Resilient Structures and Sustainable Construction
Edited by Pellicer, E., Adam, J. M., Yepes, V., Singh, A., and Yazdani, S.

ISBN: 978-0-9960437-4-8

STANDARD INFORMATION FOR CONSTRUCTION EQUIPMENT IN A RELATIONAL DATABASE

MARCO L. TRANI, MANUELE CASSANO, and DAVIDE TODARO

Dept of Architecture, Built Environment and Construction Engineering, Politecnico di Milano, Milan, Italy

In the last years, the digital evolution involved the construction sector and produced radical changes in projects elaboration and realization. The diffusion of digital models implies a particular attention on information related to the building elements. For what concerns construction planning and management, this information need to be related to the information of the elements proper of a construction site such as equipment and machines. A deep research focused on the manufacturers' sheets showed how technical information related to construction equipment are often non-homogenous and incomplete, probably because of a lack of a precise standard. The aims of this research are then the definition of a proper standard information structure for construction equipment and its digitalization thanks to the use of relational Databases and Building Information Models. To do this the amount of information collected from a wide number of datasheets have been standardized and organized in homogenous informative sets to be related in order to gain the correct information package of an equipment. The realization of a relational database permitted to store such data in a digital format and to search them in an efficient way. The realization of a BIM library permitted to provide to designers and firms a tool able to improve and automatize design choices in terms of construction issues.

Keywords: Datasheet, BIM, Construction information, Standardization, SQL database.

1 INTRODUCTION

It is known that construction field has been subject during the last years to an evolution due to the advent of digital models and, in general, IT developments. The design phase of a building projects acquires more and more importance, with the aim to reduce uncertainty during construction phase. Projects are characterized by a high quantity of information that are collected, thanks to the developments of digitalization, and then are available into graphical and computerized models. In this context acquires more and more importance the way to collect, store and express, in a digital format, information about construction elements. The presented research continues (Trani *et al.* 2016) the study made by the task group on construction planning, focusing on the need of information expression, also for what concerns the construction phase of the process: the design of site logistics and layouts. A previous report of the research (Trani *et al.* 2015) showed how the possibility of using Building information models for construction site design (*i.e.* Construction Site Information Models) allows designers to have at disposal a series of construction elements graphically developed and provided of the information necessary for the choice of the correct solution. This way of construction design needs to be supported by a strong background of information about construction equipment and machines to be stored in a unique digital platform to make it available for the designers.

The starting point of the research of information has been, then, a deep analysis on the technical sheets about construction equipment and temporary facilities. During this research, we noticed the problem of lack of homogeneity among the provided information. This lack is visible not only between information expressed for two different types of elements, but also between the information of the same type of element, given by two different manufacturers. For this reason, a large part of this research of construction information attempt is, first of all, the standardization of such information (as several countries made for building elements). The result of this research consists in a method to build a technical sheet of each equipment composed by structured standardized information.

The second point here presented consists in the organization of such information and in its digital expression to gain a simpler management. For this reason, the structure of the construction information has been created to fit the rules of a relational Data Base. In fact, the last point of the presented research consisted in the built of the database with the collected information to permit a further automation in information search and check (Train *et al.* 2015). Considering this possibility of automatically search in a database of machines, it is obvious how such information needs to be expressed in the same way and standardized.

2 STATE OF THE ART

Concerning technical information, the Italian Standard (UNI 8290 1981) defines it as the information that refers to practical and instrumental part of a discipline […] with the aim of improving its application (UNI 8290-1 1981). It is possible to notice that the main issue of the information is to be practical and useful to the scope. The standards moved through the years in this sense and tried, as much as possible, to standardize technical information to be simply read and managed. The last development of Italian standard is the UNI 11337-3 (2015), which concern the standardization of technical information about building project considering the evolution of technology of the last years. This standard concerns the structure of a datasheet for each type of building technical element. The presented research aims to update and enlarge this structure also for site equipment and machines for the previous stated aims. A precise structure of the technical information permits for sure a better choice of the machines during the design of the construction phase. Also, a field international research moves towards this kind of thought. Shapira *et al.* (2007) assume that technical specification of the equipment is one of the key factors for its selection during the design of a construction site. Huang *et al.* (2011) use the technical information for program and then optimize the position of a tower crane and material supply in o construction site. In the last year researches moved also to the use of BIM in order to support such decision making. In this sense Marzouk *et al.* (2016) match the use of building information models and algorithms for tower crane selection determining the number of cranes and their position as well as the type. Regarding equipment selection, Tuskaeva *et al.* (2016) developed a software able to evaluate construction equipment operation efficiency. More in detail, Gupta *et al.* (2016) studied developed a mathematical model for earthmoving equipment selection with costs estimation. With the basis of developing national standard and international research, the presented research aims to put in place a theoretical, but also practical, framework about information concerning equipment and machines to provide construction designers of a useful tool for selection of a large number of machine types.

3 TECHNICAL INFORMATION STRUCTURE

The technical information about equipment and machines is quite different to store compared to technical information about building products. The world of machines is populated by elements of very different types and communication points are very low. This is due to some main reasons. First of all, the information founded in literature about the equipment are more consistent compared to the others. There are, in addition, a lot of standards and guidelines that are mainly focused to the different types of machines. However, as anticipated, the research of information in this field bring to the thought that this great amount of information needs to be managed in a standardized way to have a simpler understanding of it. The whole process of information searching starts, as said, with the review of hundreds of technical sheets of different type of machines, in parallel with direct experience on site and research among published papers. This work permitted to create a structure that try to divide equipment according to their main functions in order to understand which information can be are proper of a machine.

The categorization of the elements follows a schema of inherited information from an upper level to another. So, each machine aimed to earthworks inherit the same set of information independently if is considered, as an example, an excavator or a loader. However, this schema needed to be further implemented. In fact, it is possible to say that there are a lot of machine that could have common different kind of information in addition to the main function. As an example, if we consider a mobile crane and an aerial working platform, we notice that they are classified in a different way since the have very different function. However, are both provided by a truck, a boom and a cabin (as an example). The same thing happens with trucks and excavators (and others) which have an aim completely different but share the characteristic of the engine. It is then understandable how the machines have many characteristics to be considered rather than the function of the equipment itself. These characteristics need to be standardized in order to appear in the same way in the different machines and to select them simply and apply to the single equipment. In fact, it is a very hard work to study information equipment per equipment since each one should have also about one hundred of parameters. Then it is understandable how the similar characteristics of different machine could be grouped in a specific panel of standardized information.

A deep analysis on information related to machines, that implies a research on more than 500 of technical sheets, brought to develop different sets of information grouped into five main categories, showed in Table 1:

Table 1. Categories of information sets for construction equipment.

Level 1 **Movement**	**Level 2** **Control.**	**Level 3** **Ground Interface**	**Level 4** **Moving parts**	**Level 5** **Specific functions**
Self-propelled	Driven	Wheeled	Absent	Transport
Pulled	Direct operated	Crawler	Outriggers	Earth excavation
Portable	Indirect operated	Roll	Hydraulic boom	Earth load
Static	Absent	Basement	Non-hydraulic. boom	Drilling
		Absent	Tipper	AWP
			Forklift	Material lifting
			Mobile platform	Aerial handling
			Other	Other

Category 1 represents the movement ways of each machines, identified as four property sets. Category 2 considers instead the type of control that the user has on the machine. Category 3 considers the interface between the machine and the ground that, in some cases, is crucial also for machine movements.

Generally, these first three levels deal with the general aspect of the equipment and its main visible characteristic. The related information sets are really distinguishing a machine from another, independently to their task or attached parts. So, each information set related to a category generally exclude the others of the same category (with the exception of control that in some machine could be both direct and indirect for safety reasons).

Categories 4 and 5 instead concerns information sets related not to the general structure of the machine (like the first three) but to single parts or tasks. So, it is possible that a single machine could have more than one information set related to the same level. In particular, Category 4 includes the characteristics of the moving parts of a machine.

Finally, Category 5 considers the functionalities of a machine and represents that parameters of production. This level is that inherited by the machines of the same type/function, while the others represent more a physical characteristic of the machine. Such a structure, as will be visible in the next paragraph permits to better manage the structure of a relational database.

In addition, if a new machine appears on the market, it is possible to use the created information sets for the main characteristics and, eventually, create only a new one if it is added something new. Table 2 shows an example of one of the described property sets that means a series of parameters related to the specific set. In particular, it shows Category 3 is related to the presence of a basement as ground interface (applicable as an example to tower cranes, hoists, silos, etc.).

Table 2. Information set about the basement.

Specifications	**m.u.**	**Quantity / Description**	**Description / Notes**
Installation type	-	*Value to be inserted*	Fixed or on railings
Basement type	-	*Value to be inserted*	Precast plinth, casted plinth, on outriggers, etc
Material	-	*Value to be inserted*	Basement material
Length	mm	*Value to be inserted*	Total length of the basements
Width	mm	*Value to be inserted*	Total width of the basements
Height	mm	*Value to be inserted*	Total height of the basements
Weight	Kg	*Value to be inserted*	Weight of the basement or of its elements
Load on supports out of service	kN	*Value to be inserted*	Maximum load out of service
Load on supports in service	kN	*Value to be inserted*	Maximum load out in service

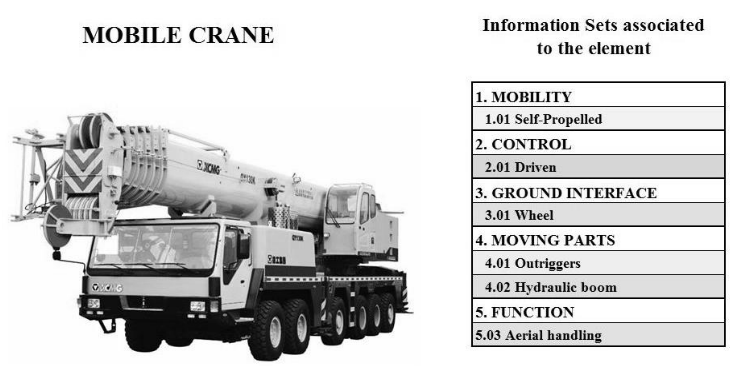

Figure 1. Structure of the sheet (related datasets) for mobile crane.

The information is represented as specification in a format able to be filled with the right variables and attributes according to the single machine examined. Each set of information is at first expressed with a table like the above. The structure of the sheet can be then realized by selecting the correct information sets as showed in the figure above.

4 DATABASE STRUCTURE AND SETTINGS

Data sets collected in table such as the above mentioned represented a valid instrument for the development of the information structure. In particular, tables are permitted to have a simple visualization of the information sets and are the main instrument used also in by manufacturers to disseminate their data. In fact, the above-mentioned information sets were a practical instrument to homogenize and organize information to reach standard datasheets for each construction equipment. In addition to this, in a world that moves towards digitalization, it is not possible to think only about sheets to fill "by hand". Such information need to be organized and managed in a digital way. To do this, a relational database complete of the totality of information stored have been realized. The DB permits, furthermore, a simpler organization and finding of this data according to the design needs inserted as input data. In fact, the organization of the data presented in the previous paragraph should remain a simpler method to organize a sheet if not digitally developed. The realization of a DB permitted to have, in addition to a collection of sheets (that remain a useful instrument of communication), a data storage to be interrogated to find the right solution.

The first step of the translation of the information panel in a database have been the writing of the tables related to each identified information set into proper datasets. After this, it was possible to express their relationships and realize the panels of information to be attached to each type of construction element, then filled with the data related to the single model. This way the entire panel of information is stored in the database and it is possible, only inserting the relationships between the sets, to put together the data needed for a single element and describe it completely.

It is important to underline how the structure given to the categories fits also the structure of the DB. In fact, the Categories/Levels 1 to 4, representing the characteristic that should be common to all types of machines according to their physical characteristics, are inserted in the DB as foreign keys that link a specific table to a specific machine. The last category, instead, represent the main functions and characterize thus the type of machine. For these reasons, the characteristic inserted in these datasets is not to be simply related to the element but inherited from an upper level that store all elements of that specific types. So, if we consider a Tower crane and a mobile crane which have physical characteristics completely different, they inherit from "Aerial handling" dataset the same function. This is also the reason the five "levels" stated in the previous paragraph are named in the database as categories. In fact, only the fifth represent an upper level in the database structure, while the others are only related parameters.

Looking at the information inserted in the last level that represents the machine itself, it is possible to read that are not single parameters but that they are related to other table that represents the defined information sets. Thanks to these links, it is possible to characterize directly each machine with its proper information sets. Then if we a consider a machine, thanks to the link created, it is automatically characterized by the whole panel of information of the chosen datasets. In addition to the categories underlined, it is added another category concerning a panel of data always present in all machines such as the data of the manufacturer or the attachments to be included in the technical sheet. The whole structure was translated in a postgis database thanks to the use of pgadmin software.

Each dataset is represented as a table which columns are the single information of the set itself. The entity "mobile crane", as an example, is represented by a table with 60 columns composed by the different related datasets. The lines of these tables become the mobile crane models of the different manufacturers to create, if completely filled, a complete panel of mobile cranes existing in commerce. It's understandable how such a structure, completely filled, makes the process of searching information about construction elements more efficient thanks also to the use of simple query tools.

5 CONCLUSIONS

The objective of this research was at first the review of information related to construction site equipment and then their categorization and translation into a digital format. The first objective was undertaken by a deep research on technical elements datasheet. Such an amount of information has been classified according to design needs and categorized according to different detail levels. In particular, this classification creates three families of elements (equipment, temporary structures, spaces), which information have been categorized for a totality of more than 50 information sets. Each information set is then characterized by a variable number of information, categorized in a standardized way, that means hundreds information collected, studied and standardized. The information standardization has a key role in construction design since the need of information sharing given by the digitalization of design issues. The expression of such information and their relationships in a digital way has been realized at first thanks to the development of a relational database able to contain in a unique platform all the categorized information and to collect data from different manufacturers. Thus, the selection of each kind of machine and temporary structure for the construction phase is made more efficient thanks to the information outputs from the database. The input data came from the construction site Information Model as well is presented in Trani *et al.* 2015. The tests carried on about the use of such a database for selecting equipment models gave good results in terms of construction design efficiency. Finally, as an output, this study lead to a collaboration with the UNI (standardization body in Italy) that aims to create standard technical sheets not only for the building elements but also for the construction site equipment.

References

Gupta, N., Gupta, R., and Pandey M., Using an Expert System for Earthmoving Equipment Selection and Estimation of Low Coasting, IJEDR, Volume 4, Issue 2, pp. 1415 – 1419, 2016.

Huan, C., Wong, C. K., and Tam, C. M., Optimization of Tower Crane and Material Supply Locations in a High-rise Building Site by Mixed-Integer Linear Programming, *Automation in Construction*, Elsevier, 20(5), 571-580, August 2011.

Marzouk, M., and Adubakr, A., Decision Support for Tower Crane Selection with Building Information Models and Genetic Algorithms, *Automation in Construction*, Elsevier, 61, 1-15, 2016.

Shapira, A., and Goldenberg, M., 'Soft' Considerations in Equipment Selection for Building Construction Projects, *Journal of Construction Engineering and Management*, 133(10), 749-760, 2007.

Trani, M., Bossi, B., Cassano, M., and Todaro, D., BIM Oriented Equipment Choice on Construction Site, in *ISEC 2015, Sust. Sol. in Struct. Eng. and Constr.* pp. *1139*–1144, 2015.

Trani, M., Cassano, M., and Todaro, D., BIM Design Flow for Construction Site, in *EURO-MED-SEC 1 - ISEC,* Interaction between Theory and Practice in Civil Engineering and Construction, 2016.

Tuskaeva, Z., and Aslanov, G., Software Product Development for the Construction Equipment Selection, *Procedia Engineering*, 165, pp 1184 – 1191, 2016.

UNI 11337-3 – Models for the Collection, Organization and Storage of Technical Information for Construction Products, 2015.

UNI 8290 – Construction Cector, Technical Information, Definitions, 1981.