Cloud-based Facility Management Benchmarking

Sofia Martins,
sofia.pereira.martins@ist.utl.pt

Instituto Superior Técnico

Abstract. Facilities expenditures, such as equipment maintenance or space cleaning, constitute a big slice of organizations base cost. Modern Facilities Management employs specific software such as Computer Aided Facility Management Software to identify and optimize facilities performance by benchmarking different categories of the non-core business indicators.
A pervasive problem, however, is that organizations do not know whether they can bring those optimizations to new levels of performance, i.e. they do not know if their FM practice is in line with the performance of the best in their industry. Overall, there is a need for a benchmarking solution that could bring FM indicators of distinct facilities together, identifying the contrasts and similarities between them.
This thesis studies the problem of FM benchmarking and proposes a cloud-based solution to integrate KPI of distinct facilities. Using this solution, organizations can track their ranking in relation to other organizations, and know if they can further optimize their Facilities Management practice.

Keywords:
Facilities Management, Key Performance Indicator, KPI, Benchmarking, Cloud Computing, Data Analysis, Measurements, Standards

1 Introduction

Facilities Management (FM) is a relatively new discipline, that started to be recognized in the 1970s. FM is a non-core activity that supports an organization to achieve its objectives (core business), making the organization more efficient, by offering employees better working conditions and rationalizing expenditures related to the facility. Thus, FM contributes to the overall performance of the organization.

FM adoption has been growing steadily, and facilities expenditure is one of the biggest slice of the organizations base cost (maintenance costs are usually the second) [1]. It is important to adopt systems to measure the effect of the FM on organizations core business, together with the ones which measure the FM own performance [2].

FM has tree main strands of activity: property management, property operations and maintenance, and office administration [2], which are increasingly

backed by specialized software such as Computer Aided Facility Management (CAFM), Building Information Models (BIM), Computerized Maintenance Management Systems (CMMS), Computer Aided Design (CAD), Building Automation Systems (BAS), Energy Management Systems (EMS), Enterprise Resource Planning (ERP), Integrated Workspace Management System (IWMS) or some combination between them for a complementary usage.

Through some of these software applications it is possible to extract measures and indicators, and with them calculate Key Performance Indicators (KPI). These KPIs give important insight into functioning of the FM functions (keeping track of KPIs is one aspect of quality control) [3].

Organizations have to perform better than their competitors, while operating at the lower costs. Thus, it is very important to be able to efectively compare infrastructures. With performance indicators is possible to perform a comparison between organizations.

Benchmarking can be defined as "part of a process which aims to establish the scope for, and benefits of, potential improvements in an organisation through systematic comparison of its performance with that of one or more other organizations" [4]. Benchmarking can be used either for comparison between distinct organizations or for comparison between facilities within the same organization, also a facility can be compared with itself at different time lines.

Benchmarking brings many advantages: *i)* justification of energy consumption, costs and practices, *ii)* identification of weaknesses/ threats, strengths/ opportunities and best practices, *iii)* addition of value to facilities integrating them in CAFM systems and supporting maintenance management. Therefore, benchmarking can be seen as an instrument to measure facilities performance, and performance indicators are very important for the FM benchmarking.

Up to now, the comparison between organization is not yet possible. Although some organizations have their own benchmarking software, this software is not compatible between distinct organizations. There is no centralized mechanism to integrate all these data. Results from them are not in the same format or have not the same KPIs. Furthermore, is still not clear which are the most important KPIs that should be used by each sector organizations. The same holds for the field of FM.

Another recent trend is cloud solutions that are being employed successfully for benchmarking in sector such as financial, maintenance and space. There are several technologies that can be used such as Infrastructure as a Service (IaaS) where the consumer has the capability to acquire processing, storage, networks, and other fundamental computing resources, Platform as a Service (PaaS) where the consumer has the capability to deploy his solution onto the cloud infrastructure or Software as a Service (SaaS) where applications are accessible from various client devices [5]. These cloud solutions present several benefits such as saving of IT costs and maintenance (since it is not necessary any installation of equipment or software, and neither their maintenance by the organization IT sector), strong integration capabilities, short time-to-benefit, and scalable computation on demand that keep up with the customer needs. Specifically in

benchmarking, cloud applications permits a easier way for entering and process the data, and can be accessible by everyone and anywhere.

A benchmarking application that enables organizations to send facilities related information in standardized format to be processed and presented graphically is a valuable addition, since it enables that every organization benchmark results can be compared with each other (by creating interfaces that can communicate with the software that captures the measurements). This makes possible a raking between them, which would generate a healthy competition that motivates the improvement of each organization FM.

Therefore, the central motivation for this work is to study the migration of facilities benchmarking to the cloud using the latest computing technologies and design a solution, where a cloud application would receive all important data from multiple sources, this data will correspond of various metrics necessary for the calculation of a set of KPIs that will be identified through an analysis of related work. Through the previous information, the solution would also carry out a benchmark comparison between distinct organizations in the industry according to the obtained Key Performance Indicators (KPIs).

1.1 Motivation

Consider a cloud solution that aggregates benchmarking information of distinct facilities, and ranks them according to their performance. Facilities managers would have a deeper insight of their own FM areas.

> **Scenario 1** Consider an organization that has applied FM and where benchmarking has been applied for some time now. This organization decides to use the application proposed in this document. Through it, verifies that its position is raking well below than expected. Thus, seeing their ranking, they become motivated to improve (as they have a perception of their space for improvement) both globally and at the level of a particular indicator.

> **Scenario 2** Consider two distinct organizations that are using the cloud application presented in this document. The first organization has been on the raking first place for some time now. However, the second organization took their place in the raking, but the first organization wants to regain its position. Thus, it creates a healthy competition among participants (who do not know the identity of the other), where improvement is still driven dynamically.

There are some solutions to address this goal, however, none of them are so simple to use. Today's solutions are difficult to use, information is difficult to read and understand, and none of them can give you your position in the market relatively your organizations competition.

1.2 Problem Statement

As we made clear before, there is not an agreement about which KPI should be applicable in each sector. According to Hinks and McNay [6], the lack of generalized sets of data and industry wide sets of KPIs results on poor comparability of performance metrics across organizations and industries. Furthermore, there still is a lack of solutions for FM that enable integrating data from different organization in a way that brings gains for them. Organizations continue to use distinct software to their FM and KPI gathering, which difficult the aggregation and analysis of all data.

Our hypothesis is that a cloud-based and vendor-independent FM solution for benchmarking will enable organizations to know their positioning and also to compare the performance of distinct facilities (in the case of facilities managed by the same entity), through a set of metrics provided by the facilities managers. To this end, it is also necessary to know what is the list of KPIs that should be used to benchmarking distinct facilities.

1.3 Methodology and Contributions

The methodology of this document will include the analysis of standard benchmarking surveys and the systematization of most commonly used indicators in FM. These indicators will undergo a prioritization to identify the most relevant. The prioritization will make use of scientific studies, existing standards for FM, and the help of FM experts, analyzing the most important indicators on a theoretical and practical level. Finally, the architecture of a cloud-based solution for FM benchmarking will be presented, that enables organizations to compare their results with others. More specifically, the contributions of this document are:

- A comparative study between the different Facilities Management standards
- The evaluation and comparison between the main FM benchmarks and the indicators produced
- The identification of the main benchmarking indicators of interest
- A survey of the main FM tools
- The design of the architecture of the cloud benchmarking application and its implementation.

2 Concepts

This section discusses key aspects of Facilities Management, Benchmarking and Cloud applications.

2.1 Facilities Management

Core activities are bound to the central business of the organization and its strategy. While the non-core activities are not necessarily required by an organization in fulfilling its value proposition to its customers, and can be outsourced

to third parties (such as security, payroll, cleaning, maintenance of the building, catering, printing, vehicle maintenance or conference facilities).

Facility Management (FM) is a non-core activity that supports an organization in the pursuit of its objectives (core business), and is considered "the practice of coordinating the physical of business administration, architecture, behaviour and engeneering science" [7] by the International Facility Management Association (IFMA). FM is a result-oriented management of facilities and services securing best value in the provision of services, making the organization more efficient, by giving better conditions and making less expenditures.

FM is supported by specialized software such as Computer Aided Facility Management (CAFM) packages that track space usage, cable pathways, employee locations, security and access control.

CAFM systems are often integrated with Computer Aided Design (CAD), important to support the planning and monitoring of spaces and activities in it, and a database back-end that contains non graphical data about the spaces. CAFM software also enables managing changes to the space since can be tried and tested in computer before they are made, which can avoid future problems. CAFM systems can be populated from Building Information Models (BIM) information containing geometry, spatial relationships, geographic information, quantities and component properties [8], also interfaces to other systems such as a Computerized Maintenance Management Systems (CMMS) to manage preventive maintenance activities. They also have the ability to help decrease the time for task request to task completion, increase the speed and accuracy of information related to each task, and provide improved cost and trend analysis [9].

These systems bring along several benefits as: *i)* efficient completion of operational sequences (entry and analysis of data), *ii)* increase the productivity of workers (by determining property improvements), *iii)* potential cost savings (in areas such as cleaning contracts and energy consumption), *iv)* analysis of information on costs, *v)* supporting management decisions, *vi)* precise valuation of fixed assets, *vii)* optimization of space utilization.

Beyond this type of software, there are others like Incident Management Systems (IMS) that are used by operators (which register incidents) or technicians (who deal with occurrences and close them) to register, centralize and follow each occurrence's status. These systems can generate an automatic work backlog for each technician, which provides work efficiency. It also has reporting services, statistics, incidents status, etc. IMS can be integrated with CMMS or with incident management systems from third party service suppliers to fill-in work order requests.

Computerized Maintenance Management Systems (CMMS) creates and associates maintenance plans, that can be grouped by type of device, for each equipment of an organization, such as air conditioning, roller stairs, furnitures, etc. Some CMMS assist in performing contract management and equipment management. Some of CMMS can be integrated with BAS to obtain equipment

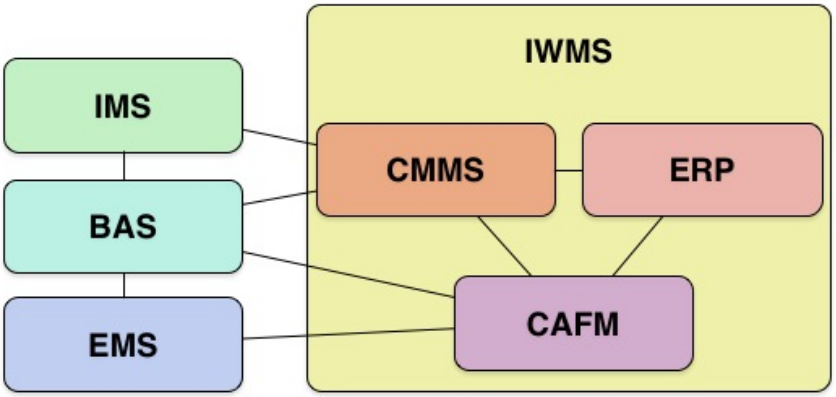

Fig. 1. Organization of the six classes of software applications for FM. The interoperability between the classes is represented by a line between them. IWMS is a group composed by the three classes: CMMS, ERP and CAFM.

usage metrics, however some information can not be possible to retrieve directly from BAS, but it is possible using gathering devices.

Building Automation Systems manage every building's environment aspect, automatically controlling devices installed in the building. Facility managers can remotely command and supervise automation sub-systems in real-time. BAS keeps a history log of the status of each device and defines alarm conditions that can be used to detect malfunction symptoms or devices failure, and can be integrated to CMMS or CAFM tools to report space usage metrics obtained from occupancy sensors.

Energy Management Systems (EMS) gathers all energy consumption information from energy meter devices installed along the building such as electric current consumption. This information can be analyzed in detail and enables facility managers to analyze consumption variation within comparable periods of time. BAS and EMS can be connected together to create consumption profiles and determine relative contribution of devices or groups of devices to the overall energy consumption.

However Enterprise Resource Planning (ERP) systems are not considered FM applications, they are very important on FM environment where management of suppliers, logistics, accounting, billing and orders is being made.

Integrated Workspace Management System (IWMS) suites integrate functionalities of an ERP for FM with CAFM and CMMS in one single application. The organization of all these softwares referred above can be seen on Figure 1.

Most of these systems today are web-based enabling an easier entering of the facilities data that can be analyzed and consulted anywhere. These analysis and benchmarking of all data results in Key Performance Indicators (KPIs) over

a core of skills that are aligned with business objectives as a way to measure current levels of performance and achievement.

2.2 Benchmarking

Benchmarking has been defined has the search of "industry best practices that lead to superior performance" by Camp [10]. It is an important process to compare performance aspects such as operating costs, maintenance and cleaning activities, space utilization, energy consumption or administrative costs. It uses different previously established metrics, identifies differences, alternative approaches and assess opportunities for improvements and change. Overall, it is a process that gives organizations instruments to know how they are performing both internally and to costumers.

Benchmarking can bring many advantages for a facility such as: *i)* not waste time and costs when someone else has already done it better, faster and cheaper, *ii)* increase the velocity of change and restructuring, *iii)* improvement in and off itself, by forcing organizations to examine present processes, *iv)* more likely implementation, because process owners are more involved.

Historically FM started with a focus on performance measurement, that had three broad purposes: *i)* ensure the achievement of goals and objectives, *ii)* evaluate, control and improve procedures and processes, *iii)* compare and assess the performance of different organizations, teams and individuals.

Over the years, however, attentions shifted to quality and consumer satisfaction [2], for this end, benchmark has a set of goals such as better prioritize and allocate resources, and identify opportunities, but it has a major goal: performance improvement of the organization. To this end, there is a set of requirements such as: *i)* know what clients require for the organization process, *ii)* key stakeholders have to be involved in the benchmarking process, *iii)* there can not be change resistance, *iv)* results are not instantaneously.

Benchmarking is not as simples as the aggregation of a few indicators. There must be meaning for each one of them, a purpose for choosing each one. Camp lists four fundamental steps for benchmarking [10]:

- **Knowing operation** to evaluate internal operation strengths and weaknesses.
- **Knowing the industry leaders or competitors** to know the strengths and weaknesses of the competition.
- **Incorporating the best** to emulate the strengths of the leaders in competition.
- **Gaining superiority** to go beyond the best practices installed and be the best of the best.

Clearly, the FM benchmarking process requires a planning phase that decides which data to collect [11].

2.3 Key Performance Indicators

Performance Indicators are collected in many complex systems which, such as education, deliver a service [3]. These indicators are not perfect measures, without error or problems of definition and interpretation, but they are important pointers to the functioning of the system and keeping track of them is one aspect of quality control [3].

The first step of benchmarking is the establishment of performance objectives and metrics. For example, the number of tasks completed in a given time interval. Just like all the actions that must be well performed to accomplish satisfactorily those objectives or goals. All these are important for all measurements and performance comparison between benchmarking parties, but it is important to know that the choosing of wrong indicators can be damaging, and therefore, it is also important to know that Measurements and Indicators are distinct concepts. Measurements are a direct representation of the scale of the organization and are direct measurable items (for organizations internal usage) while Indicators are quantifiable metrics that reflects organizations goals achievement (external usage). It is important to distinguish Performance Indicators (PI) from Key Performance Indicators (KPI). The PIs tells you what to do, while the KPIs tells you what to do to increase performance dramatically, so, they represent a set of measures focusing on most critical aspects of organizational performance for the current and future success of the organization [12].

KPIs are not the same for all the sectors and employees on an organization. Associated directors or head of advisors have custom KPI for their specific responsibilities. Also, there are various generic KPIs for other professionals and managerial personel based on business measures. However, they all must be SMART [13]:

- **Specific** well defined and clearly understood.
- **Measurable** theres a well defined process that enables the KPI tracking.
- **Attainable** must be able to be met with the resources available.
- **Realistic** that can be measured at a reasonable cost.
- **Time driven** if corresponds of a time interval.

Therefore, FM departments must have their own KPIs that are aligned with the core business KPIs [14]. The main typical FM KPIs (over a unit of time) according to Teicholz [14] are: *i)* Operational Hours, *ii)* Response Times, *iii)* Rework, *iv)* Value Added, *v)* Number and performance of suppliers, *vi)* Employee satisfaction, *vii)* Innovations (new processes), *viii)* Customer satisfaction, *ix)* Plan versus actual on contracts, *x)* Number of items on tasks lists.

2.4 Cloud Computing

Cloud Computing is arising and being applied to various fields. It provides environments to enable resource sharing in terms of scalable infrastructures, middleware and application development platforms, and value-added business applications [15].

The Cloud is an aggregation of a set of resources such as networks, servers, applications, data storages and services, in only one place, which the end user can access and use with minimal management effort or service provider interaction. The main goal of Cloud Computing is to make a better use of distributed resources, combine them to achieve higher throughput and be able to solve large scale computation problems.

2.4.1 Cloud Computing Concepts

Today we have several services that we can use, since Infrastructure as a Service (IaaS), Platform as a Service (PaaS) or Software as a Service (SaaS) [5].

Infrastructure as a Service (IaaS) the consumer has the capability to acquire processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. An example is Amazon EC2 which provides web service interface to easily request and configure capacity online [16]. For a higher layer of IaaS, computational, storage, and network an example is Amazon's Dynamo [17].

Platform as a Service (PaaS) the consumer has the capability to deploy onto the cloud infrastructure, consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. An example is Google's App Engine [18] and Heroku [19].

Software as a Service (SaaS) the applications are accessible from various client devices through either a thin client interface, such as a browser, or a program interface. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, etc.

The application developers can either use the PaaS layer to develop and run their applications or directly use the IaaS infrastructure [5].

In short, cloud solutions present several benefits that keep up with the customer needs such as saving of IT costs and maintenance, easy access and up-to-date data, short time-to-benefit, improving business processes and scalable computation on demand. These benefits have pushed many residential and commercial solutions to the cloud.

As all new technology arrives, it brings with it some issues which may prove to be disastrous if not taken care of. The major concerns about cloud computing are security and privacy, network performance and reliability.

However, if the correct service model (IaaS, PaaS, or SaaS) and the right provider is selected, the payback can far outweigh the risks and challenges. The cloud implementation speed and ability to scale up or down quickly, means companies can react much faster to changing requirements like never before.

2.4.2 Cloud Computing for FM

With Cloud Computing it is not necessary installation of any software on the organization IT equipment, thus, there are no infrastructure requirements and because the service is sold on-demand, it can be rented rather than bought. Also, cloud applications are managed and updated by the provider, who take care of server maintenance and security issues. This removes burden of the IT group, and consequently, lower costs.

Because cloud enables the access of applications with both mobile or desktop devices, personnel can work flexibly anywhere and anytime. Work traveling restrictions such as different time zones or impossible access to the software are no longer an issue.

3 Related Work

This section discusses standard organizations and benchmarking standards for FM. Also, an overview of existing benchmarking solutions such as ARCHIBUS and PNM Soft Sequence Kinetics is described. The scientific literature is also presented in this section along with a discussion of the normalization and prioritization of KPIs.

3.1 ISO and ICS

The International Organization for Standardization (ISO) is the largest developer of voluntary International Standards covering all aspects of technology and business. ISO has formed joint committees to develop different kinds of standard according to the commission they join: IEC-International Electrotechnical Commission or ASTM-American Society for Testing and Materials. The International Classification for Standards (ICS) is a structure for catalogs of international, regional and national technical standards and other normative documents developed and maintained by ISO. It covers every economic sector and activity where these technical standards can be used. Its objective is to facilitate the harmonization of information and ordering tools [20].

Thus, we selected the most important standards for FM and Maintenance for those working with facilities in various stages of their life cycle, which are shown in Table 1, ordered by ICS.

Code	Title
ICS 01. 110: Facilities Management	
ISO/CD 18480-1	Part 1: Terms and definitions
ISO/CD 18480-2	Part 2: Guidance on strategic sourcing and the development of agreements
ICS 01. 110: Document Management	
EC 82045-1:2001	Part 1: Principles and methods
IEC 82045-2:2004	Part 2: Metadata elements and information reference model
ISO 82045-5:2005	Part 5: Application of metadata for the construction and facility management sector
ICS 03. 100: Risk Management	
ISO 31000:2009	Principles and guidelines
ISO/TR 31004:2013	Guidance for the implementation of ISO 31000
IEC 31010:2009	Risk assessment techniques
ICS 03. 100: Asset Management	
ISO 55000:2014	Overview, principles and terminology
ISO 55001:2014	Management systems-Requirements
ISO 55002:2014	Management systems-Guidelines for the application of ISO 55001
ICS 03. 080: Outsourcing	
ISO/DIS 37500	Guidance on outsourcing
ICS 91. 010: Building Information Modeling	
ISO/TS 12911:2012	Framework for building information modeling (BIM) guidance
ISO 29481-1:2010	Information delivery manual-Part 1: Methodology and format
ISO/AWI 29481-1	Information delivery manual-Part 1: Methodology and format
ISO 29481-2:2012	Information delivery manual-Part 2: Interaction framework
ICS 91. 040: Buildings and Building Related Facilities	
ISO 11863:2011	Functional and user requirements and performance – Tools for assessment and comparison
ICS 91. 040: Buildings and Constructed Assets	
ISO 15686-1:2011	Service life planning-Part 1: General principles and framework
ISO 15686-2:2012	Service life planning-Part 2: Service life prediction procedures
ISO 15686-3:2002	Service life planning-Part 3: Performance audits and reviews
ISO 15686-5:2008	Service life planning-Part 5: Life-cycle costing
ISO 15686-7:2006	Service life planning-Part 7: Performance evaluation for feedback of service life data from practice
ISO 15686-8:2008	Service life planning-Part 8: Reference service life and service–life estimation
ISO/TS 15686-9:2008	Service life planning-Part 9: Guidance on assessment of service–life data
ISO 15686-10:2010	Service life planning-Part 10: When to assess functional performance
ISO/DTR 15686-11	Service life planning-Part 11: Terminology
ICS 91. 040: Buildings Construction	
ISO 15686-4:2014	Service Life Planning – Part 4: Service Life Planning using Building Information Modeling
ISO 6242-1:1992	Expression of users' requirements-Part 1: Thermal requirements
ISO 6242-2:1992	Expression of users' requirements-Part 2: Air purity requirements
ISO 6242-3:1992	Expression of users' requirements-Part 3: Acoustical requirements
ICS 91. 040: Performance Standards in Building	
ISO 6240:1980	Contents and presentation
ISO 6241:1984	Principles for their preparation and factors to be considered
ISO 7162:1992	Contents and format of standards for evaluation of performance
ISO 9699:1994	Checklist for briefing-Contents of brief for building design
ISO 9836:2011	Definition and calculation of area and space indicators

Table 1. Specific ISO standards related to Facilities Management and Maintenance organized by ICS. The list presents the standards relevant for facilities in different stages of their life cycle.

In some ICS there are only ISO standards, in others, there are also European standards and national standards such as Portuguese national standards (NP). The latter are usually the transcripts for the Portuguese European legislative body (EN-NP) or international (ISO-NP), but can also be standards developed from scratch in Portugal standards (in this case only have the designation NP). These can be consulted on Table 2.

Code	Title
Facilities Management	
EN 15221-1:2006	Part 1: Terms and definitions
EN 15221-2:2006	Part 2: Guidance on how to prepare facility management agreements
EN 15221-3:2011	Part 3: Guidance on quality in facility management
EN 15221-4:2011	Part 4: Taxonomy, classification and structures in facility management
EN 15221-5:2011	Part 5: Guidance on facility management processes
EN 15221-6:2011	Part 6: Area and space measurement in facility management
EN 15221-7:2012	Part 7: Guidelines for performance benchmarking
Maintenance Management	
NP EN 13269:2007	Instructions for maintenance contract preparation
NP EN 13460:2009	Maintenance documentation
NP EN 15341:2009	Maintenance key performance indicators (KPI)
NP 4483:2009	Guide for maintenance management system implementation
NP 4492:2010	Requirements for maintenance services
EN 13306:2010	Maintenance terminology
EN 15331:2011	Criteria for design, management and control of maintenance services for buildings
CEN/TR 15628:2007	Qualification of maintenance personnel
EN 13269:2006	Guideline on preparation of maintenance contracts

Table 2. List of European (EN) and Portuguese (NP) FM and Maintenance Standards that apply to facilities in various stages of their life cycle.

3.2 Benchmarking Standards for FM

The importance of standards resides in the creation of specifications, which normalizes how some activity is performed. In the case of benchmarking, standardizing how companies evaluate their FM data enables compatibility between organizations, and so, there is no misinterpretation between different organizations for a given measurement.

Becomes possible to compare the results between them, which empowers an improvement and enhancement of facilities management for each organization. Accordingly, it is essential to have specific standards of measurement and

metrics for ensuring a common understanding of performance and to identify performance gaps [21].

Various FM software from many organizations tend to use ISO standards and Royal Institution of Chartered Surveyors (RICS) measurement practices.

3.2.1 RICS and BICS Space Measurement Normalization

There are many standards that specify how to perform measurements, so that it can be executed equally by the different organizations. Thus, measurements must be performed by accredited specialists in the matter, such as Chartered Surveyors that are professionals members of the Royal Institution of Chartered Surveyors (RICS) and that can offer impartial, specialist advice on a variety of property related issues.

RICS has a Code of Measurement Practice that deals with practice of measurements such as valuation techniques (zoning of shops) or special uses. It specifies measurements for *i)* Gross External Areas (GEA): area of a building measured externally at each floor level, *ii)* Gross Internal Areas (GIA): area of a building measured to the internal face of the perimeter walls at each floor level *iii)* p: area within a perimeter walls at each floor level [22]. RICS provides precise definitions to permit the accurate measurement of buildings and land or the calculation of sizes (areas and volumes) presented in the RICS' Code of Measuring Practice [22].

Belonging to RICS, the (BCIS) provides built environment cost information, and is the basis of early cost advice in construction industry, since they provide services respecting occupancy costs, construction duration, repair costs, construction inflation, among others. Today, the focus is to deliver buildings to a known cost and on being able to track the reduction in costs that result from improvements in procurement [23]. For this to happen, it is necessary information provided by BCIS such as cost per $m2$ of Gross Internal Floor Area for buildings and elements.

BCIS elemental cost data usefulness is reinforced by the changing procurement methods, the changing means of information management and the growing need for through life data. Also, with the development of BIM, it is necessary that information from the BIM model be supplied at various stages along the project time line, in order that the costs can be produced and validated. This information, derived from a block model, will provide basic quantities from which element unit quantities can be derived.

The BCIS Elemental Standard Form of Cost Analysis [23] describes the rules for preparing an elemental cost analysis in standard BCIS format, and it describes the principles of analysis, instructions on the information required to complete a costs analysis, general definitions, definitions of the elements and sub-elements, and element unit quantities [23].

As referred in the BCIS Elemental Standard Form of Cost Analysis, there has to be detailed information documents about the projects, buildings, procurements, costs (there should be provided Total Costs for each element and

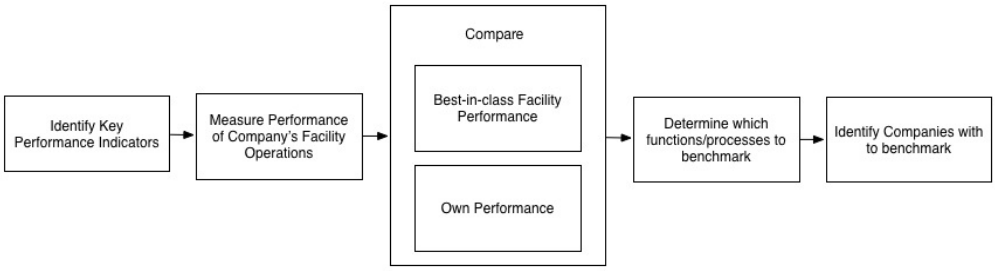

Fig. 2. IFMA Benchmarking Methodology adapted from Roka-Madarasz [1]. First step is to identify the KPI, then, use it to measure the facility performance. At this point three different paths can be taken: Best-in-class Facility Performance, Own Performance, or directly to Compare. After this, the functions of benchmark has to be chosen, just like which companies to benchmark.

sub-elements, and should be shown separately when required and for different forms of construction), risks and design criteria.

3.2.2 IFMA Benchmarking

The International Facility Management Association (IFMA) has developed a facility benchmarking useful for current FM services benchmarking that can be seen in Figure 2 as shown in the report [1].

In order to measure facilities performance, IFMA has established 9 Key Performance Indicators that must be easily measurable and that must be defined for monitoring the actual process and also to control it. These Key Performance Indicators shown in the report [1] can be seen in Table 1 on Appendix.

3.3 Existing Solutions

As specified in section 2.1, there are many types of softwares for FM solutions, like CAFM or IWMS. All of known FM solutions like Maxpanda [24] or IBM Tririga [25] are a simpler way to manage facilities, they centralize organizations information, making management more efficient through business analytics, critical alert, increasing visibility and control.

Some of them, like ARCHIBUS [26] or FM:Systems [27] have integration with CAD or BIM models, which is very important for visualization of departments occupation or others space and occupation management areas.

Most of these systems promotes their capabilities for organizations cost reduction — since they cost-justify real changes in preventive maintenance routines and predicts cost effects of preventive maintenance changes before they are made — some permits multiple users, others make possible that each user only can access specific information regarding his organization position.

There are different sectors that a FM system can focus like *i)* Capital/ Financial, *ii)* Real Estate/Retail: Construction or Project Management, *iii)* Space and Workplace, *iv)* Maintenance, *v)* Sustainability and Energy, *vi)* Move, *vii)* Higher Education and Public. Many of the existent solutions only focus in some of this sectors and not in all of them.

For Real Estate it is usual features for incorporation of current lease accounting standards, tracking of dates and contractual commitments, management of occupancy and facilities costs. On Capital/Finantial are being used features to identify funding priorities within capital programs, reduce project schedule overruns or streamline project cost accounting. In Space and Workplace it is important to have tools for space use agreements and chargeback to increase departmental accountability for space use. Maintenance requires features for automatically route and manage both incoming and planned maintenance, while at the same time keeping internal customers up to date on the progress of their work tickets, or streamline facility maintenance, service management and facility condition assessments. The Sustainability and Energy sector is also very important for defining which projects will achieve the right mix of environmental benefits and cost savings, for reduce energy consumption to meet sustainability goals, identifying poorly performing facilities and automate corrective actions.

Systems like Indus System [28], Manhattan Mobile Apps [29], PNMSoft [30] or ARCHIBUS have cloud-based software that enables users to access FM systems anywhere on mobile devices from a browser. Indus System enables users to store, share, view drawings, space, assets, related costs, leases and contracts just by accessing the browser.

For other hand, ARCHIBUS and PNMSoft are both capable of showing an organizations KPIs through their web site. The packages enables users normal usage of their daily management software and then, when necessary, the visualization of the results on a graphical web application. However, this solution is only applicable for the facilities that have ARCHIBUS or PNMSoft software installed, and only for comparison from previous results from that facility. In contrast, with our solution, any organization could benefit from this features and one more: the comparison with others organizations on the sector.

3.3.1 ARCHIBUS

ARCHIBUS is the provider Facilities Management software solution that effectively tracks and analyzes not only facilities-related information but also real-estate. ARCHIBUS is an integrated solution that applies to organizations of all sizes and sectors (here we focus on ARCHIBUS for Educational Institutions reports - Table 2 on Appendix).

The system architecture consists of three main modules (as seen on Figure 3), the first, is named ARCHIBUS Web Central and provides live enterprise access to facilities data and enables the easy maintenance and distribution of facilities information across the entire enterprise [31]. A role-based security service, allows

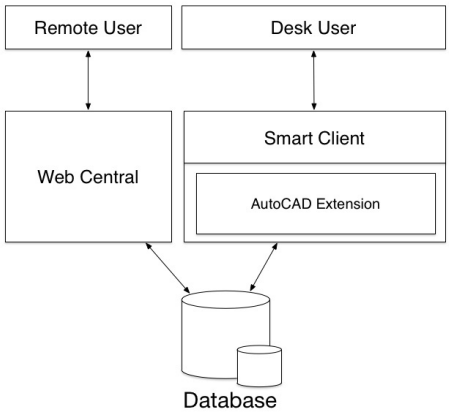

Fig. 3. Overview of ARCHIBUS software architecture adapted from ARCHIBUS Fundamentals Training [31]. The Database is the same for all modules, so the data is coherent between them. Module Extension for AutoCAD is only applicable for the module Smart Client, that can only be used by Desk Users. Remote users that are not on the office, can use Web Central to access data.

that when users log on, they only access information relevant to their roles on the organization.

ARCHIBUS have a .NET Windows application, named Smart Client, used by back-office personnel for data entry, data transfer, importing and exporting data from other systems. This module has another one integrated, the Smart Client Extension for AutoCAD or DWG Editor that is very important for those organizations who want to include Computer-Aided Drawing or BIM models.

From a technical standpoint, the software architecture of ARCHIBUS consists of a database that can be one of MS SQL, Oracle or Sybase. This database communicates with the application servers that can run on Tomcat, Jetty, WebLogic or WebSphere. The applications of SmarClient module running on the computer of the client companies, communicate with application servers through Web Services and the applications of Web Central module communicates via HTTP with those same servers [31].

Being part of the ARCHIBUS platform, ARCHIBUS Performance Metrics Framework delivers KPIs and other performance data about the real estate, infrastructure and facilities using a detailed graphical view of the data. Thus, it is possible to use analytical measures and productivity tools, which provides decision-makers to align their portfolio to organizational strategy, spotlight underperforming business units or assets, and benchmark organizational progress to achieve targeted goals.

3.3.2 PNM Soft Sequence Kinetics

PNM Soft Sequence Kinetics is an Intelligent Business Process Management Suite and covers process optimizing KPI, dynamic process change, KPI analysis, process operation and tracking, communication with external systems and mobile and cloud KPI.

This system has four main focus: Processing-Optimizing KPI, Process Operation and Visual Tracking, KPI for Process Administrators and Mobile Process KPI.

On the Process Optimizing KPI there are two different processes:

Extra-Process Performance Analytics permits the process performance tracking via runtime dashboards and displays KPI like process status levels or average execution time of a process, which helps to understand how successful the process is and highlight required improvement areas.

Intra-Process Analytics aggregation and calculation of intra-process data by real-time analytics, that is built into the Business Rule editor, which enables routing according to their results via a simple GUI, being an artificial process intelligence form which sees the business teach itself how to perform better over time.

Process Operation and Visual Tracking is possible by Flowtime that is a extension of Microsoft SharePoint with a built-in process operation environment, which enables the collaboration on processes in a familiar interface and includes advanced task management, delegation and monitoring of KPI capabilities with a tracking views, which shows the process stands.

The KPI for Process Administrators provides important indicators on process performance per type of process [32].

PNM Soft also has a mobile application named Mobile Portal, that is available as an application or an online service, where users can access the same features provided by Sequence Kinetics Flowtime and can be configured by the customer to meet his necessities. For the cloud platform PNM Soft uses Windows Azure.

3.4 Scientific Literature

Ho et al [33] report different performance measurements and indicators most used in Asia Pacific region. This research work rates the importance of 97 metrics on a five point scale and indicate if the metric was being used in their organization FM — the metrics consisted of performance measurements and performance indicators grouped by eight categories: *i)* size and use of facilities, *ii)* maintenance, *iii)* refurbishment, *iv)* cleaning, *v)* energy consumption, *vi)* ground and environment, *vii)* safety and security, *viii)* parking. These categories are represented by order of importance on Figure 4, according to the study by Ho et al [33].

Moreover, Ho et al [33] also identified which of the 97 metrics were the most used and more important to the organizations: the metrics that lead a direct financial implication were the ones with a higher rating. The 30 metrics with higher rates are especially related to the areas of: *i)* Financial such

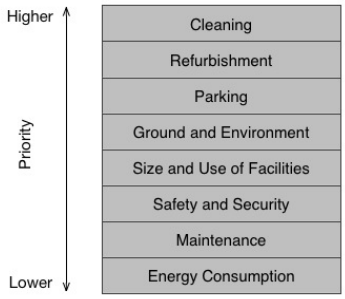

Fig. 4. Measurement Categories ordered by their importance according to the results of the research of Ho et al [33].

as Total Annual Facility Cost and Operational Cost, *ii)* Spacial such as Gross Floor Area/Usable Floor Area and Usable Area, *iii)* Maintenance such as Asset Replacement Value (Maintained), *iv)* Cleaning such as Area Cleaned and Cleanliness Status of Site.

Massheder and Finch [21], surveyed the FM benchmarking metrics used in the UK. Their work identified which metrics were used to measure performance of the FM function. They organized metrics according to five categories: *i)* business metrics, *ii)* building performance metrics, *iii)* portfolio metrics, *iv)* acquisition metrics, *v)* disposal metrics. The results of their study are presented in Table 3. As we can see, the most used metrics are the Business, Portfolio Metrics and Building Performance. The latter is considered the most important one (with percentage of use above 50% on 5 of 6 metrics presented.)

Hinks and McNay [6] identified a need to established a set of universally accepted KPI that realistically evaluate organizations performance. On their study, they identified the need to clarify and prioritize the parameters and indicators which correlated the views of the customer and the departments, to support the operational requirements of the core financial business. To this end, they used the Delphie technique [34] (used to gather expert opinion in areas where there is considerable uncertainty and/or lack of agreed knowledge [6]), where a group of the premises department and their internal customers were consulted using questionnaires, scenario workshops and group discussions set.

The first phase of Hinks and McNay's study consisted of a literature review, where the authors concluded that the practical use of KPIs frequently involves industry-specific or organization-specific indicators. They also concluded that most of the indicators were providing data that were of direct applicability for monitoring the management of FM tasks. Unfortunately these indicators were not likely to be relevant to their customers [6]. Since no single measure can adequately provide a clear performance target, it is desirable a balance between financial and non-financial measures [35]. Taking this into account, were chosen 172 KPIs that can be consulted on Hinks paper [6], also, performance indica-

Metric	Percentage of Use
Business	
Occupancy cost of operating revenue by building	43%
Occupancy cost of the total of labour and costs by business unit	29%
Occupancy of cost of operating revenue by business unit	21%
Occupancy cost of the total sales and admin cost by business unit	14%
Location analysis on basis of where key skills are available	7%
Location optimization (in context of attractors and repellers)	7%
Building Performance	
Occupancy cost per m^2	98%
Occupancy cost per person	79%
Occupancy of cost per building size	64%
m^2 per person	64%
Itemized (occupancy) cost comparisons of m^2 per person by building	36%
Absentee rates by building	0%
Portfolio Metrics	
Proportion of operational space compared to non-operational space	49%
Current market capital value compared to book value by building	21%
Current market rental value compared to rent peasing by building	14%
Proportion of Non-operational Space that is Sublet or Assigned	14%
Acquisition Metrics (only those who include real estate in FM)	
Costs of acquisition measured against returns	20%
Actual extra occupancy cost against prediction cost	10%
Amount of space coming on stream per unit time	10%
Time to find and acquire space against program	10%
Time to occupation against program	10%
Disposal Metrics (only those who include real Estate in FM)	
Holding costs per year	30%
Time to dispose of buildings against program	30%
Cost of disposal against savings	20%
Time to clear buildings against program	20%
Holding costs to lease end, break and/or estimated disposal date	10%
Number of months vacant to date	10%
Disposal performance measures against natural portfolio shed rate	0%
Months vacancy to lease end, break and/or estimated disposal date	0%

Table 3. Use of the different metrics on UK benchmarking organizations according to Massheder et al [21]. The most used metrics are the ones belonging to Building Performance, Business and Portfolio with a percentage of use above the Acquisition and Disposal categories.

tors must be comparable and sufficiently complete and objective to accurately describe the address FM function [36].

The study had a second phase where the group of responders were asked to prioritize the performance parameters from the previous KPI list, selecting a comprehensive and coherent set (they could also add indicators if they though best). At the end, the group choose 23 KPIs as the most representative of the study. On phase three, it was allocated a grade, between 0 and 10, for each KPI,

according to its importance. Less that 4 indicated that the indicator was only of minimal relevance, a mark between 4 and 7 (inclusive) indicated increasing levels of importance, and a mark which exceeded 7 identified a supremely important indicator of FM performance [6]. The list can be found on Table 4.

Performance Dimension	Metric
Business	No loss of business due to failure of premises services
General	Customer Satisfaction
Change Management	Completion of project to customer satisfaction
Environment	Provision of safe environment
Space	Effective utilization of space
Change Management	Effectiveness of communication
Maintenance	Reliability
General	Professional approach of premises staff
General	Responsiveness to problems
General	Competence of staff
Maintenance	Management of maintenance
Change Management	Responsiveness of PD to changes/requirements
Business	Value for money
Environment	Satisfactory physical working conditions
Equipment	Equipment provided meets business needs
Business	Suitability of premises and functional environment
Change Management	Quality of end product
Maintenance	Effectiveness of helpdesk service
Change Management	Achievement of completion deadlines
Equipment	Correction of faults
Maintenance	Standards of cleaning
General	Management information
Environment	Energy performance

Table 4. The final list of 23 KPIs to support operational requirements of organizations, ordered by importance according to Hinks et al [6]. Higher importance indicators come at the top.

In 2004, Costa et al [37], made a discussion about three benchmarking initiatives in United Kingdom (Key Performance Indicators Working Group, 2000), United States of America (Construction Industry Institute, 2000) and Chile (Corporacion de Desarrolo Tecnológico, 2002). They described two projects that aimed to conceive and implement performance measurement systems for benchmarking in the Brazilian construction industry.

The objective of the initiatives mentioned previously was to measure the performance of the FM sector, and to identify and evaluate best practices, through comparison of key performance indicators. To this end, a web-based online tool was developed, enabling to input previously gathered data. Tools were provided for displaying graphically the comparative performance of companies involved.

Each one of the studies considered by Costa et al selected the KPIs by combining distinct approaches: extensive reviews by a panel of experts and the publication of an initial report, selection based on previous studies, or by a committee involving both industry representatives and Construction Industry Institute.

Performance measurements as cost, safety and time were common between the studies. The resume of those systems (including the Costa et al final solution) KPI selections were essentially focused on categories such as Financial (Deviation of Cost by Project), Safety (Labor Accident Rate), Satisfaction (Client and Employee) and Performance (Project Schedule Growth). Based on the experience of these surveys, the authors also concluded that the set of measures should i) be simple and ii) well designed in order to support improvement, and iii) give a comprehensive company wide-view [37].

Costa et al [38] took the investigation further, and in 2005 they developed an online benchmarking application which offers analysis and simulation of organizations performance with respect to reference values found for each sector. The data being reported is related to reference values and general results, keeping confidential information from companies participating in the project.

3.5 Discussion

The problem of KPIs identification in the domain of FM had already been studied by distinct system industries and scientific studies. However, there is not any accorded standardization or prioritization used by the industry. The determination of which KPIs to use for a centralized benchmarking infrastructure for FM is still an open question. In order to understand what are the most relevant KPIs for the field of FM we combined the results of distinct authors. Table 5 presents the various KPIs pointed out by the scientific literature along with the frequency of reference. Through it, is possible to identify which ones are the most referenced, and which, on a theoretical level, correspond to the ones that should be used on this project solution.

KPIs are performance measurements, thus, it is indispensable to normalize them and specify how they can be achieved. Table 6 describes how each one of the previous KPIs can be calculated. Indicators on categories such as Quality and Satisfaction have to be measured through audits or questionnaires (an example of Quality of Cleaning questionnaires can be seen on tables 3 and 4 on Appendix).

After the analysis of scientific literature and existing technologies, we need to validate the information through opinions of several experts in the area. For this first phase of our study, we already contacted an expert in the field of FM to help in the selection of the most relevant KPIs to use on the context of this project. With the expert help, it was possible to conclude that some of the KPIs mentioned in literature were not the most suitable. Sometimes there were repeated KPIs with different names or KPIs that were included in other less specific. Moreover, some of the KPIs most frequently reported in the literature would not be the most suitable for the solution. The measurements necessary to the calculation of those indicators are very difficult to obtain, and organizations do not want to have all the work to obtain them, thus, they are not able to gather

Indicators	Costa et. al [37]	USA, UK and Chile Projects [37]	IFMA [1]	ARCHIBUS Ho et. al [33]	Massheder et. al [21]	Hinks et. al [6]	Total
Financial Indicators							
Total Cleaning Cost			•				1
Cleaning Cost per m^2			•	•			2
Total Maintenance Cost			•	• •			3
FM Costs				•			1
Utility Costs				•			1
Facility Budget/Corporation Budget			•				1
Occupancy Cost per m^2			•	•	•		3
Space Costs per m^2			•	• •			3
Operation Cost per m^2			•	•	•		3
Moving Costs				•			1
HSSE Costs				• •			2
Security Costs				•			1
Logistic Costs				•			1
Hospitality Costs				•			1
Project Costs (Deviation)	•	•		•		•	4
Financial Ratios		•		•		•	3
Annual Income			•			•	2
Total Annual Facility Cost			•	•	•		3
Annual Cost of Energy Purchased			•				1
Total Environment Cost			•	•			2
Outdoor Costs				•			1
Spacial Indicators							
Net Floor Area			•	• •	•	•	5
Percentage Net Floor Area			•	• •		•	4
Percentage Internal Area			•	• •		•	4
Percentage Gross Floor Area			•	• •		•	4
Support Area				•			1
Maintenance/Cleaning Indicators							
Repairs VS Preventive Maintenance				•		•	2
Asset Replacement Values			•			•	2
Percentage of Area Cleaned			•			•	2
Productivity Indicators							
Core operating hours of facility (FM)				•			1
Uptime Facility (Business)				•			1
Staff Turnover (Human Resources)				•		•	2
Absenteeism (Human Resources)				•		•	2
Environmental Indicators							
CO2 emissions				•			1
Total Energy Consumption				•		•	2
Total Water Usage				•			1
Total Waste Production				•			1
Service Quality Indicators							
Quality of Product		•				•	2
Quality of Cleaning				•		•	2
Quality of Workplace				•		•	2
Quality of Security				•		•	2
Quality of Reception and Contact Center				•			1
Quality of Document Management				•			1
Satisfaction Indicators							
Client Satisfaction	•	•				•	3
Satisfaction with FM				•			1
Satisfaction with Space				•			1
Satisfaction with Outdoors				•			1
Satisfaction with Cleaning				•			1
Satisfaction with Workspace				•			1
Satisfaction with HSSE		•		•			2
Satisfaction with Hospitality				•			1
Satisfaction with ICT				•			1
Satisfaction with Logistics				•			1

Table 5. List of KPIs covered by the literature. It is represented the various KPIs referred by the scientific literature. On the last column, it is represented the total of documents that referred that specific KPI.

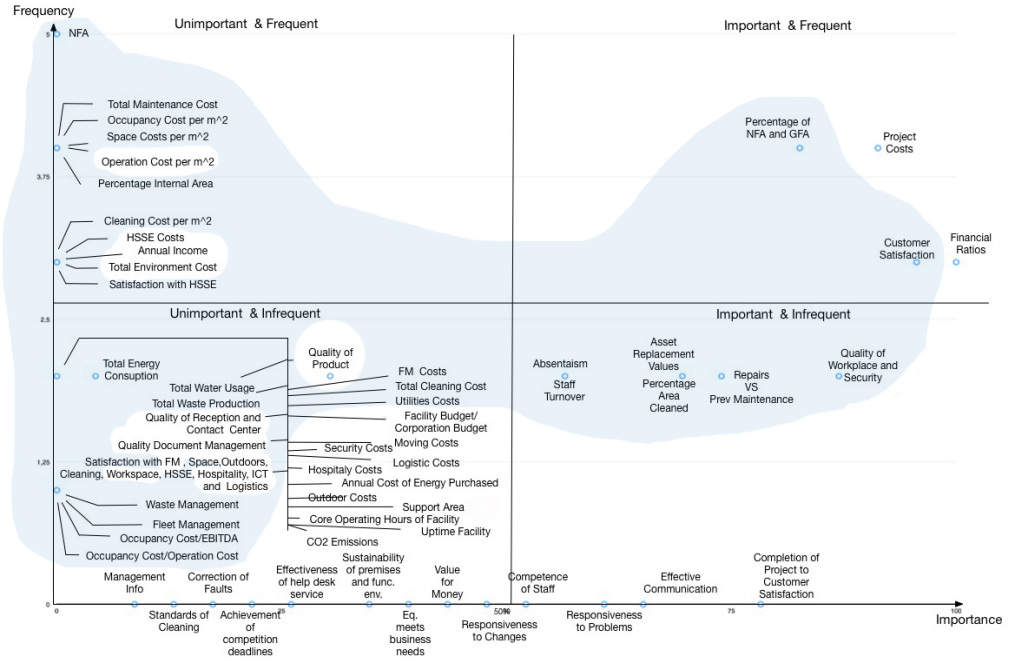

Fig. 5. FM KPIs organized according to frequency and importance. Shaded area represents the options of an FM expert.

enough data to calculate all the previously referred KPIs. The FM expert also suggested other KPIs not present in the scientific literature which may present themselfs interesting for organizations. This KPIs will be taken in consideration in order to choose the final KPIs list which can be found on Table 7. In order to understand which were the most important KPIs for FM, it was needed to cross data between the various scientific literature and the existing solutions. The Figure 5 represents the information in tables 4, 5 and the KPIs given by the FM expert. In it, it is possible to visualize the most relevant KPIs based on importance and frequency. This graphic was constructed based on a cross-over of the KPIs described on the academic literature and the field experience of the FM expert.

In order to be simpler to evaluate, a first iteration of the solution should use a short list of KPIs [37]. The proposed list of KPIs for this project can be seen on Table 7.

Indicators	Units	Description
Financial Indicators		
Total Cleaning Cost	€/mo	Sum of all cleaning costs
Cleaning Cost per m^2	€/m^2	Total Cleaning Cost/Net Room Area OR Total Cleaning Costs/Net Floor Area
Total Maintenance Cost	€/mo	Sum of costs of maintenance for electricity equipment, HVAC, elevators, escalators, generators, UPS, ICT maintenance, etc
FM Costs	€/mo	Costs of FM department OR FM outsourcing
Utility Costs	€/mo	Sum of costs for water, electricity, oil, gas and others
Facility Budget/Corporation Budget	%	(Facility Budget/Corporation Budget)x100
Occupancy Cost per m^2	€/m^2	Total Occupancy Cost/Net Floor Area
Space Costs per m^2	€/m^2	Total Space Costs/Net Floor Area
Operation Cost per m^2	€/m^2	Operation Cost/Net Floor Area
Moving Costs	€/mo	Sum of planning costs such as boxing, transport, assembling and space planning
HSSE Costs	€/mo	Sum of costs for health, safety, security and environment (outsourcing + Department)
Security Costs	€/mo	Sum of Physic Security Costs (fire prevention and protection sensors and extinguishers) and Human Security Costs (surveillance and reception)
Logistic Costs	€/mo	Sum of storage and distribution costs
Hospitality Costs	€/mo	Sum of costs for meeting rooms, conference centers, daycare centers, gyms, apartments, etc.
Project Costs (Deviation)	%	(Actual Total Project Cost - Initial Predicted Project Cost/ Initial Predicted Cost)x100
Financial Ratios		This includes various distinct KPIs such as Gross Profit Margin, Inventory Turnover, etc
Annual Income	€/yr	
Total Annual Facility Cost	€/yr	
Annual Cost of Energy Purchased	€/yr	
Total Environment Cost	€/mo	Sum of all environment costs
Outdoor Costs	€/mo	
Spacial Indicators		
Net Floor Area per FTE	m^2/FTE	Net Floor Area/Number of FTE personnel
Percentage Net Floor Area	%	(Net Floor Area/Total Level Area)x100
Percentage Internal Area	%	(Internal Area/Total Level Area)x100
Percentage Gross Floor Area	%	(Gross Floor Area/Total Level Area)x100
Support Area	m^2	
Maintenance/Cleaning Indicators		
Repairs VS Preventive Maintenance (by specialty)	%	(Number of Corrective Maintenance per month/Number of Preventive Maintenance per month)x100
Asset Replacement Values (by specialty)	%	(Annual Maintenance Cost/Maintained Assets Replacement Value)x100
Percentage of Area Cleaned	%	Area Cleaned/Net Floor Area
***P*roductivity Indicators**		
Core operating hours of facility	hours/mo	
Uptime Facility (by specialty)	%	(Facility Run Time (Production)/Total Available Time to Run or Produce)x100
Staff Turnover	%	(Number of Employee Departures (FTE)/Average Number of Staff Members (FTE) Employed)x100
Absenteeism	%	(Total Days Lost/Total Possible Days Worked)x100
Environmental Indicators		
CO2 emissions	tones/mo	Conversion of the Total Energy Consumption
Total Energy Consumption	kWh/mo	
Total Water Usage	m^3/mo	
Total Waste Production	tones/mo	
Service Quality Indicators		
Quality of Product		Values Obtained Through Audits or Questionnaires
Quality of Cleaning		Values Obtained Through Audits or Questionnaires
Quality of Workplace		Values Obtained Through Audits or Questionnaires
Quality of Security		Values Obtained Through Audits or Questionnaires
Quality of Reception and Contact Center		Values Obtained Through Audits or Questionnaires
Quality of Document Management		Values Obtained Through Audits or Questionnaires
Satisfaction Indicators		
Client Satisfaction	%	Values Obtained Through Questionnaires
Satisfaction with FM	%	Values Obtained Through Questionnaires
Satisfaction with Space	%	Values Obtained Through Questionnaires
Satisfaction with Outdoors	%	Values Obtained Through Questionnaires
Satisfaction with Cleaning	%	Values Obtained Through Questionnaires
Satisfaction with Workspace	%	Values Obtained Through Questionnaires
Satisfaction with HSSE	%	Values Obtained Through Questionnaires
Satisfaction with Hospitality	%	Values Obtained Through Questionnaires
Satisfaction with ICT	%	Values Obtained Through Questionnaires
Satisfaction with Logistics	%	Values Obtained Through Questionnaires

Table 6. List of Normalized KPIs and how they are obtained.

Indicator	Units/mo	Description
Financial Indicators		
Total Cleaning Cost	€	Sum of all cleaning costs
Cleaning Cost per m^2	€/m^2	Total Cleaning Cost/Net Room Area OR Total Cleaning Costs/Net Floor Area
Total Maintenance Cost	€	Sum of costs of maintenance for electricity equipment, HVAC, elevators, escalators, generators, UPS, ICT maintenance, etc
FM Costs	€	Costs of FM department OR FM outsourcing
Utility Costs	€	Sum of costs for water, electricity, oil, gas and others
Space Costs per m^2	€/m^2	Total Space Costs/Net Floor Area
Occupancy Cost	€/m^2	Total Occupancy Cost/Net Floor Area
Occupancy Cost per Operation Costs	%	(Occupancy Cost/Total Operation Costs)*100
Occupancy Cost per EBITDA	%	(Occupancy Cost/Earning Before Interest, Taxes, Depreciation and Amortization)*100
Spacial Indicators		
Net Floor Area per FTE	m^2/FTE	Net Floor Area/Number of FTE personnel
Percentage Net Floor Area	%	(Net Floor Area/Total Level Area)x100
Percentage Internal Area	%	(Internal Area/Total Level Area)x100
Percentage Gross Floor Area	%	(Gross Floor Area/Total Level Area)x100
Maintenance/Cleaning Indicators		
Repairs VS Preventive Maintenance (by specialty)	%	(Number of Corrective Maintenance per month/Number of Preventive Maintenance per month)x100
Asset Replacement Values (by specialty)	%	(Annual Maintenance Cost/Maintained Assets Replacement Value)x100
Percentage of Area Cleaned	%	Area Cleaned/Net Floor Area
Productivity Indicators		
Staff Turnover	%	(Number of Employee Departures (FTE)/Average Number of Staff Members (FTE) Employed)x100
Absenteeism	%	(Total Days Lost/Total Possible Days Worked)x100
Environmental Indicators		
Total Energy Consumption	kWh	
Total Water Usage	m^3	
Total Waste Production	tones	
Service Quality Indicators		
Quality of Cleaning		Values Obtained Through Audits or Questionnaires
Quality of Workplace		Values Obtained Through Audits or Questionnaires
Quality of Security		Values Obtained Through Audits or Questionnaires
Satisfaction Indicators		
Client Satisfaction	%	Values Obtained Through Questionnaires
Satisfaction with Space	%	Values Obtained Through Questionnaires
Satisfaction with Cleaning	%	Values Obtained Through Questionnaires
Satisfaction with HSSE	%	Values Obtained Through Questionnaires

Table 7. List of Final Normalized KPIs that will be used on final solution, after validation by several FM experts.

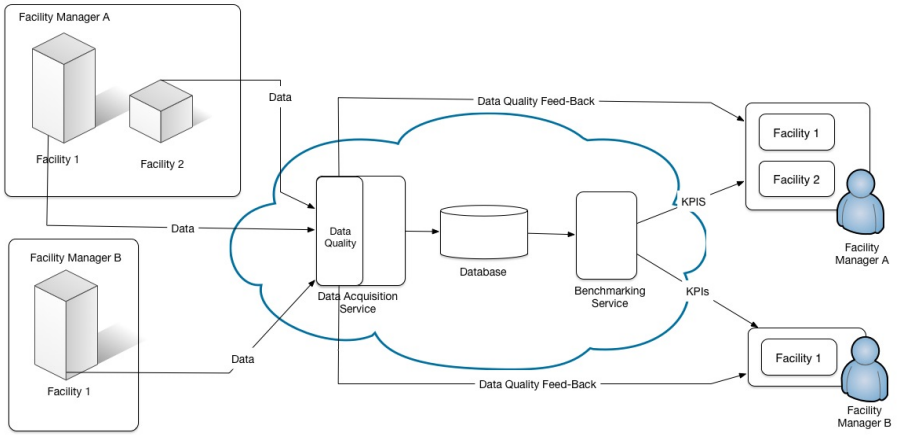

Fig. 6. FM benchmarking system architecture. Organizations send their data on a standard format, to be stored on a database. This info is then accessed by different users representatives of each organization.

4 Solution Proposal

As referred before, it is necessary a new solution where different organizations, with different FM systems, would be able to visualize their FM results through a graphical illustration of their KPIs. The most important fact here will be the aggregation of information of different organizations, that will be compared between them, bringing a better insights where your organization is in terms of FM relatively to others. Organizations will then be ranked by their results, but their information will never be shown to others, being the results always classified.

4.1 Overview

The solution will be developed as a Web Application, which will be divided in two parts. Server side and Client side. The server side will run directly on the hosting servers, while the client side will run on the browser as an endpoint to the server. The solution will:

- Use authentication service to authenticate the users of a organization
- Display KPIs through graphics
- Have a ranking between organizations
- Have a cache on the database for better performance

This document solution architecture overview can be found on Figure 6.

4.2 Architecture

Client Side The Client Side application will be running on the browser of the user connecting to the website. This application will have to display an interface so that the user can interact with the application and where the statistics about the organization will be presented. It will be used Bootstrap Framework for the web site design which enables a quicker development and permits an adaptive front-end for mobile devices. For the generation of the graphics will be used the javascript library highcharts and if necessary the D3.js for more complex graphics.

Server Side The Server Side will be running the application and will be the responsible for the processing and storage of the data sent by the Organization to the DB. It will also be responsible for organizations and users management, authentication and data management and update (CRUD - Create, Read, Update and Delete). For the Server Side will be used the Play Framework which is also responsible for the generation of HTML templates that will be sent to the Client Side.

Database It will be used a relational Database (DB), that will be theoretically divided in three: Input Data Staging Area, KPI Aggregated Data and Facility Metadata as can be seen in Figure 7. The Input Data Staging Area stores the data sent by the organization. The KPI Aggregated Data uses the Input Data Staging Area data to calculate the KPIs and store them. Without this division there would be necessary heavier queries and consequently the system would be slower. In order to deliver KPI information in real-time, the KPI Aggregated Data caches the computed information gathered by the Input Data Staging Area, making the system quicker.

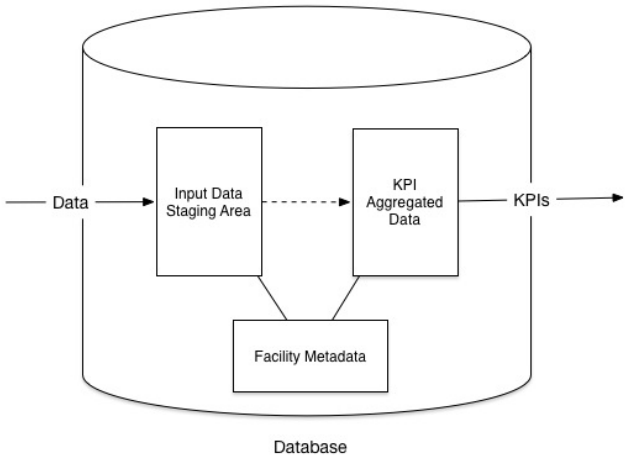

Fig. 7. Database arrangement overview. It receives the data and stores it on Input Data Staging Area, then, when the KPIs are calculated they are stored at KPI Aggregated Data.

5 Evaluation

This works validation involves the development of a proof of concept (POC) to prove its usability and claims. This concept will storage organizations data, calculate correspondent KPIs and display it through several graphics. It also creates a raking between the different organizations FM results. In order to validate the proposed solution, will be performed a set of tests:

Usability Tests evaluates the application by testing it with users. It provides a direct perception how the users interact with the application, the common errors they make and if they can execute the tasks. As a result of this test, we can understand if the application interface is well designed and perceptible.

Qualitative Tests combined with the usability tests, are possible to gather users opinions. They can help find better ways to improve the application interface.

Indicators Rating is very important to realize which indicators are the most convenient to any specific users. This can be achieved by a questionnaire or by integrating an indicator rating tool inside the application, where the users can select their preferable indicators.

Performance Tests in order to test the cache efficiency on the database. Will be made two tests. For the first test, KPIs will be asked directly to the Input Data Staging Area, on the second test, it will be used a cache, and

the KPIs will be asked to the KPI Aggregated Data. This way, it is possible to understand the performance optimization brought by the cache.

5.1 Deployment

To provide a real situation evaluation and benchmarking, this POC will be deployed on the cloud provider Heroku. Heroku is a PaaS which provides SQL Postgres Database and a Github integration, which permits a quicker and easier deployment of the application while allowing vertical and horizontal scalability on the fly [19].

6 Planning

This document project will follow the methodology depicted on the Gantt Chart of the Figure 8, which can be seen an overall view of the time line of this thesis work.

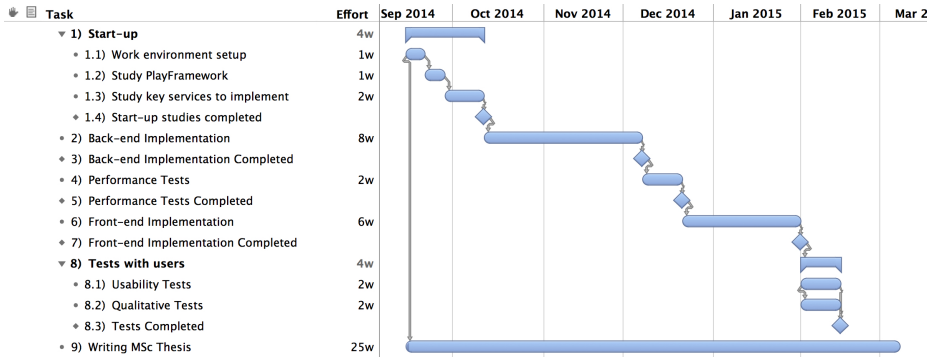

Fig. 8. Project Gantt Chart. Task planning and working time estimation.

7 Conclusions

Nowadays the lack of accurate metrics which drives decision-making, makes the achievement of an effective portfolio and operations management a challenge. This report proposes a new FM benchmarking cloud application for presenting KPIs and a ranking FM organizations. First, was introduced the concepts of FM benchmarking, the problem to be solved by this document solution and the motivation for it. Then, is described with more detail the concepts of FM, Benchmarking, KPIs and Cloud-Computing. Afterwards, is described the different Standards used nationally and internationally, the related work done by

other researchers in the field of FM benchmarking, and some technologies existent today in this area. Then, is specified the architecture of the cloud application proposed. Finally it is described how the solution will be evaluated.

With the solution proposed in this project, quantifying real property performance will be easier and organizations will have a better way to evaluate its own FM metrics, while enabling the comparison of metrics between enterprises and facilities.

References

1. Róka-Madarász, Lívia, "Facility Management benchmarking," in *8th International Conference on Management, Enterprise and Benchmarking*, pp. 171–181, 2010.
2. M. Pitt and M. Tucker, "Performance Measurement in Facilities Management," *Property Management*, vol. 26, pp. 241–254, 2008.
3. Fitz-Gibbon, Carol Taylor, "Performance indicators," *Benmchmark*, vol. 12, p. 31, 1990.
4. European Commitee for Standardization, "EN 15221-7: Facility Management - Part 7: Guidelines for Performance Benchmarking," 2012.
5. Lenk, A. and Klems, M. and Nimis, J. and Tai, S. and Sandholm, T., "What's inside the Cloud? An architectural map of the Cloud landscape," *2009 ICSE Workshop on Software Engineering Challenges of Cloud Computing*, vol. 0, pp. 23–31, 2009.
6. Hinks, John and McNay, Peter, "The creation of a management-by-variance tool for facilities management performance assessment," 1999.
7. International Facility Management Association, "IFMA Homepage." http://www.ifmaoc.org (Last accessed on May, 2014).
8. Atkin, B and Brooks, A, *Total facilities management.* 2009.
9. M. May and G. Williams, *The Facility Manager's Guide to Information Technology.* 2012.
10. Camp, Robert C, *Benchmarking: The Search for Industry Best Practices that Lead to Superior Performance.* 1989.
11. P. W. Gilleard, John D.and Yat-lung, "Benchmarking Facility Management: Applying Analytic Hierarchy Process," *Facilities*, vol. 2, 2004.
12. D. Parmenter, *Key performance indicators : developing, implementing, and using winning KPIs.* 2007.
13. Shahin, Arash and Mahbod, M. Ali, "Prioritization of key performance indicators: An integration of analytical hierarchy process and goal setting," *International Journal of Productivity and Performance Management*, vol. 56, pp. 226–240, 2004.
14. E. Teicholz, *Facility Design and Management Handbook.* McGraw-Hill Professional, 2001.
15. Zhang, Liang-Jie and Zhou, Qun, "CCOA: Cloud Computing Open Architecture," *2009 IEEE International Conference on Web Services*, pp. 607 – 616, 2009.
16. Amazon Web Services, "Amazon Web Services EC2 Homepage." http://aws.amazon.com/ec2/ (Last accessed on May, 2014).
17. DeCandia, Giuseppe and Hastorun, Deniz and Jampani, Madan and Kakulapati, Gunavardhan and Lakshman, Avinash and Pilchin, Alex and Sivasubramanian, Swaminathan and Vosshall, Peter and Vogels, Werner, "Dynamo: Amazon's Highly Available Key-value Store," in *Proceedings of twenty-first ACM SIGOPS symposium on Operating systems principles*, vol. 41, pp. 205–220, 2007.

18. Google Inc, “Google App Engine.” http://www.google.com/apps (Last accessed on May, 2014).
19. Heroku Inc, “Heroku Homepage.” https://www.heroku.com (Last accessed on May, 2014).
20. ICS, *International Classification for Standards*, 2005.
21. K. Massheder and E. Finch, “Benchmarking Metrics Used in UK Facilities Management,” *MCB University Press*, vol. 16, pp. 123–127, 1998.
22. RICS Property Measurement Group, *Code of Measuring Practice*, 2007.
23. Building Cost Information Service of RICS, *Elemental Standard Form of Cost Analysis - Principles, Instructions, Elements and Definitions*, 2008.
24. Maxpanda Inc, “Maxpanda Homepage.” http://www.maxpanda.net (Last accessed on May, 2014).
25. IBM Inc, “IBM Tririga Homepage.” http://www-03.ibm.com/software/products/en/ibmtrirfacimana/ (Last accessed on May, 2014).
26. Archibus Group, “Archibus Homepage.” http://www.archibus.com (Last accessed on May, 2014).
27. FM:Systems Inc, “FM:Systems Homepage.” http://www.fmsystems.com (Last accessed on May, 2014).
28. Indus Systems Inc, “Indus Systems Homepage.” http://www.indus-systems.com (Last accessed on May, 2014).
29. Manhattan Software Inc, “Manhattan Mobile Apps Homepage.” http://www.manhattansoftware.com/solutions/mobile-apps.html (Last accessed on May, 2014).
30. PNMSOFT Inc, “PNMSOFT Homepage.” http://www.pnmsoft.com (Last accessed on May, 2014).
31. ARCHIBUS Group, “ARCHIBUS Fundamentals Training,” 2014.
32. Sequence Kinetics iBPMS, *Sequence Kinetics, from Workflow to Social, Mobile and Intelligent BPM*, 2011.
33. D. C. Ho, E. H. Chan, N. Y. Wong, and M.-w. Chan, “Significant Metrics for Facilities Management Benchmarking in the Asia Pacific Region,” *MCB University Press*, vol. 18, pp. 545–555, 2000.
34. D. F. V. Eynde and S. L. Tucker, “A Quality Human Resource Curriculum: Recommendations from Leading Senior HR Executives,” *Human Resource Management*, vol. 36.
35. S. F. Slater, E. M. Olson, and V. K. Reddy, “Strategy-Based Performance Measurement,” *Business Horizons*, vol. 40, pp. 37–44, 1997.
36. Q. Wang, “Activity-Based Facility Management Benchmarking,” *Private Communication*, 1992.
37. D. B. Costa, H. R. Lima, and C. T. Formoso, “Performance Measurement Systems for Benchmarking in the Brazilian Construction Industry,” *International Symposium on Globalisation and Construction AIT Conference Centre, Bangkok, Thailand*, pp. 1029–1039, 2004.
38. D. B. Costa, H. R. Lima, K. B. Barth, and C. T. Formoso, “Desenvolvimento de um Sistema de Indicadores para Benchmarking na Construção Civil: Utilizando uma Abordagem de Aprendizagem,” *Porto Alegre Brasil*, 2005.

A Appendix

Indicator
Description of Facilities
Industries represented
Facility use
Hours of operation
Number of occupants
Sizes and Uses of Facilities
Gross area
Rentable area
Usable area
Square footage per occupant
Building efficiency rates
Workstation utilization rates
Office space per worker
Support area
Office Space Planning
Vacancy rates
Space allocation policies
Office type and size
Relocation and Churn
Organizational moves
Cost of moves
Churn rate
Maintenance, Janitorial and Indirect Costs
Organizational moves
Maintenance costs (by age of facility)
Percentage of replacement cost
Repair vs preventive maintenance
Outsourcing of maintenance function
Janitorial costs
Indirect costs
Utility Costs
Utility costs
Utility usage
Environmental and Life Safety Costs
Environmental costs
Life-safety costs
Support and Project Costs
Security costs
Project costs
Space planning costs
Employee amenities costs
Financial Indicators
Replacement value of facility
Lease type and cost
Cost of operations
Cost of providing the fixed asset
Occupancy cost
Financial ratios
Total annual financial costs

Table 1. Key Performance Indicators for FM organized by areas within facilities operation according to IFMA [1].

Activities and Reports
Space Management
Rooms by building
Synchronize room percentages
Highlight rooms by department
Financial statement for charge-back
Actual cost vs. budgets for departments
Historical space usage by department
Asset Management
Equipment standards and inventory
Depreciation schedules for assets
Equipment disposition history
Operations and Maintenance
Work orders scheduled vs. completed
Rooms with active work orders
Service level agreements
Parts usage history
Planning board for labor resources
Capital Budgeting
Approved projects by funding year
Available capital and expense funds
Budget by program
Geo-spatial Views
Facilities and site infrastructure master planning
Utilities, cable plant and network management
Environmental health and safety compliance
Emergency preparedness and response

Table 2. List of reports of the ARCHIBUS FM [31] software package for Educational Institutions organized by category.

Routine Cleaning	**0%**	**25%**	**50%**	**75%**	**100%**
Workspace Frequency	1x per week	2x per week	3x per week	4x per week	every day
Toilets Frequency	< 2x per week	2-3x per week	every day	2x per day	> 2x per day
Staff Supervision	poor supervision by area managers		acceptable supervision by area managers		expert supervision by area managers
Cleaning Standard	very inconsistent and of poor standard (noticeably unclean on inspection)	usually inconsistent and below standard (numerous issues to action on inspection)	consistently to an acceptable standard (issues to action on inspection)	usually consistent of a high standard (few issues to action on inspection)	always consistent and of high standard (very clean on inspection)
Customer Service	cleaning staff are impolite and not very helpful	cleaning staff are polite, but not very helpful	cleaning staff are polite and helpful	cleaning staff are proactive in offering service	cleaning staff go above and beyond the call of duty
Staff Presentation	cleaning staff look untidy and are often out of uniform		cleaning staff look acceptable and occasional exceptions are promptly rectified		cleaning staff look tidy and are always in uniform
User Complaints	monthly complaints/staff base >20%	monthly complaints/staff base = 15-20%	monthly complaints /staff base = 10-15%	monthly complaints/staff base = 5-10%	monthly complaints/staff base ¡5%

Table 3. Example of Routine Cleaning Quality Questionnaire. The percentages correspond to: 0% - very poor, 25% - poor, 50% - average, 75% - good, 100% - very good. Personnel should select the option closest to their situation.

Special Cleaning	**0%**	**25%**	**50%**	**75%**	**100%**
Flooring Frequency (deep cleaning)	< 2x per annum	2x per annum	3x per annum	4x per annum	> 4x per annum
Partitions Frequency	<2x per annum	2x per annum	3x per annum	4x per annum	>4x per annum
Windows Frequency	<2x per annum	2x per annum	3x per annum	4x per annum	> 4x per annum

Table 4. Example of Special Cleaning Quality Questionnaire. The percentages correspond to: 0% - very poor, 25% - poor, 50% - average, 75% - good, 100% - very good. Personnel should select the option closest to their situation.