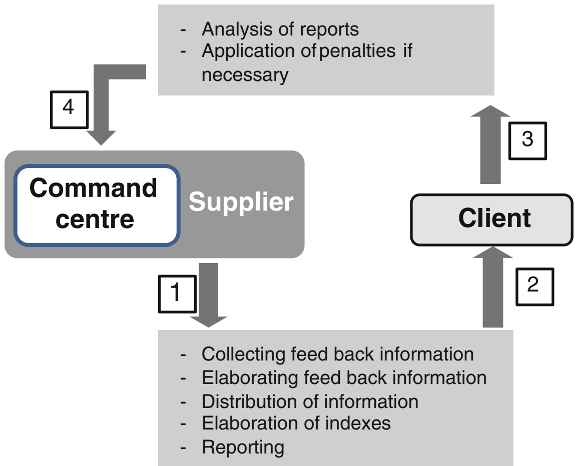

Fig. 5.5 Model of command centre managed by the supplier

distributed both to supervisors during the execution of the activities (hot questionnaires) and to users of the buildings immediately after the service delivery or after a longer period (cold questionnaires).

This model is generally practiced in those conditions in which the client:

- is not in possession of an adequate starting knowledge base and tools for information management;
- does not have a management experience carried out according to advanced forms;
- is not willing to strengthen or streamline his internal management structures;
- is willing to take advantage from the specialized know-how, organizational skills and proactive approach of the service providers.

It is evident that, for a client, the benefits coming from the adoption of this model are represented mainly by the opportunity to concentrate efforts just on his core business by outsourcing most of the management functions; however, these benefits should be compared with various possible risks, such as:

- obtaining an organization of the knowledge that is not perfectly appropriate to the client's specific needs;
- loosing part of the knowledge gained during the service if the feedback information are not properly and correctly stored and managed. It must be considered the risk that, at the end of the contract, the knowledge base may not result structured in the form and content useful for the client or the development of new tenders for the following services;
- partial ineffectiveness in monitoring the state of the services.

It is clear that these risks are partially avoidable by acting in different directions: primarily, with a correct information management in the different phases of the service. During the procurement of the service, by defining the logic and methods of acquiring information (criteria for the development of registry). During the service delivery, through management of the feedback information. At the end of the service, with the delivery of the information database correctly implemented and improved; secondly in the preparation of tender documents and requirements, paying close attention to the arrangement of several conditions that are able to adequately support the monitoring actions, such as: the content of reports, set of indicators, KPIs, object and methods of inspections and audits, etc.

- Command centre managed by a third party

A possible alternative to the two models previously described is to entrust to a third party the complete operation and management of the command centre (Fig. 5.6).

In this case, it is possible to appoint a specialist (as the supplier) for setting up the overall apparatus of the CC with activities that may include:

- inventory;
- development of the registry;

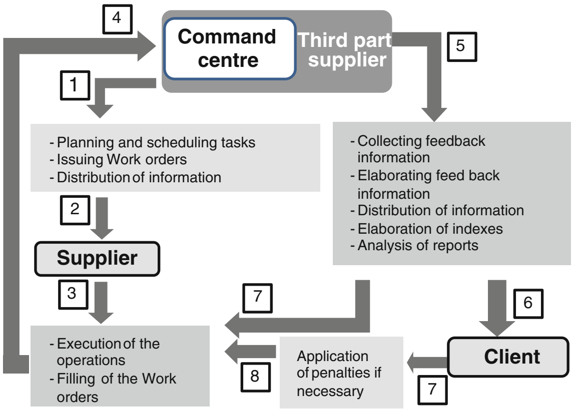

Fig. 5.6 Model of command centre managed by a third part

- study/supply and implementation of the information system;
- realization (or undertaking) of the general planning of the service;
- realization and optimization of the general time schedule starting from the plans of the various service providers;
- issue and transmission of the WO and their storing, once compiled at the tasks completion;
- storage and processing of the feedback information;
- information processing and delivery of reports to the client for its monitoring activities;
- information distribution;
- identification and reporting of critical issues to nominated supervisors;
- logistic support (i.e. information management of warehouse stocks);
- administrative support activities;
- other support activities (i.e. training, preparation of procedures, etc.).

This type of model can be adequate for a client:

- without a knowledge base about the assets that have to be operated and maintained;
- that does not have an information system already structured or that has an information system already working, that he intends to implement but without the charge of a direct management;
- owner of a real estate that is very complex in terms of technical and accounting aspects;
- willing to initiate an integrated management supported as much as possible by an information system;
- willing to take advantage from the specialized know-how, organizational skills and proactive approach of service providers particularly expert about organizational and informative subjects;
- willing to rely on an external and independent structure able to support him in control and monitoring activities.

The expected benefits of this kind of model are actually effective as much as a client is able to adequately establish roles and tasks of the supplier of the CC and to define his own needs concerning the information management.

It should not be forgotten, in assessing this model, that:

- a third party involves a significant cost and thus, during the identification of the services to be delivered by the suppliers of technical services, the client should carefully identify and separate all those activities that are under the responsibility of the supplier of the CC;
- a third party represents an additional subject that is involved in the overall management of the service. The terms of its integration should be carefully assessed;
- even the controller (the third party) must be controlled.

• Command centre in joint management

Finally, it is possible to highlight an additional model that is more and more widespread. It can be described as a joint management and it consists in setting a CC shared between the client and service supplier (Fig. 5.7).

It is a model that can present different configurations, essentially related to:

- a common platform, consisting of a single registry and information system and a set of shared procedures;
- a variable framework of activities, carried out by the service suppliers and client, all referring to the same information system. The client and the supplier jointly manage the information system, each one with his own predetermined and arranged roles and responsibilities.

The successful application of this model depends on the client's ability to:

- carefully analyze his own skills and abilities in order to understand which functions of the CC can be outsourced;

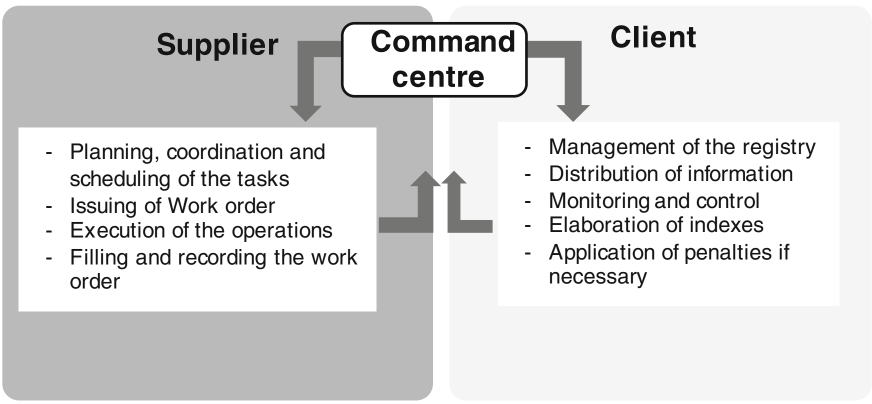

Fig. 5.7 Model of command centre managed jointly by the client and service supplier

– exhaustively determine the systemic framework of the CC and then list and deploy the different functions and, for each of them, define activities, tasks and operators;
– develop an accurate framework of the procedures for managing information flows.

An hypothesis of evolution of this model of command centre could be outlined by considering the innovative model of FM services named Open Facility Management (OFM) proposed by De Toni et al. [15]. This model is based on three principles and it can be implemented through operative tools. The basic principles are: organizational coordination among players; sharing the performance measurement systems; contract flexibility. OFM model is based on openness of the parties to the changes potentially coming, during the lifetime of a FM contract, from various factors (i.e. new needs, new end-user, new technical improvements, etc.) and on involving both traditional (client, contractors, sub-suppliers, end-users) and new subjects (consultants, university researches, etc.), considering their needs and contributes. Considering the CC in relation to the innovative proposed OFM model means to introduce and manage within its functions at least three operative tools:

– the Partnership Table (PT), that can be considered as a place where information on services, SLA and technical, managerial and organizational contract aspects are discussed and shared;
– the Shared Performance Measurement System (PMS) that collects the indicators the parties consider necessary in order to evaluate the contract;
– the flexible contract with SLA, where the parties are allowed to modify the contract conditions using SLA. Standard levels and services quality are defined through indications shared by the parties.

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Chapter 6
Building Information Modeling (BIM) and Facility Management (FM)

Abstract The aim of this chapter is to introduce the main aspects and needs of the relation between the Building Information Modeling (BIM) methodology and the Facility Management (FM) sector. In fact FM activities, which nowadays are negatively influenced by the fragmentation within the construction industry and the inadequate information exchange between Project Lifecycle Phases (PLPs), can be improved and addressed by the synchronized and collaborative nature of BIM which works as a lifecycle and interdisciplinary 3D data store. Although benefits of an efficient knowledge and process management by using BIM to support FM activities, the adoption of this new methodology for asset management and facility maintenance has been overlooked for a while. Nevertheless, recently the BIM potentiality to overcome the traditional uncertainty in the information management of the built environment and to improve deficient documentation prevalent in existing buildings has boosted the research focus towards this direction. In particular many research groups are working at defining the information requirement of BIM objects as useful for FM activities.

Keywords Building Information Modeling (BIM) · Facility Management (FM) · Information Lifecycle Management (ILM) · Process management · Information requirement

6.1 Need for an Information Lifecycle Management

Economic crisis and its impact on the construction sector [1], stricter decrees for resource and process efficiency,[1] more and more complex design information [2] motivate the Architecture, Engineering, Construction, Facility Management (AEC/FM) sector to boost innovation towards a more efficient and collaborative

This chapter is authored by Marcella Bonanomi.

[1]See the European Regulation No 305/2011 and the European Directive No 24/2014.

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construction industry. Due to long building life cycles and considering that the rate of new construction is more and more shifting to renovation and maintenance (R&M) of existing buildings (Fig. 6.1), Facility Management (FM) and asset management are likewise major levers to improve productivity and efficiency in the AEC/FM domain [3].

The FM market in fact has experienced significant growth during the last ten years since the construction sector has become more and more aware of the strategic benefits of an Asset Information Management, particularly in terms of cost savings, time efficiency and quality of information exchange between the different life-cycle stages of the construction process.

Several studies and researches also highlight that FM has been able to react in a positive way to the global financial crisis by absorbing the negative impact on growth of the construction sector. It has been forecasted that this growing trend will stabilize in the next future (Chap. 1).

Although this positive trend, reciprocal interdependencies between different stakeholders, such as real estate investors, contractors, suppliers, architects, facility managers etc. are still a major problem in the FM sector, as in the whole construction process [4]. Considering that each stakeholder possesses different set of skills, standards and tools, the communication and the information exchange are characterized by an high level of complexity. Therefore, the knowledge and process management are often time-consuming [5].

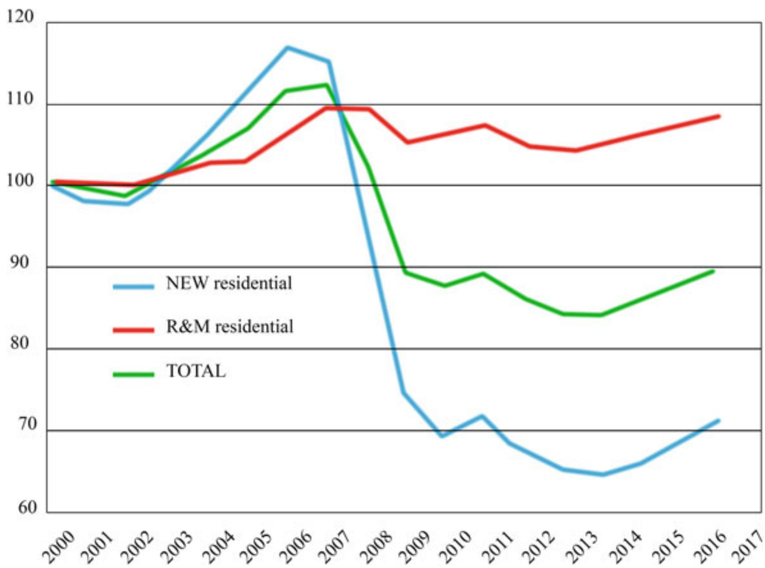


Fig. 6.1 Index market value 2000–2017. New building work versus renovation [1]

Table 6.1 Costs of inadequate interoperability by stakeholder groups and life-cycle phases [6]

Stakeholder group	Planning, design, and engineering, phase	Construction phase	Operations and maintenance phase	Total
Architects and engineers	1007.2	147.0	15.7	1169.8
General contractors	485.9	1265.3	50.4	1801.6
Specialty fabricators and suppliers	442.4	1762.2	–	2204.6
Owners and operators	**722.8**	**898.0**	**9027.2**	**10648.0**
Total	2658.3	4072.4	9093.3	15824.0

The lack of communication between the actors and the lack of interoperability between the tools are the most important reasons behind common problems arising during a building lifecycle such as information asymmetry and data fragmentation.

The inadequate interoperability which characterizes the AEC/FM sector increases the cost burden of all the stakeholders involved in the construction process. Moreover, if we consider that most of the information, which is necessary during the building use phase, has been produced in the previous lifecycle stages (i.e. design, construction etc.) and comes from different stakeholders (i.e. designers, manufacturers, etc.), it is clear the importance of an Information Lifecycle Management (ILM), above all for the FM industry.

It has been estimated that the cost of inadequate interoperability in the U.S. market is equal to $15.8 billion per year. Specifically, owners and operators bore approximately $10.6 billion, or about two-thirds of the total estimated costs (Table 6.1) [6].

As a response to this increasing complex environment, Information and Communication Technology (ICT) has been developing at a very fast pace. Many actors involved in the FM sector, such as facility managers and building owners, have begun to use Computer Aided Facility Management (CAFM) software and Facilities Information Systems (i.e. Archibus[2]) to support operation and maintenance activities of building assets (Chap. 1).

Recently, a major shift in ICT for the FM industry has been a growing interest in Building Information Modeling (BIM) due to many benefits and resource savings coming from an ILM with impacts to the all lifecycle phases of the construction process [7].

[2]Archibus is an Information System which is a worldwide market leader in the field of CAFM software. It is divided in 9 modules, each of them focused on a specific FM activity: Real Estate Portfolio Management, Capital Project Management, Space Planning and Management, Move Management, Asset Management, Environmental and Risk Management, Building Operations, Workplace Services, Technology Extensions.

6.2 BIM Definition(s) and Methodology

The concept of BIM was first proposed by Professor Chuck Eastman at the Georgia Institute of Technology around 30 years ago. Since then 3D modeling has been slowly developing as integrated analysis and object-oriented tools until 2000s when Building Information Modeling started to be adopted in pilot projects to support designers' activities.

Initial research focus was just concerned with the earlier lifecycle phases of the construction process: design (D) and construction (C). Instead, operations (O) has been overlooked for a while. Therefore, for a certain period of time, the use of BIM has been concentrated just on D + C sub-activities and tasks, such as programming and cost planning, architectural and structural design, construction planning and detailing (Table 6.2).

Recently there has been a shift from this approach, which was taking in consideration just earlier lifecycle phases, to a vision including also the building use phase. So, the BIM environment has started to be referred to the whole lifecycle process [7].

In fact, just by assuming the interdisciplinary and lifecycle approach of BIM, it is possible to really boost knowledge and process management by building up a unique and coherent working environment which facilitates stakeholders' collaboration and information exchange, in order to reduce waste of time and effort, as well as mistakes and delays [8].

Since the 70s, when the BIM concept has been proposed for the first time, many different definitions and interpretations have been developed.

By conducting a literature review, two different perspectives can be found:

– *BIM as a tool*. It represents the so called "little bim" approach which refers to the BIM acronym just as Building Information Model, and thus considering only the 3D model;

Table 6.2 Project life-cycle phases and sub-phases [27]

Design phase (D)	Construction phase (C)	Operations phase (O)
D1: conceptualization, programming and cost planning	C1: construction planning and construction detailing	O1: occupancy and operations
D2: architectural, structural and systems design	C2: construction, manufacturing and procurement	O2: asset management and facility maintenance
D3: analysis, detailing, coordination and specification	C3: commissioning, as-built and handover	O3: decommissioning and major re-programming

– *BIM as a process*. It is related instead to the "BIG BIM" approach which defines the BIM acronym as Building Information Modeling, and thus referring not just to the physical model but also to the methodology which has been adopted to develop it [9].

Therefore, the most interesting definitions underline the holistic perspective of BIM by describing it as an integration between the "little bim" and the "BIG BIM" approach. In fact BIM is both an innovative process and methodology concerning information management (BIG BIM) and a digital representation which contains and provides data coming from different sources and phases (little bim). It includes not only spatial data models but also project management (PM) related tools and processes [9].

In accordance with this holistic vision, the National Institute of Building Sciences [21] defines BIM as "an improved planning, design, construction, operation, and maintenance process using a standardized machine readable information model for each facility, new or old, which contains all appropriate information, created or gathered about that facility in a format useable by all throughout its lifecycle". Jernigan [9] provides another interesting definition by describing BIM as a "a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle".

BIM can provide data-enriched 3D models detailed according to the different Project Lifecycle Phases (PLPs) and focused on the different working areas of the construction process. For example, a BIM model can be realized with a level of information suitable for a preliminary studio of a building structure, or being detailed as a digital as-built model to support operation and maintenance activities.

Therefore, a BIM model provides not only the geometrical configuration of the building elements, but also the information set which is associated to them. For example, informational attributes which can be associated to BIM objects, as useful for the FM activities are: model, manufacturer, product page URL, etc. (Fig. 6.2).

As Smith [10] underlines "a building information model is a digital representation of the physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward".

As already underlined, the "I" of BIM can be managed according to the different PLPs and fields of the construction process. For example, informational attributes associated to building elements in the case of a BIM model developed for an energy simulation will be surely different from the parameters included in the case of a structural analysis. Then, BIM process modeling and data implementation are both related to:

– space. In which working area am I using BIM? (i.e. Facility Management, structural analysis, energy simulation, etc.);
– time. In which lifecycle phase am I using BIM? (i.e. use phase, design phase, construction phase, etc.).

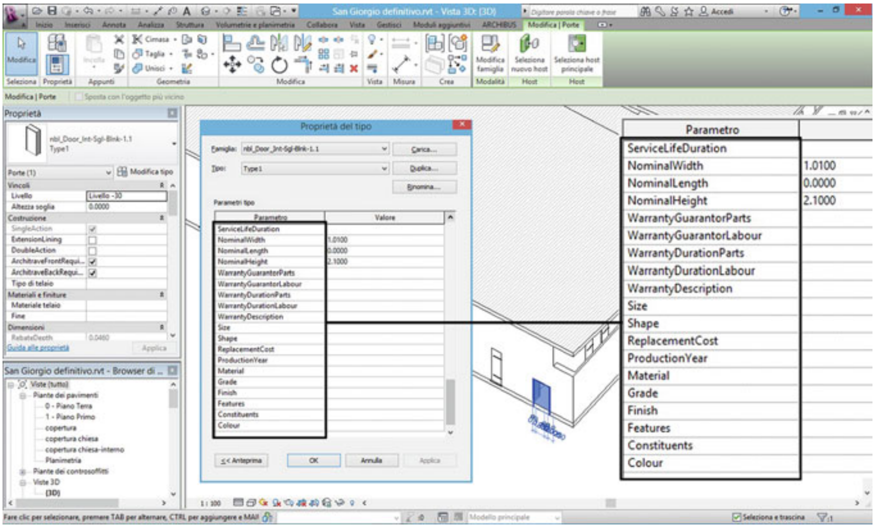


Fig. 6.2 Example of geometric and non-geometric information included in a BIM object and useful for FM activities

According to these two parameters, different datasets with different data quality and level of detail can be associated to BIM objects [11].

Focusing on the building use phase, which is characterized by a wide information requirement (Tables 3.4 and 3.18) due to the multidisciplinary nature of the FM activities, the BIM potentiality to capture and preserve data along the whole building lifecycle can reduce the traditional information loss and asymmetry characterizing data exchange between different stakeholders and phases of the construction process. For example the exchange from the design/construction stages to the use-phase is often characterized by an high level of information loss and data asymmetry [12].

Current FM activities, which nowadays are negatively influenced by the fragmentation within the AEC/FM industry and the inadequate information exchange between PLPs, can be improved and addressed by the synchronized and collaborative nature of BIM which works as a lifecycle and interdisciplinary 3D data store.

Although promising benefits of an efficient knowledge and process management by using BIM in FM, the adoption of this new methodology for asset management and facility maintenance is lagging behind other sectors of the construction process (i.e. building design, structural analysis, construction management etc.). Until now Building Information Modeling has been developing at a very fast pace for new buildings, but the implementation of BIM in the FM field is just now going one step further.

Recently the BIM potentiality to overcome the traditional uncertainty in the information management of the built environment and to improve deficient documentation prevalent in existing buildings has boosted the research focus towards this direction [13].

Although there is agreement about the benefits deriving from an ILM, which is made possible through a BIM implementation in the FM stage, it is still unclear which should be the information requirement to support FM activities in a BIM environment.

6.3 BIM-based Knowledge and Process Management

Given the tridimensional data repository nature of BIM, it is clear the importance of standardizing information requirement, as well as developing data interoperability.

By considering this new methodology in its broader perspective,[3] BIM data models are developed according not only to technical issues, but also to a functional, informational and organizational/legal structure.

The functional structure, which can be considered as both the focus and the output according to a BIM model is made, depends on:

- the *stakeholders* involved in the process, and thus on their specific information requirement. For example, a BIM model which has been developed by an energy engineers' team to perform an energy simulation will surely include different information (i.e. U-values, radiation data etc.) in comparison to a BIM model used to support a facility manager in the FM activities of a building (i.e. replacement costs, warranty starting dates, etc.);
- the *lifecycle phases* which the model refers to, and thus on the different levels of detail of information. For example, a BIM model which has been developed for a preliminary design-phase will not provide all the specific product information which a BIM model at a construction phase includes (as-built digital model). In fact, the informational structure of a BIM model becomes more and more detailed throughout the lifecycle stages of the construction process.

Then, the "functionality" of a BIM model determines its informational and organizational structure with respect to both knowledge and process management [7].

The specific questions "what kind of information", "when in the LC process" and "from who has to be provided", referring to the dataset associated to model elements, have to be answered according to the different focus/output of the BIM model.

For example, by considering a model developed to support FM activities, answers to the previous questions will be:

- what information has to be included in BIM objects? Model Number, manufacturer, replacement cost, Reference Service Life (RSL), etc.;

[3]The so called "BIG BIM" approach proposed by Jernigan [9] which refers to BIM both as the data-enriched 3D model and the methodological framework which has been adopted to develop it.

– from who among all the involved stakeholders has to be provided? Designers and products manufacturers;
– in which lifecycle stage of the construction process has to be captured? Design and Construction phase.

Therefore, in order to avoid information loss throughout the building lifecycle and, at the same time, reducing costs and improving efficiency, these answers have to be agreed by all the stakeholders involved before starting the BIM process.

Given these considerations, the design of a standardized BIM environment in which all the actors involved may work in a well-defined framework, referring both to data standardization and software/tools interoperability, is one of the main research topic.

Focusing on information standardization, it has to be first underlined that model elements are enriched both with:

– geometrical data, which are for the most part dimensions (i.e. length, width, height, thickness, etc.) and are automatically given by the BIM software (Fig. 6.3);
– non-geometrical data, which are not automatically provided by the BIM environment and then they can be implemented according to the diverse functionalities of the BIM model (i.e. Facility Management, structural analysis, etc.).

For example, focusing on the FM information needs, non-geometrical data may refer to the spatial relation of assets (i.e. connected/aggregated/intersected etc.), as well as to more specific information such as date of installation, warranty description, replacement cost, etc.

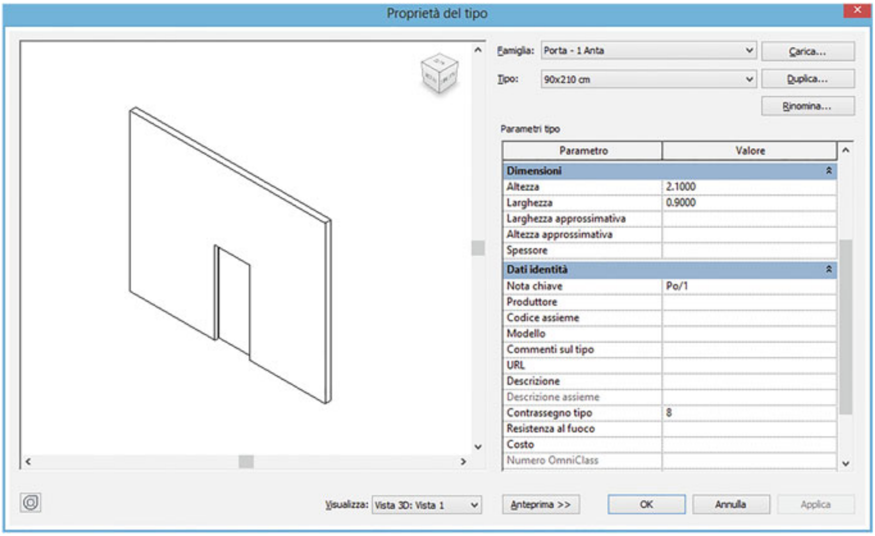


Fig. 6.3 Example of geometrical information automatically provided by a BIM object

Since these data are not automatically included in the model elements, there could be two different paths in order to implement this knowledge in a BIM environment:

- it can be built a specific information structure through the implementation of data standards in the BIM software. For example, the COBie[4] standard has been developed as a data schema able to collect and store all the information which is necessary to the use-phase of a building;
- it can be developed an information exchange through plug-in and/or interoperable tools. For example, focusing on the FM sector, the BIM software can be directly linked to the CAFM (Computer-Aided Facilities Management) system[5] in order to have bidirectional information exchange.

Besides the informational issue, also organizational and legal structures have to be clearly defined in order to identify:

- roles of all the stakeholders involved in the BIM process;
- responsibilities for data input and data output;
- level of access and authorizations to the different information and tools which constitutes the Common Data Environment (CDE) of a BIM process.

6.4 Standardized Content and Organization Requirements Along a BIM Process: LoDs (Levels of Development)

Since the informational issue of a BIM model determines not only the specific content requirement, but also its organizational structure, it is clear the importance of a standardization process regarding content and organization requirements.

Answering this standardization need, the American Institute of Architects (AIA) has developed the Building Information Modeling Protocol Exhibit, a document template defining the informational, organizational and legal structure of a BIM process. It identifies protocols, expected levels of development (LoDs) of each model element according to the different lifecycle phases and specific responsibilities/authorized uses of the BIM model(s).

[4]The Construction Operations Building information exchange (COBie) was devised by the United States Army Corps of Engineers in 2007 as a data standard able to store and deliver building information in a usable format for everyone throughout all the PLPs. COBie is being widely promoted as a highly effective data schema enabling integration between BIM platforms and CAFM systems. In fact, this schema allows the team to document their knowledge about a building asset in both its spatial and physical aspects.

[5]The Facilities Information System Archibus has recently developed a plug-in in collaboration with the software house Autodesk to make possible bidirectional data exchange with the BIM software Revit.

As well explained in the AIA definition [13], the concept of LoD, which is the acronym of Level of Development, describes “the level of completeness to which a Model Element is developed”.

This term is generally used to describe geometric and non-geometric information provided by a BIM model element. Moreover, the LoD does not provide only the content requirement required to a model element but it also describes its relative space and time frame. In fact, it specifies what information, in which lifecycle stage and from who among all the stakeholders involved in the construction process has to be provided.

LoDs increase more and more along the stages of the construction process. From the first activities of the design phase, such as conceptualization, programming and cost planning to the last ones regarding the operations phase (i.e. asset management and facility maintenance) data levels of detail change a lot.

Therefore, considering that information requirement and level of detail characterizing a BIM process may considerably vary, a standardized BIM environment has to be defined as proposed by the AIA classification [13]:

- “LOD 100. It is the overall building massing indicative of area, height, volume, location, and orientation.

  The authorized uses of the model are:

– *analysis* based on volume, area and orientation by application of generalized performance criteria assigned to the model elements;
– *cost estimating* based on current area, volume or similar conceptual estimating techniques (i.e. square feet of floor area, condominium unit, etc.);
– *schedule* for project phasing and overall duration.

- LOD 200. Model elements are modeled as generalized systems or assemblies with approximate quantities, size, shape, location and orientation. Non-geometric information may also be attached to model elements.

  The authorized uses of the model are:

– *analysis* for performance of selected systems by application of generalized performance criteria assigned to the model elements;
– *cost estimating* based on the approximate data provided and conceptual estimating techniques (i.e. volume and quantity of elements or type of system selected);
– *schedule* to show ordered, time-scaled appearance of major elements and systems.

- LOD 300. Model elements are modeled as specific assemblies that are accurate in terms of quantity, size, shape, location and orientation. Non-geometric information may also be attached to model elements.

The authorized uses of the model are:

- *construction* for the generation of traditional construction documents and shop drawings;
- *analysis* for performance of selected systems by application of generalized performance criteria assigned to the model elements;
- *cost estimating* based on the specific data provided and conceptual estimating techniques;
- *schedule* to show ordered, time-scaled appearance of detailed elements and systems.

• LOD 400. Model elements are modeled as specific assemblies that are accurate in terms of quantity, size, shape, location and orientation with complete fabrication, assembly and detailing information. Non-geometric information may also be attached to model elements.

The authorized uses of the model are:

- *construction* model elements are virtual representations of the proposed element and are suitable for construction;
- *analysis* for performance of approved selected systems based on specific model elements;
- *cost estimating* based on the actual cost of specific elements at buyout;
- *schedule* to show ordered, time-scaled appearance of detailed specific elements and systems including construction means and methods.

• LOD 500. It represents the level of development in which the model can be used for supporting FM activities. Building components/systems are modeled as constructed assemblies actual and accurate in terms of size, shape, location, quantity and orientation. Non-geometric information may also be attached (i.e. installation data, warranty description, Reference Service Life, etc.) to model elements.

The authorized uses of the model are:

- *general usage* for maintaining, altering and adding to the project."

In conclusion, LoDs define content and process requirements at five progressive levels of completeness. "Each subsequent LoD builds on the previous level and includes all the characteristics of previous levels" [13].

Therefore, in a BIM-based process, the Level of Development has to be established for each model element, as well as the author responsible for modeling that particular building element according to the identified LoD. This informational and organizational structure has to be agreed and defined by all the actors involved in the BIM process by filling out the Model Element Table (Table 6.3).

Table 6.3 Example of a model element table to be filled-out by all the stakeholders involved in a BIM process [13]

Model elements utilizing CSI Uniformat™	LOD	MEA	LOD	MEA	LOD	MEA
A substructure						
A1010 standard foundations						
A1020 special foundations						
A1030 slab on grade						
A2010 basement excavation						
A2020 basement walls						

Model Element Table: Identify (1) the LOD required for each Model Element at the end of each phase, and (2) the Model Element Author (MEA) responsible for developing the Model Element to the LOD identified

6.5 Information Requirements for the Building Operational Phase: the COBie Standard

As it has already been underlined in the previous paragraph, LoDs codify the informational and organizational structure to be used in a BIM environment along a construction process (from the first preliminary design stage to the building use-phase). Nevertheless, the five progressive levels of development defined by the AIA do not declare what non-geometric information have to be included in the model elements. The AIA just declares that "non-geometric information may also be attached to model elements", but it does not specify what kind of information is needed. Then, it leaves open the possibility of defining the so called "non-geometric" information according to the different focus/output according which the BIM model has been developed.

The COBie (Construction-Operations Building information exchange) data standard proceeds in this direction by defining a specific information schema focused on the FM information needs.

COBie is a data standard which has been developed by iden-tifying and codifying all the information which are necessary to the use phase of a building (i.e. Installation Data, Warranty Description, Reference Service Life, etc.). In fact data collection necessary to FM activities is most of the time a costly and time-consuming procedure, since the use-phase of a building needs all the information which has been elaborated in the previous stages of the construction process. Moreover, in the AEC/FM sector the information exchange has traditionally been done on paper and then the percentage of information loss, once the building is completed, is very high.

For all these reasons, COBie was devised by the United States Army Corps of Engineers in 2007 as a data standard able to store and deliver building information in a usable format for everyone throughout all the PLPs.

COBie is being widely promoted[6] as a highly effective data schema enabling integration between BIM platforms and CAFM systems. In fact, its schema allows the team to document their knowledge about a building asset in both its spatial and physical aspects. Spatially, it can document the spaces and their grouping into floors/sectors and other zones. Physically it documents the components and their grouping into product types and other systems.

One of the primary benefits of COBie is that it enables a structured information exchange and collection from the design phase to the use phase, by allowing data to be gradually added during the whole construction process. At the end, the completed spreadsheet is available to be delivered to the facility manager.

Therefore, by using COBie as a data schema in a BIM environment, it is possible to get a unique, coherent and complete database in which all the information which is necessary to the FM activities is stored and can be anytime exchanged with other stakeholders (i.e. engineers, architects, etc.).

> The COBie information can be either be kept as delivered, or held in ordinary databases, or it can be loaded into existing Facility Management and Operations applications, either automatically or using simple copy-and-pasting. The owner should be explicit about the purposes for which the information is required and about the timing and content of any interim deliveries [14].

The COBie schema is structured according to five progressive delivery phases, the so called Data Drops (Fig. 6.4) [14].

- "DATA DROP 1: the model describes requirements and constraints (i.e. required functionality and environmental conditions for the space, required performances for finishes, etc.).

The rationale for the data drop is to approve the "Outline Business Case" by checking if the emergent design and specifications are consistent with the client brief in terms of function, cost and carbon. It will be made up as a massing model indicating space allocation and overall site location;

- DATA DROP 2: the model represents the outline solution (i.e. functionality of the space, environmental conditions of the space, actual finishes, list of furniture and equipment for each room) and it allows to produce schedules (i.e. doors, windows, furniture, etc.) to inform the cost model.

The rationale for the data drop is to select the "Main Contractor" and so checking first if the interpreted design and specifications are consistent with the client brief in terms of function, cost and carbon and then if the potential suppliers can demonstrate capability and integrity through the competitive process and be selected to deliver the asset.

[6] COBie has been adopted by the UK Government as the official data format enabling information exchange between different LC stages. It is the information base for the United Kingdom's Building Information Modeling (BIM) implementation.

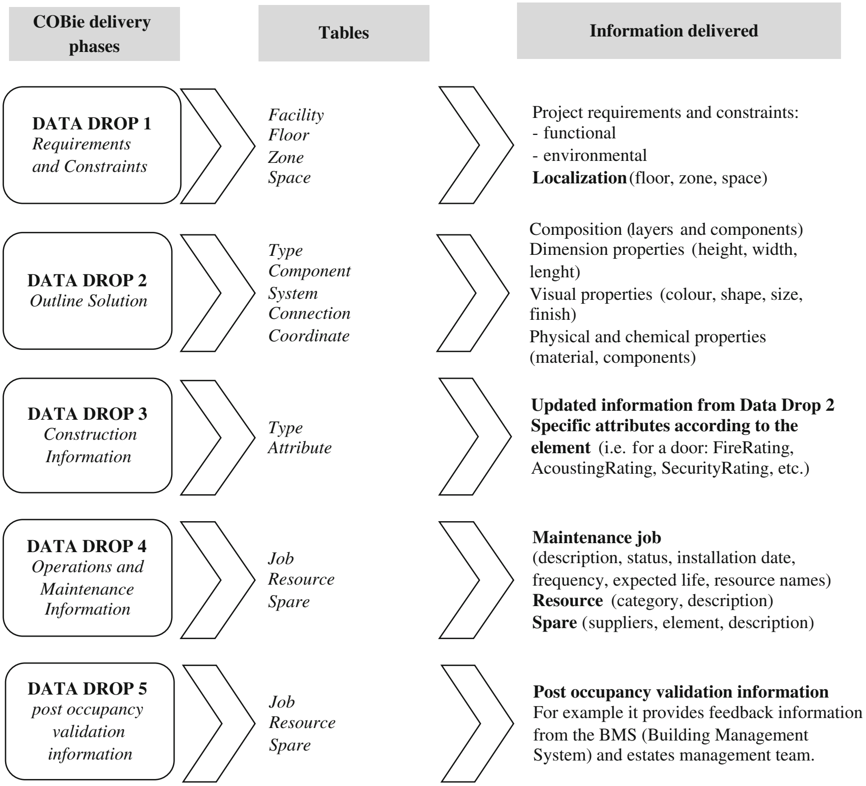


Fig. 6.4 Informational structure of the COBie data drops [14]

- DATA DROP 3: the model represents construction information and it represents a fully coordinated technical solution. Therefore, fully coordinated technical drawings can be generated for construction, as well as various schedules (i.e. doors, windows, furniture, etc.) for orders.

The rationale for the data drop is to approve the "Agreed Maximum Price" by checking if the developed design and specifications are consistent with the client brief in terms of function, cost and carbon performance.

- DATA DROP 4: the model represents operations and maintenance information. Operational and detailed functional information supplied by the product manufacturers are being collected. Therefore, the model represents the building as built and it contains all the information regarding systems and equipments as actually installed and provided by the various contractors to maintain them. Information necessary to FM activities can then be extracted from the model.

The rationale for the data drop is to take position of the "Operations and Management" Information.

- DATA DROP 5: the model represents post occupancy validation information and ongoing O&M, and thus the building in use. For example it provides feedback information from the BMS (Building Management System) and estates management team."

Therefore, COBie works as an informational spreadsheet, organized in tables,[7] to be gradually filled out along the construction process according to the five progressive data drops. Different tables, with diverse content requirements, are associated to each data drop. These tables are classified into three categories:

- design. The specific tables of this category are: facility, floor, space, zones, type, component, systems;
- build. The tables concerning the building category are: job, resource, spare;
- common. The tables which are included in this category are: instruction, contacts, documents, issues, coordinates, attributes, connections.

The tables which include the information necessary to the FM activities, and thus to be completed in the Data Drop 4, are named "Job", "Resource", "Spare".

6.6 Information Management for the Building Operational Phase: PAS 1192-3:2014

Given the importance of an information management process referring to the building use phase, the BSI (British Standards Institution) has published a document which is named BSI PAS 1192-3:2014, "Specification for information Management for the operational phase of assets using building information modeling".

By focusing on a BIM implementation focused on the FM sector, this specification aims at underlining the need for an Information Management Process (IMP), and thus for an Asset Information Model (AIM), as a unique and coherent data store concerning building assets (Fig. 6.5).

According to this BSI specification, the AIM should include the following information:

- data and geometry describing the assets and the spaces/items associated with them;
- performance data;

[7]COBie Tables: Instruction, Contact, Facility, Floor, Space, Zone, Type, Component, System, Assembly, Connection, Spare, Resource, Job, Impact, Document, Attribute, Coordinate, Issue, Picklists.

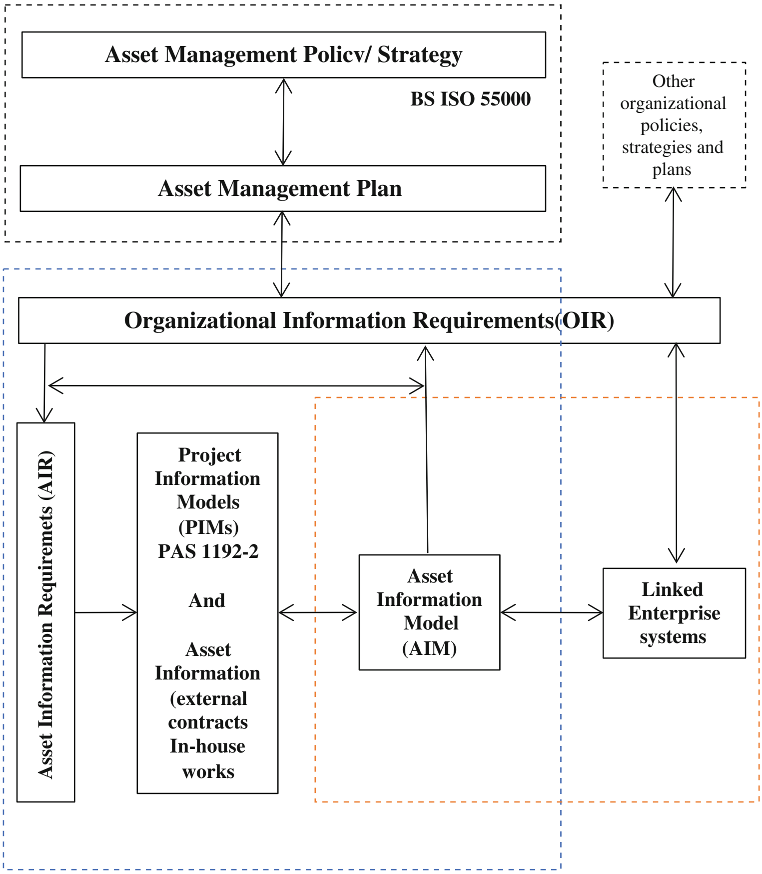


Fig. 6.5 The information management process as proposed by the BSI PAS 1192-3:2014

– supporting information (i.e. specifications, operation and maintenance manuals, health and safety information etc.).

Most of these information come from previous lifecycle phases (i.e. capital/delivery phase of the construction projects). Therefore, in order to manage building assets at optimal whole life cost, the relationship between design/construction phases and operation and maintenance phase is really important.

Data transfer processes between lifecycle stages are necessary to:

– create a unique, complete and rich AIM able to exchange information with a Project Information Model (PIM);
– revise the Asset Information Model each time the assets are modified.

The AIM has to be first enriched with data coming from the PIM, but then it has to be continuously updated during the whole operational lifecycle of the assets. It should include not only handover from design and construction phases, but also daily O&M activities.

The Asset Information Model in fact has to work as a data repository, but also as a means of accessing and receiving information. In a first phase, it should collect data from all the other parties involved throughout the project stages. Then, during the building use phase, the organization is responsible of the continuous update of the AIM which can be managed in two different ways:

– totally within the data model (all the information concerning building assets are included in the BIM objects);
– accessed via links and cross-references to existing enterprise information systems.[8] Information exchange between existing enterprise systems and the AIM has to be defined by the organization according to their information requirements and relationship management systems with the other stakeholders involved in the FM activities. For example, it has to be clearly defined what kind of information is available to external contractors or in-house working teams as useful for their contracts or works.

Therefore, Asset Information Requirement (AIR) shall define the structure, process and content of information to be contained in, exchanged with or linked to the Asset Information Model according to the Organization Information Requirement (OIR).

Moreover, the informational structure concerning each building asset has to be defined according to the activities it supports and it has to be useful for its maintenance and management. Then, the type of information required at each information exchange will be different depending on the nature and practices of the organization but the method shall be unique and coherent to avoid information loss and data asymmetry. For example, COBie is the schema for information exchange to be used in the UK Government mandated projects.

Focusing on the content requirement, the AIM shall generally contain:

– "information concerning the original brief, specification, design intent and analysis relating to the original installation of the asset and any subsequent changes;
– 3D object-based model(s) of the environment and location of the asset;
– information, or links to information, concerning the ownership of the asset and any rights or covenants associated with the asset;
– information, or links to information, and data obtained from the maintenance, survey or other work carried out on the asset during its lifetime" [17].

Going into detail, the informational structure of an asset shall specifically include:

[8]Archibus has recently developed a plug-in in collaboration with Autodesk to make possible bidirectional information exchange with the BIM software Revit.

- *legal information* (i.e. ownership, and then contractual information, property boundaries in case of an asset is networked and/or interfaced with an another one by making a unique system, work instructions, legal obligations such as health and safety file information, etc.);
- *commercial information* (i.e. asset description and function, vendor data, KPIs, condition and performance targets/standards, spares description/quantity/location, etc.);
- *financial information* (i.e. original purchase/leasing cost, current replacement cost, etc.);
- *technical information* (i.e. design parameters, asset dependencies and interdependencies, commissioning dates and data, performance characteristics, etc.);
- *managerial information* (i.e. identification number, asset location, spatial data as room size/pavement area, warranties description and duration, work schedules and details of the tasks to be carried out, list of the maintenance activities already performed, any hazardous content/waste, asset end of life, etc.).

6.7 BIM-Objects Information Requirements and Data Standards

Given the importance of defining the information requirement of a data model, many research groups are working on this topic. In fact, standardizing the knowledge and process management in a BIM environment guarantees to overcome information loss and data asymmetry determining negative effects in terms of cost and time efficiency, above all on the FM sector.

By taking a step forward LoDs, which define progressive levels of development without specifying the so called "non-geometric" information to be associated to model elements, research groups are now focusing also on the specific content requirement to be included in BIM objects.

Recently they have developed some data standards aiming at identifying which information has to be included in BIM objects in order to ensure an Information Lifecycle Management. In particular:

- the *BSI PAS 1192-3:2014* defines the information management process (Fig. 6.5) for the building operational phase of assets. It specifies relations and information flows between stakeholders, as well as the content requirement of BIM objects. It declares that an Asset Information Model shall include:
  - legal information;
  - commercial information;
  - financial information;
  - technical information;
  - managerial information concerning building assets.

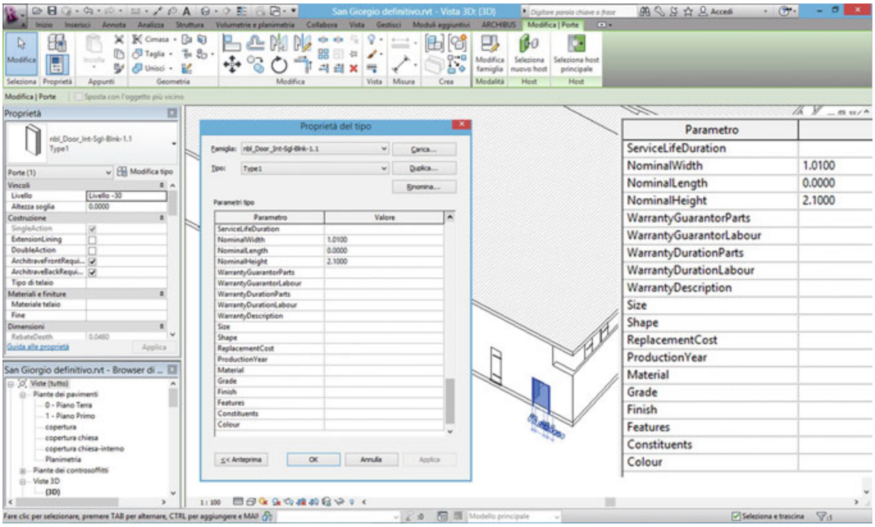


Fig. 6.6 Parameters included in a door downloaded from the NBS BIM Library. Focus on parameters useful for FM activities

- the *NBS BIM Object Standard*[9] has standardized the dataset to be included in BIM objects (Fig. 6.6) in order to support the development of a shared use of individually authored models in a CDE. It declares that a model element shall be characterized by:
  - general requirements;
  - information requirements;
  - geometry requirements;
  - functional requirements;
  - metadata requirements.
- the *Specifiers' Properties information exchange (SPie) project* aims at defining the minimum standard set of information (Table 6.4) to be included in a BIM object in order to create a set of product templates to be first completed by manufacturers and then used by all the actors of the construction process. It includes all the COBie parameters.
- the *Product Data Templates (PDTs)* (Fig. 6.7), being elaborated by the Chartered Institution of Building Service Engineers (CIBSE), are standardized datasets, following a master template, aiming at identifying all the information required by each party involved in the construction process. They provide data about the following categories:

[9]The NBS BIM Object Standard has been assumed by the NBS BIM Library as the official data standard according which all the BIM objects downloadable from the library are implemented.

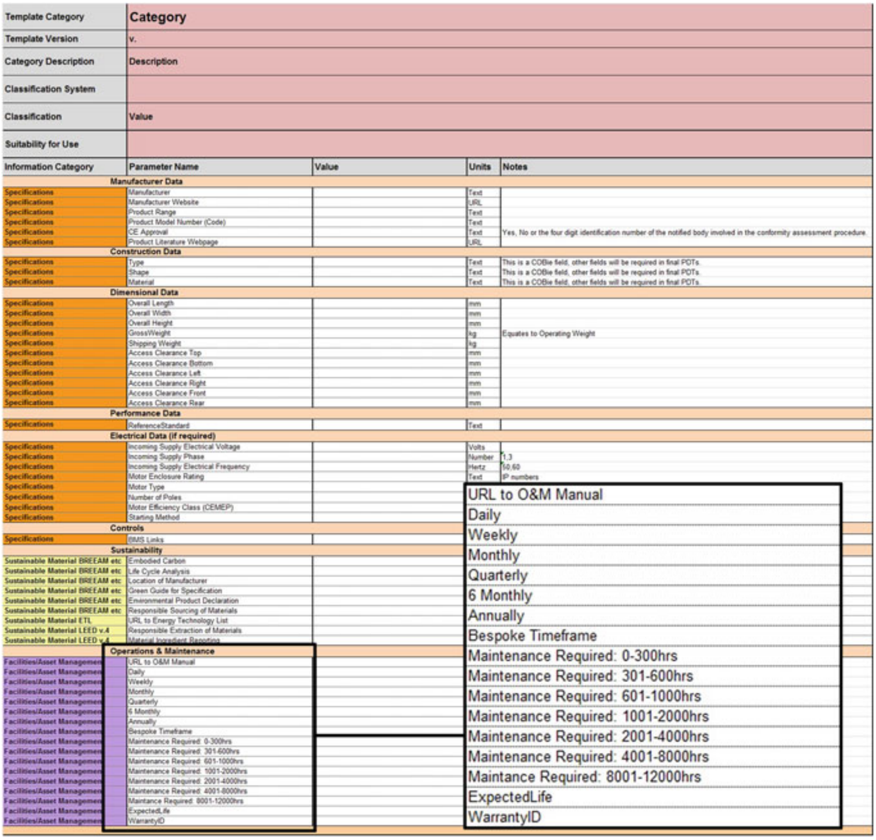
Table 6.4 Some parameters useful to FM activities extracted from the SPie datasheet template of a generic door [26]

Door style	Door_DOOR_Flush Wood Doors_US	Flush wood doors template
Manufacturer	n/a not defined	The organization that manufactured and/or assembled the item
Model label	Not defined	The model number and/or unit designator assigned by the manufacturer of the manufactured item
Asset accounting type	Fixed	Identifies the predefined types of asset from which the type required may be set
Warranty name	n/a	The name of the warranty
Warranty description	n/a	Description of the warranty
Warranty guarantor parts	n/a	Organization acting as guarantor of parts warranty
Warranty duration parts	n/a	Duration of parts warranty (years)
Warranty guarantor labor	n/a	Organization acting as guarantor of labor warranty
Warranty duration labor	n/a	Duration of labor warranty (years)

  - manufacture;
  - construction;
  - geometry;
  - sustainability;
  - operations and maintenance.

- the *INNOVance database*, aiming at creating an Italian BIM database in which building objects and construction products, besides being 3D modeled, will also include a set of standardized parameters useful for the whole construction service life. The standard datasheet according to each building elements will be described provides information about:

  - general parameters such as shape, color, geometry, etc.;
  - composition;
  - performance;
  - economic aspects;
  - operational activities.



Template Category	Category			
Template Version	v.			
Category Description	Description			
Classification System				
Classification	Value			
Suitability for Use				
Information Category	**Parameter Name**	**Value**	**Units**	**Notes**
Manufacturer Data				
Specifications	Manufacturer		Text	
Specifications	Manufacturer Website		URL	
Specifications	Product Range		Text	
Specifications	Product Model Number (Code)		Text	
Specifications	CE Approval		Text	Yes, No or the four digit identification number of the notified body involved in the conformity assessment procedure.
Specifications	Product Literature Webpage		URL	
Construction Data				
Specifications	Type		Text	This is a COBie field, other fields will be required in final PDTs.
Specifications	Shape		Text	This is a COBie field, other fields will be required in final PDTs.
Specifications	Material		Text	This is a COBie field, other fields will be required in final PDTs.
Dimensional Data				
Specifications	Overall Length		mm	
Specifications	Overall Width		mm	
Specifications	Overall Height		mm	
Specifications	GrossWeight		kg	Equates to Operating Weight
Specifications	Shipping Weight		kg	
Specifications	Access Clearance Top		mm	
Specifications	Access Clearance Bottom		mm	
Specifications	Access Clearance Left		mm	
Specifications	Access Clearance Right		mm	
Specifications	Access Clearance Front		mm	
Specifications	Access Clearance Rear		mm	
Performance Data				
Specifications	ReferenceStandard		Text	
Electrical Data (if required)				
Specifications	Incoming Supply Electrical Voltage		Volts	
Specifications	Incoming Supply Phase		Number	1,3
Specifications	Incoming Supply Electrical Frequency		Hertz	50,60
Specifications	Motor Enclosure Rating		Text	IP numbers
Specifications	Motor Type			
Specifications	Number of Poles			
Specifications	Motor Efficiency Class (CEMEP)			
Specifications	Starting Method			
Controls				
Specifications	BMS Links			
Sustainability				
Sustainable Material BREEAM etc	Embodied Carbon			
Sustainable Material BREEAM etc	Life Cycle Analysis			
Sustainable Material BREEAM etc	Location of Manufacturer			
Sustainable Material BREEAM etc	Green Guide for Specification			
Sustainable Material BREEAM etc	Environmental Product Declaration			
Sustainable Material BREEAM etc	Responsible Sourcing of Materials			
Sustainable Material ETL	URL to Energy Technology List			
Sustainable Material LEED v.4	Responsible Extraction of Materials			
Sustainable Material LEED v.4	Material Ingredient Reporting			
Operations & Maintenance				
Facilities/Asset Managemen	URL to O&M Manual			
Facilities/Asset Managemen	Daily			
Facilities/Asset Managemen	Weekly			
Facilities/Asset Managemen	Monthly			
Facilities/Asset Managemen	Quarterly			
Facilities/Asset Managemen	6 Monthly			
Facilities/Asset Managemen	Annually			
Facilities/Asset Managemen	Bespoke Timeframe			
Facilities/Asset Managemen	Maintenance Required: 0-300hrs			
Facilities/Asset Managemen	Maintenance Required: 301-600hrs			
Facilities/Asset Managemen	Maintenance Required: 601-1000hrs			
Facilities/Asset Managemen	Maintenance Required: 1001-2000hrs			
Facilities/Asset Managemen	Maintenance Required: 2001-4000hrs			
Facilities/Asset Managemen	Maintenance Required: 4001-8000hrs			
Facilities/Asset Managemen	Maintance Required: 8001-12000hrs			
Facilities/Asset Managemen	ExpectedLife			
Facilities/Asset Managemen	WarrantyID			

Fig. 6.7 Product Data Template (PDT). Focus on the operations and maintenance parameters [23]

Since the large number of research groups working on data standards, it is clear the growing need of the construction sector to define BIM-Objects information requirements.

For example, if we consider the Construction Strategy developed by the UK Government [15], it becomes clearer the growing need for standardizing BIM objects information contents. In fact, in the BIM Maturity Level 2,[10] construction

[10]The UK Government has defined a "Construction Strategy" asking for the use of Building Information Modeling with a Maturity BIM Level 2 for public sector projects by 2016. The UK Government has recognized that the process of moving the construction industry to a full collaborative environment will be progressive, with distinct and recognizable milestones being defined within that process, in the form of three levels. Collaboration at BIM Level 2 is file-based as opposed to paper-based (BIM Level 0) or through integrated web services (Level 3).

products and building elements are not just described by geometric information, but also by a series of metadata included in the model elements.

Given the mandatory nature of this strategy, a lot of actors of the construction process are willing to start working according to BIM Level 2. The problem is that few manufacturers have already modeled their products as intelligent objects containing also non-geometric information. In fact, there is still confusion about the BIM-Objects information requirements. A main question is then arising: "What data are needed in product models to satisfy the public sector client and other players using Level 2 BIM?" and, above all, "What information shall be included in BIM objects to support FM activities?"

Standardizing datasets in order to handle an information management process focusing also on the building use phase is useful not only to define what information must be included in BIM-Objects to support FM activities, but also to enable the development of interoperable overlays between BIM software and information systems. In fact, as the BSI PAS 1192-3:2014 underlines, an Information Lifecycle Management can be managed in two different ways: totally within the BIM model (all the information useful for FM activities is included in BIM objects) or accessed through interoperable overlays between BIM software and information systems (i.e. between Revit and Archibus) (Chap. 7). Therefore, many actors involved in the FM industry have begun to investigate the possibility to use BIM as a lifecycle and interdisciplinary data-store from which extract useful information for Facilities Information Systems and then support operation and maintenance activities in a BIM environment.

6.7.1 NBS BIM Object Standard

The NBS BIM Object Standard, which has been set by the NBS (National Building Specification),[11] is an industry standard aiming at meeting the need of information standardization coming from the AEC/FM sector [25].

In fact by standardizing the information included in model elements, it is possible to develop an object-based approach where the BIM methodology really works as a lifecycle data store. Standardizing property sets to be associated to BIM objects is one of the main goals to be achieved in order to support the development of a shared use of individually authored models in a Common Data Environment.[12]

A BIM object in fact is generally able to provide:

[11]The National Building Specification is part of RIBA Enterprises Ltd, which is wholly owned by the Royal Institute of British Architects (RIBA). It is committed to define specification products and information solutions which cover building construction, engineering services and landscape design.

[12]According to the PAS 1192-2:2013, a common data environment is a single source of information for any given project used to collect, manage and disseminate all relevant approved project documents for multi-disciplinary teams in a managed process.

– visualization data giving the object a recognizable appearance;
– model geometry representing the physical characteristics of the construction products/building elements;
– information content, to be defined according to the different lifecycle stages and outputs of the BIM model. For example, as already underlined, the information requirement of a data model developed in the construction phase to support FM activities will surely have a different information content in comparison to a model used for a structural analysis developed in a preliminary design phase;
– behavioral data such as detection, maintenance and clearance zones.

Considering the huge potentiality of BIM objects, it is clear the importance to develop a standardized approach for BIM objects, as creating digital libraries (i.e. the National BIM Library) where these digital building elements can be downloaded and then used by all the actors of the construction process according to a data quality standard.

The NBS National BIM Library is working towards achieving this goal. In fact each object which can be downloaded from the BIM library has been developed according to the NBS BIM Object Standard (Fig. 6.6). This is a standardized property set that:

– is aligned with the COBie data schema;
– adopts a consistent approach regarding classification of building elements;
– applies a standard naming convention;
– standardizes levels of detail, content requirements and tridimensional presentation of BIM objects.

Moreover, all the BIM objects which have been developed according to this standard, and thus downloadable from the NBS National BIM Library, are created in the Industry Foundation Class (IFC) format. In this way, it is ensured the consistent and straightforward use of these intelligent objects in the various BIM platforms, as well as achieving stakeholders' collaboration and interoperability of tools.

Focusing on the specific property set defined by the NBS BIM Object Standard, it can be seen the following classification according to all the parameters have been grouped:

- *general requirements*, such as the appropriate 'IfcTypeObject' and 'IFC predefined type' from the BuildingSMART International IFC schema[13];
- *information requirements* which includes the whole COBie property set and the so called "NBS_General" properties (i.e. Manufacturer URL, Product Information, etc.);

[13]The Industry Foundation Classes (IFC) schema, which has been developed by the International Alliance for Interoperability (IAI), now BuildingSMART International, represents a data model structure for sharing construction and facility management data across various applications (tools and software) used in the building domain. It is a neutral and open specification that is not controlled by a singular vendor or group of vendors [28].

- *geometry requirements* which are further classified into general data, shape data, symbolic data, space data, surface and material data.
- *functional requirements* describing behavioral characteristics, constraints and connectivity;
- *metadata requirements* which include naming convention for files, objects, properties, materials, values and images.

Focusing on the information which may be useful for the building use-phase, besides the geometric information and the COBie parameters (i.e. NominalWidth, NominalLength, WarrantyGuarantorParts, WarrantyDescription, etc.) (Fig. 6.6), also the data within the 'geometry requirements' category concerning the space description are particularly relevant for the FM activities. In particular:

– minimum operation space;
– access space;
– placement and transportation space;
– installation space;
– detection zone space.

The functional requirements describing constraints and connectivity of the building assets may be useful for the FM activities in order to understand physical configurations/interrelations between building elements.

6.7.2 SPie: Specifiers' Properties Information Exchange

As the Royal Institute of British Architects (RIBA), also the buildingSMART alliance is working at defining the minimum standard set of information to be included in a BIM object by developing the Specifiers' Properties information exchange (SPie) project [26].

The SPie project has been undertaken in 2007 by the members of the buildingSMART alliance in collaboration with the Specifications Consultants in Independent Practice (SCIP) and the help of the Construction Specifications Institute (CSI), some software companies, as well as public and private sector representatives. The objective of the SPie project is to create a set of product templates to export products data into an open-standard format to be first completed by manufacturers and then used by all the actors of the construction process (i.e. designers, builders, operators, owners, etc.).

The key point about Building Information Modeling, in fact, is that a model should provide not only the geometry of a building element, but also a set of non-geometrical information.

There are many different attributes concerning building assets that have to be captured during the design and construction phases and then maintained during the use phase. Moreover, different types of building elements/components are characterized by different information requirements. "For example, it may not be meaningful to specify the color of a pump, however, the color may be the most important characteristic of an assembly such as a kitchen wall. Other properties pertain to both products and assemblies. For example a fire rated wall will itself be composed of products such as drywall and doors that have their own fire rating as well" [26].

In this sense, product manufacturers and replacement parts suppliers play a key role in providing specific information about building assets. This is the main reason why the buildingSMART alliance is developing this set of product templates to be completed with products information directly by manufacturers.

Focusing on the parameters defined by these product data templates which can be useful for the FM activities, it is possible to underline all the COBie parameters, since these standardized datasheets are totally aligned with the COBie data schema. Then, in this data standard there can be found useful parameters (Table 6.4) such as:

- Manufacturer;
- Model Label;
- Warranty Name;
- Warranty Description, etc.

6.7.3 PDTs: Product Data Template(s)

Aiming at answering the same question, which is the minimum set of information to be included in a model element to support an ILM in a BIM environment, the CIBSE[14] is working on a project developing the so called Product Data Templates (PDTs) [23].

PDTs are standardized dataset, following a master template, aiming at identifying all the information required by every party involved in the construction process (Fig. 6.7). They are written in Excel format and then usable in all BIM platforms.

[14]The Chartered Institution of Building Service Engineers is an International professional engineering association based in London representing building services engineers. It is a full member of the Construction Industry Council (CIC) and it is consulted by the government on matters concerning construction, engineering and sustainability.

A completed PDT[15] become a PDS (Product Data Sheet)[16] which is a sort of product-specific description answering the information needs of the construction process. Moreover, the standard template according to all the PDSs have been developed enables end-users to automatically extract data according to the diverse needs of the different lifecycle stages.

The informational structure of a PDS allows much of an output data schema (i.e. COBie) to be automatically populated. Nevertheless, it has to be said that PDTs provide only general product information. Therefore, they do not include specific parameters such as replacement cost, reference service life, etc. As the CIBSE itself declares on its website "Obtaining such data remains a normal project process of enquiry and quotation. Application-specific fields of 'output' data-formats are not answered by the PDS" [23].

PDTs just provide a qualitative/quantitative description of the following three information categories (Fig. 6.7):

- *specification*, which includes manufacturer data, construction data, dimensional data, performance data, electrical data, controls;
- *sustainability*;
- *operations and maintenance*.

Focusing on the FM informational needs, and then on the "Operations and maintenance" category, the PDTs provide the following parameters (Fig. 6.7):

- URL to O&M manual;
- classification of the O&M activities according to their relative frequency (daily, weekly, monthly, quarterly, 6 monthly, annually, bespoke timeframe);
- classification by hours of the maintenance required (0–300, 301–600, 601–1000, 1001–2000, 2001–4000, 4001–8000, 8001–12,000 h);
- expected life;
- warranty ID.

6.7.4 INNOVance: the Italian BIM Database

The INNOVance project [24] has been funded by the Italian Ministry of Economic Development and developed by a consortium made of universities (Milan, Turin, Naples and other national research centers), builders' associations (Consorzio

[15]The filling out of the PDTs from products manufacturers is the final goal strongly promoted by the CIBSE.

[16]The manufacturer owns the PDS and is free to use it on its website and in any library it chooses. The manufacturer remains responsible for the accuracy and completeness of its data on the PDS.

Ancenergia), trade associations, national energy associations (ENEA) and IT companies (SAP, Autodesk) [16].

The research project aims at creating an Italian BIM database, similar to the English NBS BIM Library. Building objects and construction products available on this BIM platform, besides being 3D modeled, will also include a set of standardized parameters useful for the whole construction service life. In this way, the efficiency, in terms of costs and time, in using and maintaining objects information will be consistently improved throughout the entire lifecycle by linking continually updated, extensible life-cycle objects data to independent software using Building Information Models.

The fundamental steps which have been made to develop this BIM database can be summed up as it follows:

– standardizing a naming system for each entity (product and/or process) part of the construction process;
– defining the informational structure and content associated to each named entity;
– pairing each entity in the database with a BIM object.

Considering the heterogeneity of the Italian construction sector, the codification process has been a necessary step to overcome difficulties and errors in data exchange. Therefore, one of the main goal of the INNOVance project has been both to codify and standardize a naming system.

After having univocally codified the names of construction products, building objects, etc., the INNOVance team has developed a datasheet with a set of standardized parameters for each one of these entities.

All these datasheets will be open and free since they will be uploaded on the INNOVance web-platform. Moreover, the project aims also at developing specific plug-ins for existing BIM software, so that it will be possible to upload these data-enriched BIM objects developed by INNOVance directly in the BIM software. It is also planned to guarantee the interoperability of this BIM database with the IFC standard, due to the collaboration with Building Smart Italy [16].

Going into detail about the parameters which has been selected by the INNOVance project as useful for the whole construction process, and then included in the developed datasheets, they have been classified into the four following categories:

- *descriptive information* which includes: geometry, shape and visual and/or construction appearance (i.e. finish, geometry, color, etc.);
- *composition data* describing elements/substances from which is made of the analyzed entity;
- *performance characteristics* including mechanical resistance, fire reaction, health and safety, acoustic and thermal performance (i.e. U-values), environmental impact data (i.e. GWP, EP, AP, etc.);
- *economic and operational parameters* such as cost, construction technology, etc.

Focusing on the informational needs of the FM activities, the most useful parameters included in these datasheets are those ones included in the category "economic and operational parameters". For example, it is possible to extract information about the scheduled maintenance activities for the specific building object/construction product analyzed. In particular, the datasheet includes: description of the maintenance activity, frequency, indication about the possibility for the user to directly carry out by himself the maintenance activity, the estimated cost and the ID.

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Chapter 7
Methodological Experimentation: Proposal of a Datasheet Template for FM Activities in the BIM Environment

Abstract The aim of this chapter is to investigate a possible implementation of the existing BIM-Objects Information Requirements and data standards in relation to information need of FM processes. In order to address this topic, it is presented the output of a methodological experimentation carried out at Politecnico di Milano with the aim of defining a datasheet template enabling information exchange to support FM activities in a BIM environment. The proposed data schema together with its protocol compilation shall support FM activities by defining a dataset to be included in model elements as necessary to multiple activities which characterizes facility management phase (i.e. maintenance scheduling, space management, spare parts management, etc.). Ongoing research is showing some areas of possible integration of the protocol/data format with FM activities, such as the development of a maintenance manual starting from the design and construction information as provided by the BIM model. The developed datasheet template is also allowing some experimentation concerning the implementation of existing interoperable overlays between BIM software and Facilities Information Systems.

Keywords BIM-Objects information requirements · Data standards · FM-based implementation · Interoperability · Facilities information systems

7.1 Need for an Implementation of Existing Data Standards in Relation to Information Needs of FM Processes

Building Operations and Maintenance (O&M) often represent one of the most expensive building-related activities, since the lack of stakeholders' communication and data interoperability throughout the whole construction process.

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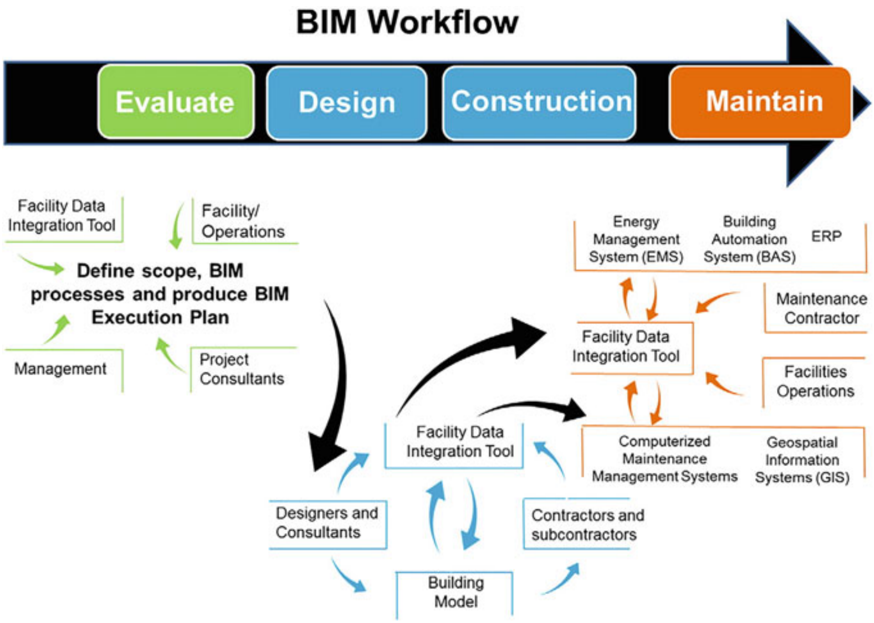

Fig. 7.1 BIM lifecycle workflow [1]

This means that, in order to overcome ineffective and partial information exchanges from the design and construction stages to the use phase, building-related information shall be properly captured, used and stored through the whole asset's life cycle by making them standard and interoperable (Fig. 7.1).

Building Information Modeling represents both the tool and the methodology which can make the AEC/FM stakeholders able to achieve this goal. BIM is able to manage asset-related information along the building lifecycle by providing both the physical and functional characteristics of a facility (Chap. 6).

BIM can both enhance efficient and effective O&M planning, monitoring and control and increase the quality of data, as well as decrease risk and costs. There is significantly growing evidence linking BIM benefits to FM activities, as demonstrated by the current research trend focused on defining BIM standards for the handover of facilities management data (Chap. 6).

Although many research groups, as governments,[1] are working on this strategic topic, facility managers and asset owners are still skeptical about the value of implementing the BIM methodology into their existing processes and activities [1].

Given these considerations, a research group from Politecnico di Milano is focusing on the topic of BIM implementation in the field of FM activities [2].

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[1]The United Kingdom (UK) Government is driving to define BIM standards for the handover of facilities management data in the form of Construction Operations Building Information Exchange (COBie) and the Facilities Management (FM) Handover Model View Definition (MVD).

The main goal of the research project[2] is to standardize a datasheet template referring to operations and maintenance phase to enable information exchange in a BIM environment. This data schema should define for each building element a minimum dataset as necessary to multiple activities which characterizes facility management phase (i.e. maintenance scheduling, space management, spare parts management, etc.). In particular, research objectives can be described as it follows:

– definition of a data schema together with its compilation protocol (information taxonomy) for exchanging data related to FM activities in a BIM environment;
– elaboration of a datasheet template for each construction product/building element in order to enhance the information lifecycle management of data concerning FM activities;
– validation of the developed datasheet template in a BIM environment.

In order to address these goals, the research activity has faced the following steps:

– defining the reference scenario by analyzing existing BIM-Objects Information Requirements and data standards (Chap. 6);
– adopting a building registry and a maintenance plan prototype[3] as a primary source of information to define which are the attributes useful to FM activities and processes;
– defining which are the informational attributes to be included in the datasets as useful for FM activities by analyzing the adopted maintenance plan prototype;
– codifying the information previously identified in the maintenance plan prototype in datasets compatibly organized with the analyzed BIM-Objects Information Requirements and data standards;
– selecting and adopting a BIM software;
– defining the information taxonomy by identifying which information included in the developed datasets can be automatically provided by the BIM software as element properties (i.e. geometric information) and by existing BIM-Objects Information Requirements and data standards (i.e. material, manufacturer, model, product page URL, etc.);
– identifying possible sources (i.e. bill of quantities, abacus building components, manufacturer documentation, etc.), referring to different phases of the building process, for each informative attribute of the dataset which is not automatically provided neither by BIM software nor existing data standards;

[2]The research project is an in-depth study inside the PRIN (Progetto di Ricerca di Interesse Nazionale) research "Built Heritage Information Modelling/Management—BHIMM".

[3]The maintenance plan prototype has been developed within the context of a research project commissioned by ATE (the technical office in Politecnico di Milano for buildings management, valorization and development) aiming at developing a model of an information registry, unique for the entire building process and oriented to the needs of knowledge connected with operations and maintenance management.

– transferring and representing the building case study[4] in a BIM environment to test and validate the developed datasheet template.

The definition of this data schema is now allowing experimentations about:

– development of a maintenance manual starting from design and construction information as provided by BIM model;
– definition of possible datasets to integrate existing BIM-Objects Information Requirements and data standards;
– definition of possible datasets to implement interoperable overlay between BIM software and management information system (in particular Archibus) [2].

7.2 Critical Review of the Reference Scenario. Analysis of Existing Data Standards

The first step of the research project has been analyzing the existing data standards and information requirements in relation to the informational needs of building use and maintenance.

Specifically, it has been understood which are the informational attributes included in existing data standards as useful for FM activities. In this sense, a critical review has been done, aiming at defining strengths and weaknesses of the standardized information requirements which are already been developed by many research groups.

The existing BIM-Objects Information Requirements and data standards (Chap. 6) which have been taken as the reference scenario for the research project, and thus critically analyzed, are:

– the *COBie schema* [4] devised by the United States Army Corps of Engineers as a data standard able to store and deliver building information in a usable format for everyone throughout all the PLPs. Now it has been adopted by the UK Government as the official data format enabling information exchange between different lifecycle stages through the progressive filling out of the five data drops (Fig. 6.4);
– the *NBS BIM Object Standard* [7] which has been developed by the National Building Specifications (NBS) as the data standard to be included in all the BIM objects freely available to download from the NBS National BIM Library[5] (Fig. 6.6);

[4]The building case-study used to validate the developed datasheet template has been assigned by ATE (the technical office in Politecnico di Milano for buildings management, valorization and development). It is a students' residence which is currently under construction in Milan.

[5]The NBS National BIM Library is the fastest growing BIM library in the UK. It is an open and free web platform where it is possible to download a comprehensive collection of BIM objects ranging from building fabric systems to mechanical and electrical objects.

- the *SPie project* [8], still under development by the buildingSMART alliance, which aims at creating standardized datasets to be first completed by manufacturers with the specific products information and then used by all the actors of the construction process (Table 6.4);
- the *Product Data Templates* (PDTs) [5] developed by the Chartered Institution of Building Services Engineers (CIBSE) as datasets, following a master template, aiming at identifying all the information required by each party involved in the construction process, and thus providing a qualitative and quantitative description of building elements (Fig. 6.7);
- the *INNOVance project* [6] developed by a consortium of universities, builders and trade associations, as well as IT companies, with the aim of creating an Italian BIM database from which it will be possible to freely download BIM objects of construction products and building elements enriched with a set of standardized parameters.

All these data standards provide some attributes which are useful to support FM activities and processes (Chap. 6). To briefly recap:

- the *COBie schema* has been specifically developed to satisfy the information needs of the building operational phase and thus it includes useful parameters such as Installation Data, Warranty Description, Reference Service Life;
- the *NBS BIM Object Standard*, besides including all the COBie parameters, also provides some useful parameters concerning assets space management which are: minimum operation space, access space, placement and transportation space, installation space and detection zone space;
- the *SPie project* includes all the COBie parameters;
- the *PDTs*, developed by the CISBE, take into consideration the building use-phase by defining a specific category of parameters named "Operations and Maintenance";
- the *INNOVance project* includes a specific category of attributes named "economic and operational parameters" in the technical datasheets provided for all the construction products and building elements freely available to download from the developed BIM database;

In order to understand which parameters have been included in the analyzed data standards and information requirements as useful or not for FM activities, the research project has developed a comparing table (Fig. 7.2).

By comparing the informational structure of these data standards with the content requirement defined by the PAS 1192-3:2014, "Specification for information Management for the operational phase of assets using building information modeling" (Chap. 6), which has been adopted by the research project as the most recent and complete specification for the Information Lifecycle Management concerning the operational phase of assets, it is clear that each of the analyzed data standards shows some strengths and weaknesses.

According to this PAS, in fact, the Asset Information Model, and thus the information requirement adopted as data standard for the BIM-Objects included in

COBie	NBS Standard	SPie	PDT	INNOVance
Category (UNICLASS)	COBie Parameters	COBie Parameters	Model	Maintenance Activity Description
Description	Manufacturer URL		Manufacturer	Frequency
Asset Type	Minimum Operation Space		Manufacturer URL	Cost
Tag Number	Access Space		Access Clearance Top	ID
Model Number	Placement and Transportation Space		Access Clearance Bottom	
Warranty Description	Installation Space		Access Clearance Left	
Warranty Start Date	Detection Zone Space		Access Clearance Right	
Warranty Guarantor Parts			Access Clearance Front	
Warranty Duration Parts			Access Clearance Rear	
Warranty Guarantor Labor			URL to O&M Manual	
Warranty Duration Labor			Daily	
Warranty Duration Unit			Weekly	
Replacement Cost			Monthly	
Expected Life			Quarterly	
Name (JOB)			6 Monthly	
Category			Annually	
Duration			Bespoke Timeframe	
Start			Maintenance required: 0-300hrs	
Frequency			Maintenance required: 301-600hrs	
Name (SPARE)			Maintenance required: 601-1000hrs	
Description			Maintenance required: 1001-2000hrs	
Suppliers			Maintenance required: 2001-4000hrs	
Name (RESOURCE)			Maintenance required: 4001-8000hrs	
Description			Maintenance required: 8001-12000hrs	
			Expected Life	
			Warranty ID	

Fig. 7.2 Comparison table in which existing data standards are analyzed in relation to information useful for FM activities

the model, shall generally contain a set of specific information concerning building assets (Chap. 6). In particular:

– *legal information* (i.e. ownership, and then contractual information, property boundaries in case of an asset is networked and/or interfaced with an another one by making a unique system, work instructions, legal obligations such as health and safety file information, etc.);
– *commercial information* (i.e. asset description and function, vendor data, KPIs, condition and performance targets/standards, criteria of non-conformance, spares description/quantity/location, etc.);

- *financial information* (i.e. original purchase/leasing cost, current replacement cost, etc.);
- *technical information* (i.e. design parameters, asset dependencies and interdependencies, commissioning dates and data, performance characteristics, etc.);
- *managerial information* (i.e. identification number, asset location, spatial data as room size/pavement area, warranties description and duration, work schedules and details of the tasks to be carried out, list of the maintenance activities already performed, any hazardous content/waste, asset end of life, etc.).

Considering this informational structure as the most recent and complete specification for the Information Lifecycle Management, it is clear that the COBie schema is surely the most complete among all the reviewed data standards, since it provides parameters according all the categories mentioned above. Nevertheless, it shows some lacks concerning the "commercial information" category, because it does not provide any information about condition and duty of assets, key performance indicators, condition and performance targets or standards, criteria of non-conformance. Moreover it does not include any details of historical asset failures, causes and consequences, nor asset-related spatial data (i.e. minimum operation space, access space, etc.).

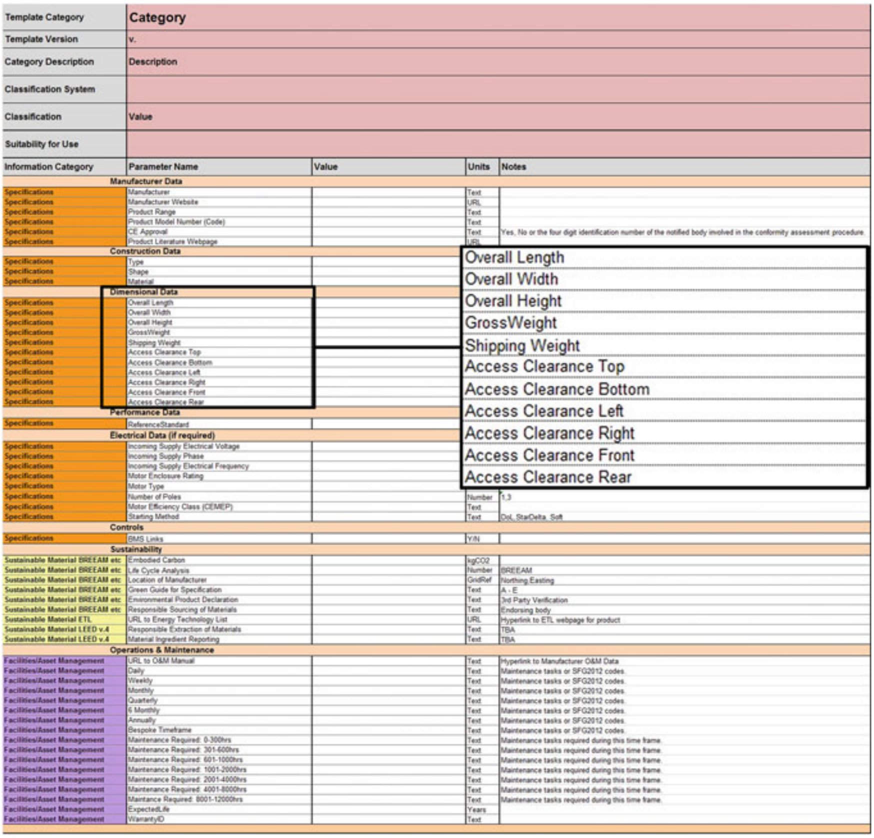
The NBS BIM Object Standard, as well as the SPie project, since they adopt all the COBie parameters in their informational structures, show the same weaknesses of the COBie schema. Nevertheless, the NBS BIM Object Standard, on the contrary to the COBie schema, provides some asset-related spatial data (minimum operation space, access space, placement and transportation space, installation space, detection zone space).

As the NBS BIM Object Standard, also the Product Data Template developed by the CISBE provides asset-related spatial data. Although, this datasheet is more specific concerning the "minimum operation space" attribute, since in the "dimensional data" category it describes the access clearance from different point of views (bottom, top, left, right, front, rear) (Fig. 7.3).

Nevertheless, the PDT, as the technical datasheets developed by the INNOVance project, shows again some weaknesses about the "commercial information" of assets. As for the COBie schema, there is no information about condition and duty of assets, key performance indicators, condition and performance targets or standards, criteria of non-conformance, as well as any data about historical asset failures.

7.3 Adoption of a Maintenance Plan Prototype as an Information Source for Developing a FM-Based Datasheet Template

The research project has adopted a maintenance plan prototype to understand the information which is useful to FM activities and processes, after having critically reviewed the existing BIM-Objects Information Requirements and data standards



Template Category	Category			
Template Version	v.			
Category Description	Description			
Classification System				
Classification	Value			
Suitability for Use				
Information Category	**Parameter Name**	**Value**	**Units**	**Notes**
	Manufacturer Data			
Specifications	Manufacturer		Text	
Specifications	Manufacturer Website		URL	
Specifications	Product Range		Text	
Specifications	Product Model Number (Code)		Text	
Specifications	CE Approval		Text	Yes, No or the four digit identification number of the notified body involved in the conformity assessment procedure.
Specifications	Product Literature Webpage		URL	
	Construction Data			
Specifications	Type			
Specifications	Shape			
Specifications	Material			
	Dimensional Data			
Specifications	Overall Length			
Specifications	Overall Width			
Specifications	Overall Height			
Specifications	GrossWeight			
Specifications	Shipping Weight			
Specifications	Access Clearance Top			
Specifications	Access Clearance Bottom			
Specifications	Access Clearance Left			
Specifications	Access Clearance Right			
Specifications	Access Clearance Front			
Specifications	Access Clearance Rear			
	Performance Data			
Specifications	ReferenceStandard			
	Electrical Data (if required)			
Specifications	Incoming Supply Electrical Voltage			
Specifications	Incoming Supply Phase			
Specifications	Incoming Supply Electrical Frequency			
Specifications	Motor Enclosure Rating			
Specifications	Motor Type			
Specifications	Number of Poles		Number	1,3
Specifications	Motor Efficiency Class (CEMEP)		Text	
Specifications	Starting Method		Text	DoL, StarDelta, Soft
	Controls			
Specifications	BMS Links		Y/N	
	Sustainability			
Sustainable Material BREEAM etc	Embodied Carbon		kgCO2	
Sustainable Material BREEAM etc	Life Cycle Analysis		Number	BREEAM
Sustainable Material BREEAM etc	Location of Manufacturer		GridRef	Northing Easting
Sustainable Material BREEAM etc	Green Guide for Specification		Text	A - E
Sustainable Material BREEAM etc	Environmental Product Declaration		Text	3rd Party Verification
Sustainable Material BREEAM etc	Responsible Sourcing of Materials		Text	Endorsing body
Sustainable Material ETL	URL to Energy Technology List		URL	Hyperlink to ETL webpage for product
Sustainable Material LEED v.4	Responsible Extraction of Materials		Text	TBA
Sustainable Material LEED v.4	Material Ingredient Reporting		Text	TBA
	Operations & Maintenance			
Facilities/Asset Management	URL to O&M Manual		Text	Hyperlink to Manufacturer O&M Data
Facilities/Asset Management	Daily		Text	Maintenance tasks or SFG2012 codes.
Facilities/Asset Management	Weekly		Text	Maintenance tasks or SFG2012 codes.
Facilities/Asset Management	Monthly		Text	Maintenance tasks or SFG2012 codes.
Facilities/Asset Management	Quarterly		Text	Maintenance tasks or SFG2012 codes.
Facilities/Asset Management	6 Monthly		Text	Maintenance tasks or SFG2012 codes.
Facilities/Asset Management	Annually		Text	Maintenance tasks or SFG2012 codes.
Facilities/Asset Management	Bespoke Timeframe		Text	Maintenance tasks or SFG2012 codes.
Facilities/Asset Management	Maintenance Required: 0-300hrs		Text	Maintenance tasks required during this time frame.
Facilities/Asset Management	Maintenance Required: 301-600hrs		Text	Maintenance tasks required during this time frame.
Facilities/Asset Management	Maintenance Required: 601-1000hrs		Text	Maintenance tasks required during this time frame.
Facilities/Asset Management	Maintenance Required: 1001-2000hrs		Text	Maintenance tasks required during this time frame.
Facilities/Asset Management	Maintenance Required: 2001-4000hrs		Text	Maintenance tasks required during this time frame.
Facilities/Asset Management	Maintenance Required: 4001-8000hrs		Text	Maintenance tasks required during this time frame.
Facilities/Asset Management	Maintance Required: 8001-12000hrs		Text	Maintenance tasks required during this time frame.
Facilities/Asset Management	ExpectedLife		Years	
Facilities/Asset Management	WarrantyID		Text	

Fig. 7.3 *PDT* Product Data Template. Focus on the dimensional parameters (*CIBSE*—Chartered Institution of Building Service Engineers)

by comparing their informational structure with the content requirement defined by the PAS 1192-3:2014.

In this way it has been possible to understand the informational needs of a maintenance manual (Fig. 7.4). In particular, the parameters included in the general schema of a maintenance manual are:

– element code;
– intervention;
– activity;
– cost;
– activity code;
– description;
– frequency;
– operator;
– duration;

Element code	Intervention	Activity	Cost %	Cost (€ / sqm)	Activity code	Description	Frequency	Operator	Duration (h/ man/sqm)	Failures code	Failures
3.1.1.2.E	Inspection	Visual inspection of the wall (indoor and outdoor)	1%	0,91	3.1.1.ISP.1	Evaluation of the degradation	Annual	OPC	0,01	3.1.1.Mg1 3.1.1.Mg2 3.1.1.Mg3 3.1.1.Mg4	Efflorescence Degradation of joints Discoloration Biological layer
		Examination of the cleanness of the wall	1%	0,91	3.1.1.ISP.6	-	Annual	PUL	0,01		
	Cleaning	Cleaning of the wall cladding	3%	2,73	3.1.1.PUL. 1	Cleaning the superficial surface of the wall | indoor	when needed	PUL	0,01		
	Maintenance	Remake of the painting	3%	2,73	3.1.1.MAN.1	Remake of the painting | indoor	Bian-nual	IMB	0,08		
		Recovery of the damaged parts of the wall	35%	31,85	3.1.1.MAN.2	Recovery of the damaged tiles	when needed	MRT	0,5		
	Replacement	Partial replacements of elements	35%	31,85	3.1.1.SOST.1	-	when needed	MRT	1		

Fig. 7.4 Example of a maintenance manual [2]

– failures code;
– failure.

Given this informational schema, it is clear that all the existing data standards show some lacks about at least one of the parameters necessary to develop a maintenance manual. For example, if we suppose to adopt the COBie schema as data standard to manage information in a BIM environment and then to develop the maintenance manual starting from the design and construction information as provided by the BIM model, we will lack data to fill out the "Failures" column of the maintenance manual (Fig. 7.4). Or again, by considering the technical datasheets developed by the INNOVance project as the BIM data format able to handle the ILM in a common data environment, we will face some difficulties in filling out the "Operator" and "Duration" columns (Fig. 7.4).

Given these considerations, the research project has developed a datasheet template (Fig. 7.5) aiming at satisfying the information needs of the FM activities and processes, focusing in particular on the information needed to develop a maintenance manual.

The proposed datasheet template has been developed by bringing together parameters taken from the different BIM-Objects Information Requirements and data standards which have been taken as the reference scenario for the research project (Chap. 6). Moreover, to develop the datasheet, it has also been considered the informational structure proposed by the PAS 1192-3:2014 (Fig. 6.5).

Through the adoption of this datasheet template, it would be possible:

– an integration of the COBie schema focused on the content requirement of a maintenance plan (Fig. 7.6).
  In this way, it would be possible to develop maintenance manuals starting from the data included in BIM objects. This procedure is not possible yet, since the

Parameter	Description	Unit of measurement
IDENTIFICATION PARAMETERS		
Category		OMNICLASS
Description		text
Asset Type		text
Model Number		code
Tag Number		code
Asset Dependencies		text
COMMERCIAL PARAMETERS		
Manufacturer		URL + @
Key Performance Indicator		text
Spares Identity		code
Spares Quantity		number
FINANCIAL PARAMETERS		
Replacement cost		euro
TECHNICAL PARAMETERS		
Height		mm
Length		mm
Emergency Position		s/n
Core Material		text
Finish Material		text
Opaque surface		%
Opaque surface		sqm
Glazed surface		%
Glazed surface		sqm
MANAGERIAL PARAMETERS		
Reference Service Life		year
Installation Date		gg/m/anno
Starting Date Warranty		gg/m/anno
Description Warranty		text
Duration Warranty		months
Reference Warranty		@
Maintenance Activity		text
Type Maintenance Activity		text
Frequency		daily, monthly, four-monthly, bi-annual, annual
Duration		hrs
Operator		text
Cost Maintenance Activity		euro
Access Clearance Top		sqm
Access Clearance Bottom		sqm
Access Clearance Right		sqm
Access Clearance Left		sqm
Access Clearance Front		sqm
Access Clearance Rear		sqm
Failure		text

Fig. 7.5 Example of the datasheet template developed by the research project for a generic door. It is an integration of parameters taken from the COBie schema and the PDT with new ones identified by the research as useful for FM activities

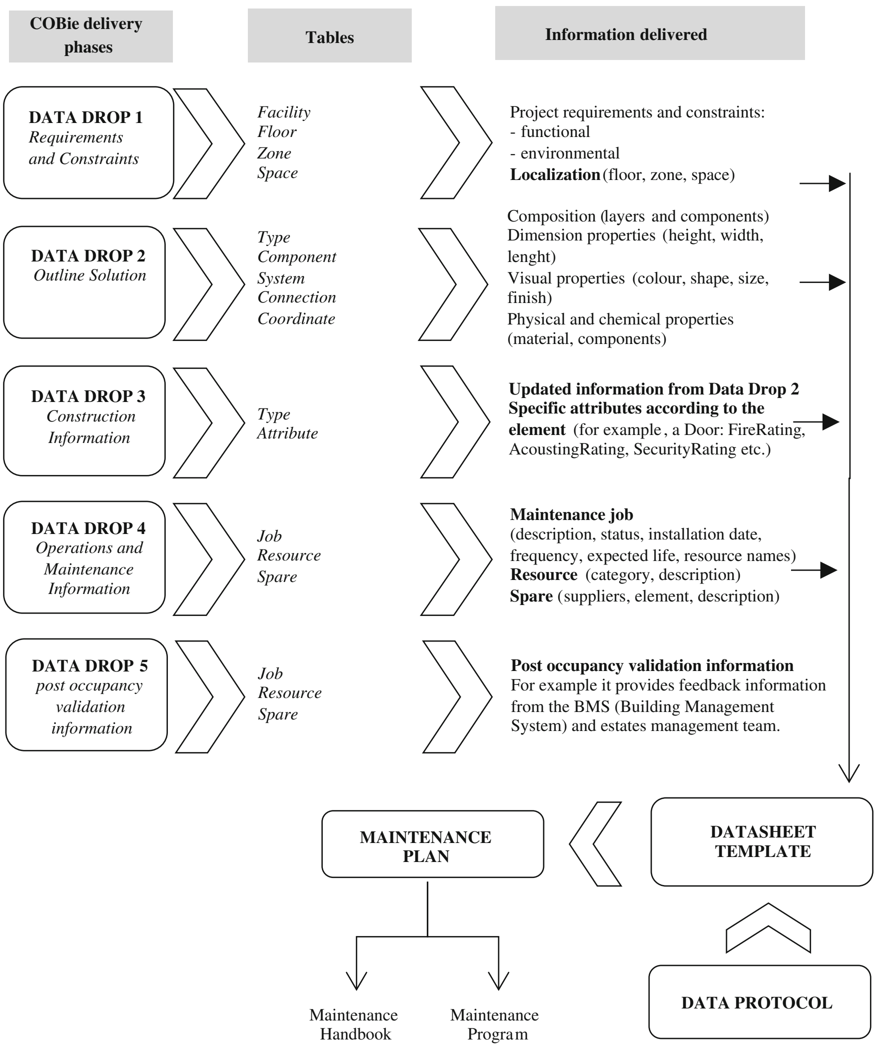


Fig. 7.6 Possible integration of the COBie schema with the developed datasheet template focused on the content requirement of a maintenance plan

COBie data format does not provide any information about assets breakdown modalities/decay, nor it has working resources' coding system to link each maintenance activity to its worker (correspondence among breakdown modalities—maintenance activity—worker);

– an implementation of current BIM-Objects Information Requirements and data standards which are adopted by the existing BIM libraries. For example, the NBS BIM Object Standard [7], which is the data schema adopted by the BIM library "NBS National BIM Library" (Fig. 6.6) may be implemented with the

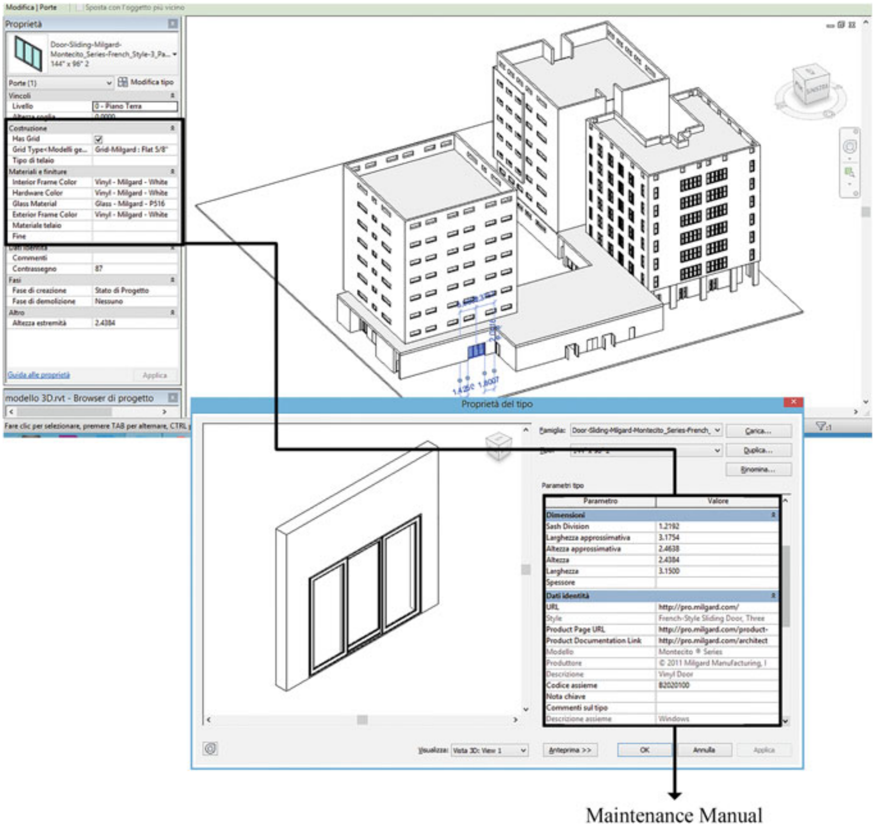


Fig. 7.7 Possible implementation of the NBS BIM-object standard with the developed datasheet template in order to develop maintenance manuals starting from the datasets included in BIM objects

parameters defined as useful for FM activities by the developed datasheet template (Fig. 7.7);

– a simulation of Building Operating conditions at the very early stage of the building design. In this way, the developed data template may be used by all the actors of the construction process as a decision support tool concerning the facility management phase of a building;
– a definition of possible datasets to implement interoperable overlay between existing BIM software and Facilities Information Systems.

7.4 BIM Software and Information Systems. Existing Overlay and Possible Implementation

Nowadays many software companies working in the field of CAFM (Computer Aided Facility Management) applications and Facilities Information systems are focusing on developing overlays with BIM software. It has been understood the potential of a two-way data exchange between BIM applications which capture, manage and store data throughout the building lifecycle and information systems supporting FM activities and processes.

In fact, BIM software, as for example Autodesk Revit, are able to manage just some functions useful for the primary knowledge of a building property, such as spaces and facilities inventories. BIM applications are not yet able to manage all the information which are necessary to perform FM activities.

Moreover, as already underlined, existing BIM-Objects Information Requirements and data standards do not include all the parameters which are useful, for example, to develop a maintenance manual.

Since the potential of the BIM methodology to manage information throughout building lifecycle, the Facilities Information System Archibus has developed an overlay with the BIM software Revit [3] in order to have a two way communication between the two applications. In the grey box proposed below, it is described how it works the existing overlay. In particular they are described the procedures to activate the overlay ("Starting procedures"), number and codify rooms ("Space Planning and Management"), number and codify assets ("Asset Management").

In fact, the research project has identified weaknesses and strengths of the existing overlay after having analyzed its current functioning. In particular:

- it works well to extract spaces and facilities inventories from the BIM model;
- it is not yet able to manage all the other information needed by FM activities and processes due to the lack of the useful parameters in the BIM environment.

Given these considerations, the research project has first understood how it works the existing overlay and then tested it in order to individuate possible areas of implementation.

In fact, as proposed by the BSI PAS 1192-3:2014, an Asset Information Model (Chap. 6) can be managed in two different ways:

- totally within the BIM model (all the information concerning building assets and useful for FM activities are included in the BIM objects) (Fig. 7.7);
- accessed via links and cross-references to existing enterprise information systems.

In the first case, the path to follow is the implementation of existing BIM-Objects Information Requirements in relation to the FM information needs; for example, by bringing together the developed datasheet template with the current data standards. In this way all the necessary information to develop, for example, a maintenance manual may be directly extracted from the BIM model (Fig. 7.7).

In the second scenario, the BIM model is used just to extract information about spaces and facilities inventories and then all the other data are directly managed within the Information System.

The research project is now working for understanding strengths and weaknesses of both the scenarios. Therefore, focusing on the second scenario, the first step has been the analysis and understanding of the existing overlay between Revit and Archibus (see the grey box below).

The Overlay Between Revit and Archibus
How to activate it, manage spaces and assets

- **Starting procedures to activate the overlay**

0# Activating the overlay between Revit and Archibus

0.1 start the Archibus Smart Client
0.2 from the Archibus ribbon, select the command “Preferences”
0.3 select “Autodesk Revit” in the field “CAD application” and select “Yes” in the field “Public Enterprise Graphics on Save”
0.4 start Autodesk Revit
0.5 all of the Archibus commands are now on the Archibus tab of the Revit Ribbon menu

1# Creating the building registry in Archibus

1.1 select the module “Space Planning and Management”
1.2 select “Space Inventory and Performance”
1.3 select “Background Data”
1.4 select “Define Geographical Locations” (Fig. 7.8)
  1.4.1 select the command “Add New” and define:
   – Geographic Region
   – Country
   – Region
   – State
   – City
   – Site

1.5 select “Define Locations”
  1.5.1 select the command “Add New” and define:
   – Site
   – Building
   – Floor

2# Linking the Revit model to the Archibus database

2.1 from the Revit Project Browser select the view to be linked to the Archibus database
2.2 from the Archibus tab select the command “Properties”

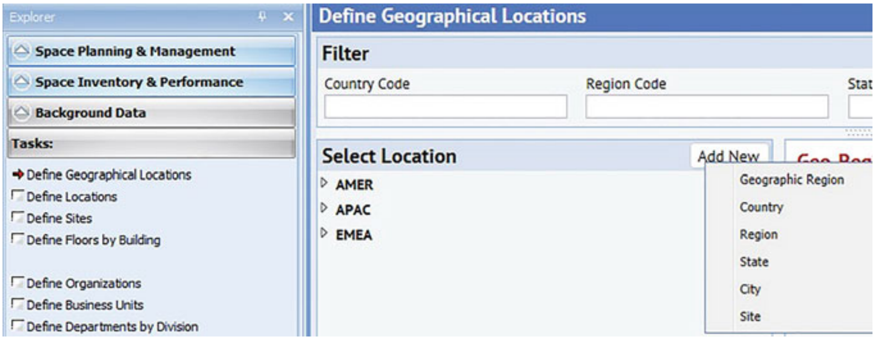


Fig. 7.8 Screenshot describing the procedure to create the building registry in Archibus

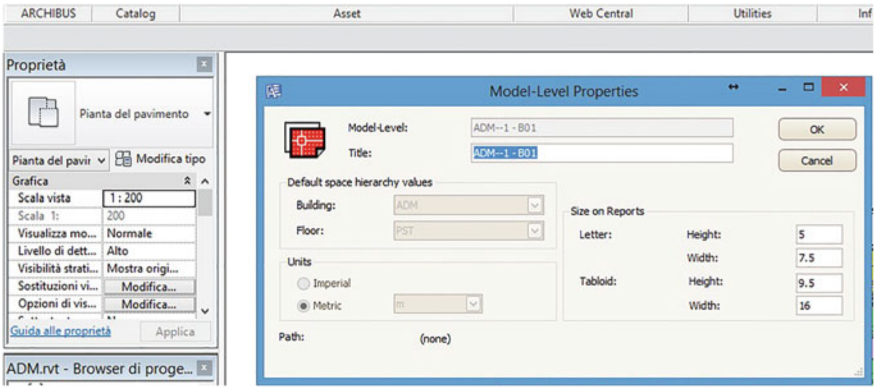


Fig. 7.9 Screenshot describing the procedure to link the Revit model to the Archibus database

2.3 in the window "Model—Level Properties" (Fig. 7.9)
  2.3.1 fill out the fields "Building" and "Floor" by clicking on the command "Browse" which recall to the Archibus tables
2.3.2 select the unit of measurement (m)
2.4 repeat the procedure for all the views to be linked to the Archibus database

- **Space planning and management**

3# Managing the assets—rooms

3.1 from the Revit Project Browser select the view in which there are the rooms to be linked to the Archibus database
3.2 from the Revit "Start" tab select the command "Room" and click on each room to be linked to the Archibus database

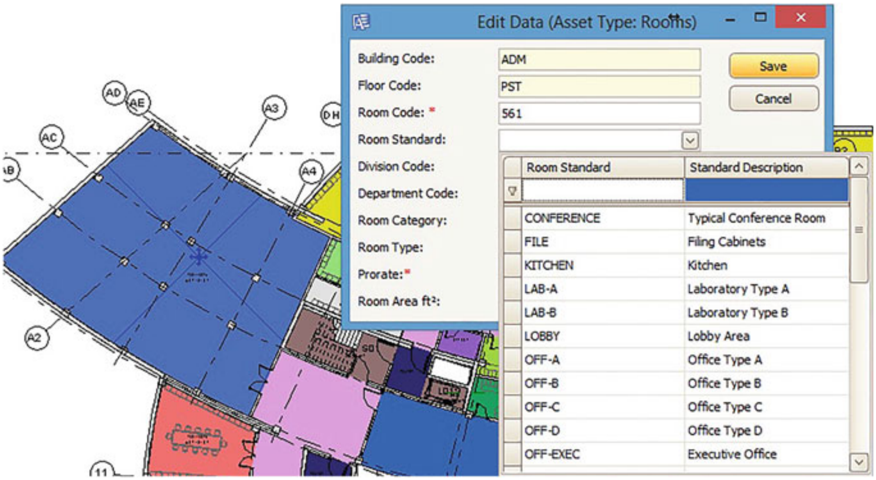


Fig. 7.10 Screenshot representing the procedure to manage “room” assets

3.3 select one of the room and from the “Archibus” tab select the command “Edit Data”

3.4 in the window “Edit Data” there are automatically associated (Fig. 7.10):
- Building Code
- Floor Code
- Room Code
- Room Area

3.5 fill out the remaining fields by clicking on the “Browse” command which recall to the Archibus Tables (Fig. 7.10):
- Room Standard
- Division Code
- Department Code
- Room Category
- Room Type

3.6 from the “Archibus” tab select the command “Catalog” and:

3.6.1 select the field “Rooms” from the menu “Asset Type”

3.6.2 from the menu “Select assets by” choose among the options:
- Select Multiple
- Select Multiple by Rectangle
- Current View
- Entire Model

3.7 after having carried out the numbering and export procedures, the filling out of the fields “Room Standard”, “Division Code”, “Department Code”, “Room Category” and “Room Type” can be done also with Archibus;

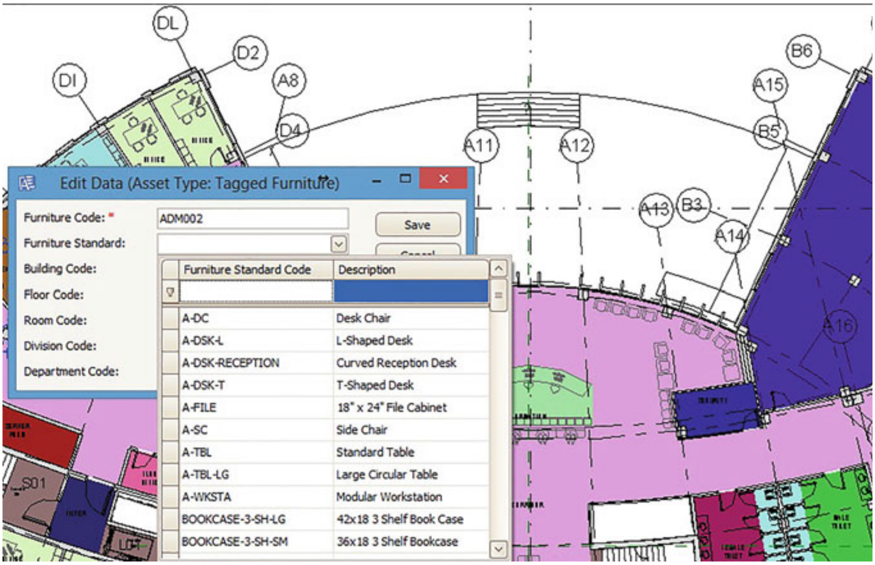


Fig. 7.11 Screenshot describing the procedure to manage "furniture" assets

3.8 then, to export in the Revit model all the data filled out in Archibus, select the command "Synchronization" and then "Read Database Fields"
3.9 in the window "Read Database Field"
    3.9.1 select the field "Rooms" from the menu "Asset Type"
    3.9.2 from the menu "Select Assets by" choose the options:
    – Select Multiple
    – Select Multiple by Rectangle
    – Current View
    – Entire Model

- **Asset management**

4# Managing the assets—furniture

4.1 from the Revit Project Browser select the view in which there are the assets to be linked to the Archibus database
4.2 click on each asset to be linked to the Archibus database
4.3 from the "Archibus" tab select the command "Number"
4.4 in the window "Number" it is possible to define:
– Furniture Code
– Furniture Number
– Room Type
4.5 from the "Archibus" tab select the command "Edit Data" and select the assets to be linked to the Archibus Database (Fig. 7.11):

4.5.1 they are automatically provided:
- Furniture Code
- Building Code
- Floor Code
- Room Code

4.6 fill out the remaining fields by clicking on the “Browse” command which recall to the Archibus Tables (Fig. 7.11):
- Furniture Standard
- Division Code
- Department Code

4.7 from the “Archibus” tab select the command “Catalog” and:

4.7.1 select the field “Tagged Furniture” from the menu “Asset Type”

4.7.2 from the menu “Select assets by” choose among the options:
- Select Multiple
- Select Multiple by Rectangle
- Current View
- Entire Model

4.8 after having carried out the numbering and export procedures, the filling out of the fields “Furniture Standard”, “Division Code”, “Department Code” can be done also with Archibus;

4.9 to export in the Revit model the data filled out in Archibus select the command “Synchronization” from the panel “Utilities” and select from the menu the field “Read Database Fields”

4.10 in the window “Read Database Field”

4.10.1 select the field “Rooms” from the menu “Asset Type”

4.10.2 from the menu “Select Assets by” choose among the options:
- Select Multiple
- Select Multiple by Rectangle
- Current View
- Entire Model

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Chapter 8
Conclusions

This book proposes a thorough analysis of information management within FM services. The aim of the book is to highlight some key concepts that should be well known and applied by the various operators of FM services, both in the problem setting and problem solving: in other words, both in the investigation activities to be carried out in a stage preliminary to the setting of the service and the subsequent drafting of the tender, and in those ones of drafting, negotiation and application of Facility Management agreements.

Although the influence of a well-organized information management on quality, efficiency and effectiveness of FM services, in current practice field-operators do not reveal to be fully aware of the risks associated with poor information.

The topic of information seems to be implicit within the supply of the service; in technical specifications of FM tenders, orientations and requests regarding information management are often extremely general or even absent. Instead, the needs related to information management depend importantly on the specific context, that is, at least: characteristics of the real estate; organizational models of the service and level of integration; client's goals and organization; users' expectations. Being aware of the needs coming from the specific context means to be able to express requirements about many important subjects, such as: modalities of data collection and processing, priority in data capture, information traceability, organization of the knowledge base, characteristics of the system of tools, management of feedback information, process of control, reporting, and so on.

Furthermore, field operators should keep in mind that nowadays a helpful set of international standards is available (i.e. guidelines, criteria, framework of tools, examples, etc.) regarding most of the basic subjects involved in information management, such as criteria for classification and coding, organization of documents, profiling of information systems, rules for interoperability, and so on.

Being aware of these issues means for FM operators to acquire criteria, methods and tools for an enhancement both in the culture and practices, a process improvement (both at strategic and tactical level) and an innovation proposal that, starting from the

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topic of information, can interest the whole field of services for the built environment, as, for example, the current experimentations regarding BIM applications.

So, in conclusion, some key words and related statements could summarize basic criteria to be considered for an approach to an "information oriented" FM service:

- *Knowledge base*. Knowledge is the core and the value of FM services. Information management means to act in order to create the necessary conditions for collecting data and referring them to specific contexts and goals, and thus creating knowledge. Efficiency and effectiveness of the decisions and the operations, that take place during the whole lifecycle of a service, depend significantly on the quality of the knowledge base and the supports for data processing; the more the knowledge base expands and the more the abilities of planning and acting proactively increase. The knowledge base may concern many subjects, such as characteristics and behaviours of the technical elements, features and uses of space, operators' behaviours, costs, and so on.
- *Gradualism*. All the aspects connected to information must be considered according to the criterion of gradualism. The knowledge base can grow over time only through a continuous process of data collection. This continuous process has to be well managed and planned by constantly doing inventory activities, collecting data coming from various processes (i.e. from energy assessment, diagnostic surveys, etc.) and gathering feedback information from various sources. The knowledge base must follow the building throughout its whole lifecycle, being entrusted its implementation to the various suppliers, that will alternate over time.
- *Classification and coding*. The condition for constantly collecting and processing data is to represent the building according to a breakdown structure, as well as classify and codify all its constituting parts, that is assuming a unique framework for the identification of spatial components and building elements. Many international standards—most of them assuming the hierarchical open structure as logical scheme—may be assumed as a reference in order to organize this framework. This framework allows a gradual information allocation at various levels over time, and thus avoiding unwanted redundancy and ambiguity.
- *Decisional and operational support tools*. The knowledge base is the core of information flow. The information system can be considered as the "engine" able to manage this flow, process data, direct and make available information for its use, both for decision making and operational tasks. Whatever is the strategy (buy or develop "in house"), an information system must be defined preliminarily through a framework of requirements, that have to be carefully referred to the specific context of application. Furthermore, the implementation process of an information system must follow the criterion of gradualism, growing over time in accordance with client's needs and resources and evolution of the services.
- *Uniqueness of the building*. Information is produced and used at different stages of the construction process (planning, design, construction, commissioning, monitoring, operation). Even if many operators process and produce information, different for scope and structure, this is always related to the uniqueness of

the building and the processes affecting it during its whole life cycle. Despite these considerations, it is uncommon to see an effective design of an information structure contemporary to, and consistent with, the different lifecycle stages of the construction work. The result is a chain of diseconomies of the process in all its phases, with phenomena, at the same time, of information redundancy, inconsistency, lack of communication and loss of information. An efficient organization should be able to connect, combine and aggregate into a single information management process multiple and heterogeneous information, coming from the different stages of the construction process. This means to be able to provide coordinated services for design, construction and operation, as well as combine appropriately knowledge management and project management methods and tools.

– *Building Information Modelling*. In response to the needs of the FM field for handling heterogeneous information by developing a unique and coherent information management process, Building Information Modelling (BIM) represents both an innovative methodology and efficient tool to reach this goal. Due to long building life cycles, process diseconomies, phenomena of information loss, data asymmetry and so on, there is a growing need for an Information Lifecycle Management (ILM). This means to address an information management process in a common data environment by using innovative methodologies and tools such as BIM. Since BIM is both a methodology concerning information management and a digital representation containing and providing data coming from different sources and phases, it needs standards relating both to information requirements and process management.
– *BIM-Object Information Requirements and data standards*. In order to handle an effective ILM in a BIM environment, information requirements and data standards need to be developed also in relation to the multidisciplinary nature and wide information requirements characterizing FM activities. Although many benefits and resource savings for FM processes coming from an ILM in a BIM environment, existing BIM-Objects Information Requirements show some lacks in relation to the building use phase. Therefore, current BIM data standards must be implemented considering also the information needs of FM activities.
– *BIM software and information systems*. The implementation of existing data standards pave the way to two different methods of accessing and receiving information useful for FM activities: totally within the BIM model (all the information for FM activities are included in BIM Objects) or accessed via links and cross-references to information systems. Therefore, the development of a dataset focused on the information needs of FM activities may enable the integration of current BIM-Objects Information Requirements (information to be included in model elements) and the implementation of existing interoperable overlays between BIM software and facilities information systems.

Given these key-words, “conclusions” is not the right term but rather, in the field of knowledge management and information tools for Building Maintenance and Facility Management, it is so much better to talk about experimentation and innovation.

Glossary

Asset (physical) Item formally accountable (EN 13306:2010, "Maintenance terminology")

Asset Information Management Discipline of managing asset-related organizational data and information to a sufficient quality to support organizational objectives and outcomes (PAS 1192-3:2014, "Specification for information management for the operational phase of assets using building information modelling")

Asset Information Model (AIM) Maintained information model used to manage, maintain and operate the asset (PAS 1192-2:2013, "Specification for information management for the capital/delivery phase of construction projects using building information modelling"). Data and information that relates to assets to a level required to support an organization's asset management system (PAS 1192-3:2014, "Specification for information management for the operational phase of assets using building information modelling")

Asset Information Requirement (AIR) Data and information requirements of the organization in relation to the asset(s) it is responsible for. (PAS 1192-3:2014, "Specification for information management for the operational phase of assets using building information modelling")

Audit Systematic, independent and documented process for obtaining audit evidence and evaluating it objectively to determine the extent to which the audit criteria are fulfilled (EN ISO 19011:2011, "Guidelines for auditing management systems")

Audit criteria Set of policies, procedures or requirements used as a reference against which audit evidence. If the audit criteria are legal (including statutory or regulatory) requirements, the terms "compliant" or "non-compliant" are often used in an audit finding (EN ISO 19011:2011, "Guidelines for auditing management systems")

C. Talamo and M. Bonanomi, *Knowledge Management and Information Tools for Building Maintenance and Facility Management*,
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Audit evidence Records, statements of fact or other information, which are relevant to the audit criteria and verifiable. Audit evidence can be qualitative or quantitative (EN ISO 19011:2011, “Guidelines for auditing management systems”)

Benchmark Reference point or metric against which a strategy, process, performance and/or other entity can be measured (EN 15221-7:2012, “Facility Management—Part 7: Guidelines for Performance”)

Benchmarking Process of comparing strategies, processes, performances and/or other entities against practices of the same nature, under the same circumstances and with similar measures (EN 15221-7:2012, “Facility Management—Part 7: Guidelines for Performance”)

Building Information Modeling (BIM) Process of designing, constructing or operating a building or infrastructure asset using electronic object-oriented information (PAS 1192-2:2013, “Specification for information management for the capital/delivery phase of construction projects using building information modelling”)

Classification Systematic identification and arrangement of business activities and/or records into categories according to logically structured conventions, methods, and procedural rules represented in a classification system (ISO 15489-1:2004, “Information and documentation—Records management—Part 1: General”)

CIC Scope of Services Multi-disciplinary scope of services published by the Construction Industry Council (CIC) for use by members of the project team on major projects (PAS 1192-2:2013, “Specification for information management for the capital/delivery phase of construction projects using building information modelling”)

COBie (Construction Operation Building information exchange) Structured facility information for the commissioning, operation and maintenance of a project often in a neutral spreadsheet format that will be used to supply data to the employer or operator to populate decision-making tools, facilities management and asset management systems (PAS 1192-2:2013, “Specification for information management for the capital/delivery phase of construction projects using building information modelling”)

Command centre The entity which, within a service, oversees a number of organizational activities relating to: support the delivery of operational services with particular reference to the functions of planning and coordination, management of information flows, monitoring and checking. The objective of these activities is to pursue efficiency and the full achievement of performance and service levels predetermined by the client and the sharing of information between the client and supplier

Common Data Environment (CDE) Single source of information for any given project, used to collect, manage and disseminate all relevant approved project documents for multi-disciplinary teams in a managed process (PAS 1192-2:2013, "Specification for information management for the capital/delivery phase of construction projects using building information modelling")

Data Information stored but not yet interpreted or analyzed (PAS 1192-2:2013, "Specification for information management for the capital/delivery phase of construction projects using building information modelling")

Data room A physical location (PDR for physical data room), where information (in the form of files and documents placed in binders, folders and boxes) are temporarily maintained and available for viewing. We have a virtual data room (VDR) when documents are presented in digital format

Degradation Detrimental change in physical condition, with time, use or external cause. Degradation may lead to a failure. In a system context, degradation may also be caused by failures within the system (EN 13306:2010, "Maintenance terminology")

Document The physical support of the information in a specific form. This may take the form of a paper sheet, the screen of a video monitor of a computer system, an electronic board, a blackboard, etc. and the figures, type, size and distribution on the available surface may vary without affecting the main purpose of the information system. A document is permanent. Program results displayed on a screen do not make any document unless it is stored. Document can be information stored in a database which can be shown on a screen or printed out (EN 13460:2009, "Maintenance. Documentation for maintenance")

Documents review Activity aiming at searching, selecting, analysing, gathering and organizing the various and heterogeneous documents coming from design, construction, operations and maintenance phases

Due diligence The process of conducting a walkthrough survey and appropriate inquiries into the physical condition of a commercial real estate's improvements, usually in connection with a commercial real estate transaction. The degree and type of such survey and inquiry may vary for different properties, different user purposes, and time allotted (ASTM E 2018—08, "Standard Guide for Property Condition Assessments: Baseline Property Condition Assessment")

Element Construction entity part which, in itself or in combination with other such parts, fulfils a predominating function of the construction entity (i.e. elements are: external wall, floor, roof, etc.) (e.g. predominating functions are: space enclosing, supporting, servicing, furnishing). (ISO 12006-2:20015, "Building construction—Organization of information about construction works—Part 2: Framework for classification of information")

Facility Management (FM) Integration of processes within an organisation to maintain and develop the agreed services which support and improve the effectiveness of its primary activities (UNI EN 15221-1:2011, “Facility Management—Part 1: Terms and definitions”)

Facility management agreement Written or oral agreement stating the terms and conditions for provision of facility services between a client and an internal or external service provider (UNI EN 15221-1:2011, “Facility Management—Part 1: Terms and definitions”)

Framework Documented set on the rationale of how to create a common understanding of the way of work (ISO/DIS 37500:2007, “Guidance on outsourcing”)

Full Time Equivalent (FTE) Full Time Equivalent that can be determined by dividing the total number of hours worked by the number of regular working hours in a working week (e.g. working 32 h when a regular working week consists of 40 h equals 0.8 FTE) (EN 15221-7:2012, “Facility Management—Part 7: Guidelines for Performance”)

Global service for maintenance Integrated activities of maintenance with full responsibility by supplier of the results in terms of achieving and/or maintaining of performance levels established by the client (UNI 11336:2004, “Global service for maintenance of buildings—Guidelines”)

Hierarchy Structure of levels in which each level includes its lower levels. Taxonomies are frequently arranged in a hierarchical structure. Typically they are related by supertype-subtype, also called parent-child relationships (EN 15221-4:2011, “Facility Management—Part 4: Taxonomy, Classification and Structures in Facility Management”)

Industry Foundation Classes (IFC) IFC is an open international standard for BIM data that is exchanged and shared among software applications used by the various participants in a building construction or facility management project. It specifies a conceptual data schema and an exchange file format for Building Information Model (BIM) data (ISO 16739:2013, “Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries”)

Information Representation of data in a formal manner suitable for communication, interpretation or processing by human beings or computer applications (PAS 1192-2:2013, “Specification for information management for the capital/delivery phase of construction projects using building information modelling”)

Information exchange Structured collection of information at one of a number of pre-defined stages of a project with defined format and fidelity (PAS 1192-2:2013, “Specification for information management for the capital/delivery phase of construction projects using building information modelling”)

Information Lifecycle Management (ILM) Process of managing the entire lifecycle of information

Information Management Task and procedures applied to inputting, processing and generation activities to ensure accuracy and integrity of information (PAS 1192-2:2013, “Specification for information management for the capital/delivery phase of construction projects using building information modelling”)

Information Management Process (IMP) Process to manage information related to the operational phase of an asset (PAS 1192-3:2014, “Specification for information management for operational phase of assets using building information modelling”)

Information model Model comprising: documentation, non-graphical information and graphical information. NOTE The model is conveyed using PDF, COBie and native model files (PAS 1192-2:2013, “Specification for information management for the capital/delivery phase of construction projects using building information modelling”)

Information Requirement (IR) Data and information required to achieve the objectives for which the model has been made

Index A ratio between two quantitative entities

Indexing Process of establishing access points to facilitate retrieval of records and/or information. (ISO 15489-1:2004, “Information and documentation—Records management—Part 1: General”)

Indicator Measured characteristic (or a set of characteristics) of a phenomenon, according to a given formula, which assess the, evolution. Indicators are related to objectives. The indicators can be used to: measure a status; compare (internal and external benchmarks); diagnose (analysis of strengths and weaknesses); identify objectives and define targets to be reached; plan improvement actions; continuously measure changes over time (EN 15341:2007, “Maintenance Key Performance Indicators”)

Information Data processed according to specific goals, referred to a context and managed to be used, shared and combined

Information integration The sharing of essential data or information between the parties involved in a process

Information system Decisional and operational support tool consisting of databases, procedures and functions to collect, store, process, use and update the information necessary for the setting, the implementation and management of the maintenance service (UNI 10951:2001, “Systems of information for the maintenance management of buildings. Guidelines”)

Integrated services Set of functions performed by an organization for client or user according to a logic of integration of the different management aspects (asset, technical, administrative, etc.) with the objective to operate according to a systemic vision, to achieve maximum efficiency in the coordination and searching for synergies

Inventory A system of activities and procedures aiming to provide the knowledge of the dimensional and physical characteristics of a Real Estate. The goal of a Real Estate inventory is to gather the information useful for planning, managing and checking the provision of facility services. This goal is achievable through a plurality of integrated activities, such as analysis, audits, surveys, collection and selection of technical, administrative and legal data and documents

Item Part, component, device, subsystem, functional unit, equipment or system that can be individually described and considered (EN 13306:2010, "Maintenance terminology")

Key Performance Indicator (KPI) Measure that provides essential information about the performance of facility services delivery (UNI EN 15221-1:2011, "Facility Management—Part 1: Terms and definitions")

Knowledge The result of application, processing, relating, combining of information in specific contexts

Knowledge acquisition Process of locating, collecting, and refining knowledge and converting it into a form that can be further processed by a knowledge-based system (ISO/DIS 37500:2007, "Guidance on outsourcing")

Knowledge base A collection of facts, assumptions, beliefs, and heuristics that are used in combination with a database to achieve desired results, such as a diagnosis, an interpretation, or a solution to a problem (McGraw-Hill Dictionary of Scientific & Technical Terms, 6E, Copyright © 2003 by The McGraw-Hill Companies, Inc.)

Knowledge transfer Structured process of imparting pre-existing or acquired information to a team or a person, to help them attain a required level of proficiency in skill (ISO/DIS 37500:2007, "Guidance on outsourcing")

Level of Definition (LoD) Collective term used for and including "level of model detail" and the "level of information detail". The "level of model detail" is the description of graphical content of models at each of the stages defined for example in the CIC Scope of Services. The "level of model information" is the description of non-graphical content of model at each of the stages defined, for example, in the CIC Scope of Services. (PAS 1192-2:2013, "Specification for information management for the capital/delivery phase of construction projects using building information modelling")

Maintenance manuals for maintenance technicians A comprehensive and systematic collection of information concerning the building and related to three characteristics: firstly, information that identifies and describes the different technical elements constituting the building; secondly, information concerning all the methods of maintenance; inspection and checking necessary to maintain those elements under operating conditions; thirdly, the so-called "feedback information" concerning the various types of performed activities (inspections, monitoring, corrective actions due to failure, planned scheduled activities, replacements) (UNI 10874:2000—"Maintenance of buildings. Criteria in order to write maintenance and use manuals")

Maintenance plan Structured and documented set of tasks that include the activities, procedures, resources and the time scale required to carry out maintenance (EN 13306:2010, "Maintenance terminology")

Maintenance schedule Plan produced in advance detailing when a specific maintenance task should be carried out (EN 13306:2010, "Maintenance terminology")

Net Floor Area (NFA) Net Floor Area that is the calculated area of Internal Floor Area (IFA) excluding the Interior Construction Area (EN 15221-6:2011, "Facility Management—Part 6: Area and Space Measurement in Facility Management")

Operation Combination of all technical, administrative and managerial actions, other than maintenance actions, that results in the item being in use (EN 13306:2010, "Maintenance terminology")

Organization Information Requirement (OIR) The organization shall determine, catalogue and maintain its requirements for information to meet the needs of its asset management system and other organizational functions (PAS 1192-3:2014, "Specification for information management for operational phase of assets using building information modelling")

Process Set of interrelated or interacting activities which transforms inputs into outputs (EN ISO 9000:2005, "Quality management systems—Fundamentals and vocabulary")

Product Data Sheet (PDS) A PDS is a digital description of a specific product. When a manufacturer completes a Product Data Template (PDT) it becomes a Product Data Sheet. The standard format of the PDS enables its users to automate their data operations (CISBE—Chartered Institution of Building Services Engineers)

Product Data Template (PDT) A PDT is standard 'questionnaire' for each equipment type. Each PDT aims to anticipate the information sought by every party—from specification through operations to decommissioning and replacement. PDTs are written in Excel format and are usable with all BIM platforms (CISBE—Chartered Institution of Building Services Engineers)

Project Information Model (PIM) Information model developed during the design and construction phase of a project (PAS 1192-2:2013, "Specification for information management for the capital/delivery phase of construction projects using building information modelling")

Project Lifecycle Phases (PLPs) The highest-level, time-based subdivisions of a project across several Organizational Scales. At the highest 'scale', Project Lifecycle Phases (PLPs) include Design Phase (D), Construction Phase (C) and Operation Phase (O). Phases are subdivided into Sub-phases, which are in return subdivided into smaller parts (BIM Excellence, Copyright © 2015 by ChangeAgents AEC Pty Ltd)

Real estate Encompasses land along with anything affixed to the land, such as buildings. Real estate, immovable property, real property, realty are used synonymously (EN 15221-4:2011, "Facility Management—Part 4: Taxonomy, Classification and Structures in Facility Management")

Registry A data base—supported by appropriate methods for classification of the buildings and their technical components and spaces—containing the information necessary to describe the consistency, the functional and the technical characteristics of the built assets

Registry system A framework of criteria useful for the classification and coding of spatial and technical elements and of an apparatus of sheets, useful for collecting information, over time according to the same formalized scheme

Service Result of activities performed by the provider according to the agreed scope, service levels and client demands (ISO/DIS 37500:2007, "Guidance on outsourcing")

Service level agreement (SLA) Agreement between the client or customer and the service provider on performance, measurement and conditions of services delivery. A Facility Management agreement consists of general clauses, applicable to the whole agreement, and SLA specific clauses, only applicable to a facility service. In a Facility Management agreement, several SLAs are included (UNI EN 15221-1:2011, "Facility Management—Part 1: Terms and definitions")

System Set of interrelated or interacting elements (EN ISO 9000:2005, "Quality management systems—Fundamentals and vocabulary")

Space Three-dimensional, material construction result contained within, or otherwise associated with, a building or other construction entity. A space may be bounded physically or notionally (i.e. room, corridor, atrium, cleared zone (at an airport), roadway, square, working space around a machine, swimming pool, etc.). A key property of a space is the function or user activity it is intended to serve (ISO 12006-2:2001, "Building construction—Organization of information about construction works—Part 2: Framework for classification of information")

Taxonomy Practice and science of classification. A knowledge map of a topic typically realised as a controlled vocabulary of terms and or phrases. An orderly classification of information according to presumed natural relationships. A classification system for improved information management, which should contribute to improving the capability of users to sustain and improve the operations of their business, into a series of hierarchical groups to make them easier to identify, study, or locate (EN 15221-4:2011, "Facility Management—Part 4: Taxonomy, Classification and Structures in Facility Management")

Work order (W.O.) Document containing all the information related to a maintenance operation and the reference links to other documents necessary to carry out the maintenance work standard (EN 13460:2009, "Maintenance—Documentation for maintenance")