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# CONSRAT. Construction sites risk assessment tool

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ABSTRACT

One peculiarity of the construction sector is that each construction site represents a unique workplace. The specific characteristics of the site affect risk generation and its evolution. However, available risk assessment tools do not capture the specificities of construction sites that may affect risk, because they only focus on assessing identified risks from a predefined hierarchy of events. This paper proposes a new "site risk" concept that is defined as the risk associated to the whole construction site that is generated by having together different elements which individually affect risk. Potential risk synergies may exist and they only can be captured adopting the construction site as unit of analysis. In doing so, a new CONstruction Site Risk Assessment Tool (CONSRAT) is presented. This is done considering also both organizational structure and resources jointly with material conditions. The tool was used to assess 150 construction sites in order to obtain convergent and internal validity evidences. Another validated tool was used as external criterion: the Qualitative Occupational Safety Risk Assessment Model (QRAM). Results provide adequate validity evidences for both the internal structure and the expected relationships with the external criterion. CONSRAT design and complete instructions for its use are described. As a unique contribution, CONSRAT adopts a new site risk approach to assess the main live conditions, complexity factors and organizational structure characteristics which are related to construction site risk.



## 1. Introduction

Construction sites represent a workplace with limited access for research purposes, which means the lack of exposure measures (Swuste et al., 2012). Swuste et al. (2012) pointed out that "construction is different", due to these special characteristics of the construction process. In fact, studies at task level only represent the 2.28% of all available research, that makes necessary to drive more attention to safe construction task (Zhou et al., 2015).

Research based on accidents rates mainly focuses on the accidents related tasks or risks (Conte et al., 2011), or the size of the company (McVittie et al., 1997), or the accident hierarchy to risk assessments (Pinto, 2014; Swuste et al., 2012). Other studies have included personal characteristics and interpersonal and organizational variables that may be implicated in the occurrence of work-related accidents by means of self-reported measurements (Sesé, 2003; Tomas et al., 1999). All these approaches generally implement in a correct way and ex post facto design, but they have limited information on the contexts where the accidents occurred. Safety cannot be improved by only looking to the past and taking measurements against the occurred accidents, because this information is so specific and distinctive for each accident, that it becomes difficult to develop knowledge with enough generality (Hollnagel, 2008). Reconstruct scenarios of accidents obtaining their information is valuable but it may be broadened. Occupation risk model (ORM) developed by the Dutch Workgroup Occupational Risk Model (WORM), is one important example of this line. This model provided several lists of major scenarios of accidents per industrial sector. Large studies are developing from this model, for example, Ale et al. (2008) develop an ORM to quantifying occupational risks that analyses scenarios to link cause with consequences. Jørgensen et al. (2010) adapts ORM model form SME in Danish context. Finally, Aneziris et al. (2008) quantified risk assessment for fall from height. Other current research complement these lines is working on precursor analysis field, near misses or leading indicators capable to anticipate the accident obtaining predictors (Cambraia et al., 2010; Chi et al., 2012; Grabowski et al., 2007; Hinze et al., 2013; Memarian and Mitropoulos, 2013; Rozenfeld et al., 2010; Toellner, 2001; Wu et al., 2010; Yang et al., 2012).

It is important to note that the quality of obtained evidences strongly depends on the accuracy of applied assessment methods. Pinto et al. (2011) pointed out that general safety risk assessment methods are not specific for construction. Some instruments for

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assessing specific construction risks have been developed. One example is the Qualitative Occupational Safety Risk Assessment Model (QRAM) that incorporates uncertainty using fuzzy set (Pinto, 2014). QRAM analyses up to nine types of accidents, taking into account the effectiveness of the protections and the possibility and severity of risks. Risk assessment includes the dimension of organizational safety climate and the workplace safety level. In turn, the CHASTE method (Construction Hazard Assessment with Spatial and Temporal Exposure) tries to estimate the quantitative value of probability risk before accident occurs, by loss-of-control event (Rozenfeld et al., 2010). Other example is the TR index (*Talonrakentaminen Riski*, Building construction risk in Finnish) (Laitinen et al., 1999) that takes into account main items on building sites, calculated as a percentage of the 'correct' items related to all the observed items. This method could be useful as a means of objective feedback for the companies (Laitinen and Päivärinta, 2010; Laitinen et al., 1999). These methods are conclusive on risk levels by means of different methodologies: QRAM, comparing with others validated models and expert opinion; CHASTE, applying the method to 14 activities, expert workshop and interviews with site engineers; and finally TR index was validated though correlations between its TR index and accidents rates of sites grouped according TR index.

These tools use well-structured techniques to specify risk levels and focus on the pursuit of accuracy over traditional risk assessment. But these methods limit the possibility of analysing all elements that make up the construction site affecting risk. Elements such as complexity, size, human resources, internal organization, Health and Safety (H&S) plan, access, circulation, process, machinery, among others, are not specifically valued. The main drawbacks lie in the relative complexity of its application at the construction site as a control tool, as well as its limitations to comprise the analysis of the general conditions and also the specific conditions of the construction site stage. For example, TR index does not systematise other conditions regarding the construction site structure or its environment. In addition, these tools do not contemplate structure resources or other elements of site's organization to complete the analysis. In this sense, construction companies are similar to an organic structure that manifests itself in its processes (Swuste et al., 2012). Although processes may determine the organizational structure on site, the main contractor's resources seem to be determinant to assure the adequate amount of resources on site. The quantitative relationship between company scale and construction safety on site is still a gap at current research. More attention must be paid to determine the effects of organizational factors and their role in site safety (Swuste et al., 2016; Zhou et al., 2015). Specially, we stress the following four ones classified from literature: Site complexity that includes project complexity, site restrictions and level of construction or size of site (Fang et al., 2004b; Hatipkarasulu, 2010; Hon et al., 2010; Manu et al., 2013); Organizational structure resources that includes size of firms, type of promoter or contractor and their involvement, or foreman authority (Camino López et al., 2008; Cheng et al., 2010b; Hallowell, 2011; Hallowell and Gambatese, 2009, 2010; Holte et al., 2015; Liao and Perng, 2008; Pérez-Alonso et al., 2011; Zou et al., 2010); Complexity of organizational design that refers to site internal structure and includes number of companies and their organization, the subcontracting levels and number of workers (Hallowell and Gambatese, 2009, 2010; Hinze et al., 2013a, 2013b; Liu et al., 2013; López-Alonso et al., 2013; Manu et al., 2013; Swuste et al., 2012; Yung, 2009); finally, Safety management resources that is referring to the preventive functions of the persons in charge and the existence of safety supervisors (Abudayyeh et al., 2006; Baxendale and Jones, 2000; Hallowell, 2011; Hallowell and Gambatese, 2009, 2010; Hinze et al., 2013a; Jarvis and Tint, 2009; Liu et al., 2013; Manu et al., 2013).

Beyond solving these tools' limitations, and taking into account the impact of organizational element on risk, it seems necessary a new approach based on the construction site risk analysis instead of restrict to obtain a measurement of each accident events from a hierarchy (Pinto, 2014; Swuste et al., 2012). In this way, this new approach means connect most of the physical elements related with site risk and its organizational structure. We refer to site elements that contain live conditions able to generate risk such as general site conditions (e.g. site access, circulations, order or collective protections), and main stage tasks conditions (e.g. access, falls or other risks, work process analysis and the collective and personal protections used on this main stage, auxiliary resources and machinery). Other important elements to consider are organizational characteristics such as complexity, size, resources, internal organization or preventive resources, among others.

In order to achieve this challenge, we introduce the concept of "site risk", which comprises the associated risk to the whole construction site that is generated by having together those different elements that individually generates risk. The aim of this study is to design and validate a new tool for assessing the site risk: CONstruction Site Risk Assessment Tool (CONSRAT). This instrument tries to meet the lack of tools for analysing the construction site as unit of analysis, with own identity and a structure which are different from the companies that compose the site.

## 2. Methods

### 2.1. Procedure

CONSRAT is built taken into account actual literature knowledge and personal technical experience of authors about H&S on construction sites. ScienceDirect database has mainly used for doing the literature review in the period 2011–2014. Firstly the search was focused on tools oriented to assess construction site risks, using as keywords: safety construction, construction risk assessment, construction site risk, construction resources, construction organization, and construction structure. Finally, the search was extended to more general terms as accident construction. A total number of 1864 studies were found and a final number of 135 that had direct relationship or implications to our study. Then we focus on tools that were specifically designed for risk site assessment. Literature review results about construction tools showed both a limited knowledge circumscribed to focus on individual construction risks, and the lack of methods focusing on site risk.

Previous knowledge focused on sites (Laitinen et al., 1999; Laitinen and Päivärinta, 2010; Pinto, 2014; Rozenfeld et al., 2010), general knowledge of Occupational Safety Risk Assessment (OSRA) and organizational elements, and all our technical background on safety construction were used to develop CONSRAT. In addition, a panel of 11 construction safety experts was consulted to obtain content validity evidences about our classification and variables composition. Finally, a sample of 150 sites was assessed with CONSRAT and QRAM methods in order to obtain both internal and convergent validity evidences.

### 2.2. Sample

In order to address the empirical validation of CONSRAT, a randomly extracted sample of 150 construction sites with diverse typologies, construction phases and sizes was used. All sites have building construction typologies; the highest percentage corresponds to new construction (88%), completed by reforms and extensions (12%). The sample has similar proportions of single and multi-family housing (48% and 45% respectively, and 7% other uses). Most of the sites are from one to two floors (57%, height from 3 to 9 m.); in second place we have buildings from three to five floors (38%, height from 9 to 18 m).

Related to site organizational resources, we can underline that promoters are mostly professional companies (55%), followed by private individual (30%), and the rest of Public Administration (15%). The most of contractors are companies with different legal forms (96%), followed by any of the self-employed configuration (with or without workers, 4%). Most of the sites have one contractor (85%), and more than one firm (67%) working simultaneously on site. Sites with subcontracting represent the majority of the cases in our sample (62%). The mean number of workers in the sites of our sample is 14. Most of sites have site foreman (47%), followed by nobody in charge (23%) and single worker in charge (20%). In the majority of our sites there is not documented H&S plan (57%).

About site general information, the most common work stages is flat structure works (34%) and brickwork (24%), followed by facade works (20%) and roofs (18%). Most of the cases we have one main work (58%) and the workers are located on perimeters of floors or roofs (58%), followed by, interior floor (18%), and outdoor on auxiliary resources (15%).

### 2.3. Instruments

The Qualitative Occupational Safety Risk Assessment Model QRAM (Pinto, 2014) was used as external criterion to CONSRAT for obtaining convergent validity evidences. QRAM is a tool designed to the construction industry and proposes a procedure for the estimation of risks at work, through a structured list of questions and their further processing to carry out the evaluation. The tool analyses up to nine types of accidents, taking into account the effectiveness of the protections and climate, using of fuzzy sets theory to improve the use of imprecise information. The final outcome of this tool shows several types of Risk Levels (RL). It was validated by a panel of experts and convergence validity evidences with other tools were also obtained. QRAM uses the ALARP (As Low a level As Reasonably Practicable) criteria to ranking the risks. Above ALARP levels, it considers the unacceptable level, below the acceptable, and between them, the ALARP area that means to practice a continuous improvement of safety conditions.

### 2.4. Statistical analyses

Convergent and internal validity evidences were obtained by correlational analysis. Two correlation matrices were estimated, one between CONSRAT's risk and organizational variables, and another one between all CONSRAT variables and QRAM Risk Levels indicators (RL). Statistical assumptions for linear correlation were tested. Correlation matrices were estimated with SPSS 21.0 software (SPSS IBM Corp. Released, 2012).

## 3. Results

### 3.1. CONSRAT, the tool

The tool is structured in three parts: the form to be completed on field work on site by a technician (Appendix A), and the composition and weights to build 10 organizational, and 10 risk variables (Sections 3.1.3 and 3.1.4 Appendices B and C). The tool includes only a significant group of variables that are representative of the requirements of the proposed definition of site risk, while the type of sites is unlimited and consequently, the corresponding elements to be evaluated. CONSRAT form includes two broad parts of indicators (I and II) and two different valuation criteria. The first part refers to general information, organizational and resources factors on site. The second part, mainly evaluative of works conditions, is divided into four sections to determine the current risk conditions on site. The valuation criterion specifies the meaning of each level to be assessed and is developed at next Section 2.2.

The tool cannot be considered as a classical risk assessment tool, if not a site risk assessment. For this reason, it does not include assessment of each individual risk. But it includes expressly fall from height risk as one on his variables, because the general prevalence of this risk (Ale et al., 2008; Aneziris et al., 2008) and the specific prevalence in construction sector (Camino López et al., 2011, 2008; Swuste et al., 2012). The general scheme of the tool structure, indicating for each section their corresponding items according to Appendix A is:

- I. General information and organizational factors:
  - i. Identification data: items 1–4
  - ii. Construction site characterisation: items 5–9
    - a. Stage of the works. Locations: items 10–13
  - iii. Promoter characterisation: items 14–19
  - iv. Constructor characterisation: items 20–30
  - v. H&S Plan adequacy: items 31–32
- II. Risk factors on site:
  - i. H&S Plan compliance: item 33
  - ii. General conditions valuation: items 34–38
  - iii. Stage conditions valuation: 59 items
    - a. Access: item 39
    - b. Fall from a height: items 40–45
    - c. Other risks concurrence: items 46–57
    - d. Process valuation: items 58–60
    - e. Collective protections: items 61–70
    - f. Personal protection equipment: items 71–74
  - iv. Auxiliary resources and machinery: 22 items
    - a. Auxiliary resources: items 75–85
    - b. Elevation resources: items 86–92
    - c. Other machinery: items 93–97

#### 3.1.1. Levels of valuation

The existing indices that measure safety conditions in construction sites use several different scales. The most simple of all of them uses a dichotomy format: correct/incorrect, such as for example in the TR index (Laitinen et al., 1999). This index was formerly used in combination with other factors and weights, such as safety plans, criteria changes at construction sites and company accident rates, in order to follow safety campaigns (Laitinen and Päivärinta, 2010). Other studies also use polytomous variables, such as for example the CHASTE method with four levels (Rozenfeld et al., 2010). Finally, in other cases, five or more levels are used (Hollnagel, 2008; Pinto, 2014; Rubio-Romero et al., 2013).

CONSRAT combines different scales for answering the different indicators. In general, a four level scale with zero corresponding to a full accomplishment level and three meaning very deficient or non-existent accomplishment level was used. A value ranging from 0.00 through 1.00 with equivalent increments of 0.33 is assigned to each level. In other cases a dichotomous scale is applied to value presence/absence or valuing the adequacy of protections. Specific scales used to each item are included in the form (Appendix A). Valuation criterion is also at Appendix A, at the end of the form.

The use of those four levels is justified by having a broad enough scale to avoid too wide valuations, but at the same time precise enough to prevent the result of the evaluation from falling in ambiguous zones with labels such as medium, partial or just fair accomplishment. With that kind of scale would be unclear what the final result of the evaluation might be. The final goal is to know whether or not the site that has been assessed is acceptable or not. In summary, it is a bipolar scale without a neutral point (favourable, 0 and 1, or unfavourable 2 and 3).

*3.1.2. Field work fulfilment*

CONSRAT registers responses and assessments to a total of 97 items (using the questionnaire and criteria of Appendix A) and entails a four step process:

Step 1: Filling in the assessment template and rating (Appendix A). In doing so, we use the form and valuating with criteria that appears at the end. This step begins with an interview to the person in charge of site, the checking of the documentation that must be on site and filling the data required in the form. We have to ask to the foreman all items that we do not deduce just checking the site or documentation (i.e. type of contracting, number of workers or companies, subcontracting, etc.). It is important to check H&S plan, explicitly its previsions for actual work stage to be able to assess its actual compliance. Then, we begin a general visit to the construction work to assess its general elements. It is mainly outside and affecting the areas commonly used by all workers to access, located equipment and stockpile. For each element, and follow the form we just select the corresponding level according to the valuations criteria (four or two levels depending of each item). Then, we go into the building and assess its general collective protections without arriving to main stage. If we have several protections (several types, levels, etc.) we will always choose the worse. After that, going on to main stage, we will check its access. Finally, arriving to the main stage location and with similar criteria, we have to evaluate its specific conditions going on with the form items. Some items may need make questions to the foreman or workers, as the continuation of exposure and process (items 42 and 59), and observe an enough work time sequence.

Step 2: Items scoring. Items are direct, using mentioned valuation criteria at the end of the form. For each rating corresponds a scoring. As we have seen at Section 2.2 we have two different levels, general valuation with four and dichotomous valuation. This reduced criterion is used for items that do not need more clarification (i.e. adjustment to the phase, needed of more, risk identification).

Step 3: Levels of variables estimation. Final variable levels are estimated using the aggregate rules on Appendices B and C for organizational variables and risk variables respectively.

*3.1.3. Organizational variables*

According to literature review and an expert panel content validity process, a total of ten organizational variables were considered. Table 1 shows the composition of each variable and the main literature references.

Relating the literature on safety risk management with our tool, it can be seen that CONSRAT only includes two of the most mentioned safety program elements: "safety manager on site", and "written and comprehensive safety and health plan" (Hallowell, 2011; Hallowell and Gambatese, 2009, 2010; Hinze et al., 2013). As these authors claim, safety inspections are an element of safety management. Thus, although our tool might be considered as one more element of a safety risk management system, we do not propose it as a valid tool to evaluate the safety risk management system. We have considered in CONSRAT only those safety management elements that a technician can objectively verify on a single visit on site. We have avoided other elements which are based on perceptions (e.g. "upper management support", "employee involvement", etc.). Additionally, we have not incorporated other elements that need specific and more complex tools, including surveys, to obtain them (e.g. "subcontractor selection and management", "substance abuse programs", "safety and health committees", etc.).

In order to obtain content validity evidences for the classification of variables in Table 1, a panel of 11 experts was carried out. All participants were experts with more than 15 years of experience on the field of construction. Some of them have professional experience as projectors and/or directors of several buildings constructions assuming safety and health functions. Five of them, in addition, have academic experience training in architecture or engineering subjects, including specific training on safety and

**Table 1**
Organizational variables, composition, CONSRAT and main literature references.

| Variable | Item | CONSRAT references[a] | Literature references |
|---|---|---|---|
| OV1. Complexity of project | New construction site or reform and extensions | 5 | Fang et al. (2004a), Hon et al. (2010), and Manu et al. (2010) |
| | Building configuration | 6 | |
| | Special environment conditions | 18 | |
| OV2. Size of site | Number of floors | 7 | Hatipkarasulu (2010) and HSE (2009) |
| OV3. Stage characteristics | Main work stage | 10 | Manu et al. (2010) |
| | Secondary work stage | 11 | |
| OV4. Promoter resources | Type of promoter | 14 | Behm (2005), Hinze et al., 2013, Liu et al. (2013), Wu et al. (2015), and Xinyu and Hinze (2006) |
| OV5. Constructor resources | Type of constructor | 20 | Cheng et al. (2010a), Camino López et al. (2011), Hallowell and Gambatese (2009), (2010), Holte et al. (2015), and Liao and Perng (2008) |
| | Constructor's Role | 21 | |
| | Site management structure | 28 | |
| OV6. Internal organization structure | Type of contracting | 17 | Hallowell (2011), Hallowell and Gambatese (2009), (2010), Hinze et al. (2013a, 2013b), Liu et al. (2013), López-Alonso et al. (2013), Manu et al. (2013), Swuste et al. (2012), and Yung (2009)) |
| | Number of companies at site | 22 | |
| | Level of subcontracting | 24 | |
| | Number of works | 12 | |
| OV7. Job planning and design | Employee location assignments | 13 | Fang et al. (2004a), López-Alonso et al. (2013), and Manu et al. (2010) |
| | Total number of workers on site | 27 | |
| | Ratio of number of workers of principal constructor over total workers at site | 26/27 | |
| OV8. Coordination resources | Designation H&S coordinator | 15 | Fang et al. (2004a) and Ros et al. (2013) |
| | Documented work of H&S coordinator | 16 | |
| OV9. Preventive functions | Preventive functions of the structure | 29 | Baxendale and Jones (2000), Hallowell (2011), Hallowell and Gambatese (2009), (2010), Hinze et al. (2013a), Jarvis and Tint (2009), Liu et al. (2013), Mahmoudi et al. (2014), and Manu et al. (2013) |
| OV10. H&S plan adequacy | Presence at site of H&S Plan | 31 | Fang et al. (2004a), Hallowell (2011), Hallowell and Gambatese (2009), (2010), Hinze et al. (2013), and Ros et al. (2013) |
| | Appropriateness of H&S plan's previsions | 32 | |

[a] See Appendix A for further information.

health subjects. They were asked to classify all the 22 different items listed in Table 1 into one of the ten variables mentioned above. They were not forced to assign all the items to a given factor, i.e., they were allowed to not classify any of them if they thought there was no logical, technical or theoretical reason to do so. The result was that the experts correctly assigned all the given items, and consequently their associated item, to the variable previously considered by us, except in two items. The two non-concordant items were "Type of promoter" and "Number of works". In both cases, the a priori classification was changed maintaining the one supported by the panel of experts. The resulting final classification of each item/variable was supported by an average of 78.73% of the experts (*SD* = 12.89).

Appendix B contains a summary of the rating scales, the scoring procedure used for measuring all items, and the aggregation rules to build organizational variables. The different metrics and scales used for item measurement reflect an increasing pattern in the level of either complexity or resources regarding that item. Thus, in all cases a higher observed value implies more complexity or more level of resources. In order to have all the different items measured in a common scale, the original observed values were transformed into percentiles according to its own range of measurement scale. With those values for each item the value of each organizational variable as the average of observed values in percentiles of its corresponding items was calculated. In this case complexity and resources do not have a specific classification like one will see at risk variables. The levels go from 0.00 to 1.00 that means from less to more levels on complexity and resources.

#### 3.1.4. Risk variables

CONSRAT holds a risk variables structure concerning the material conditions on site which is close to the organization of a building construction and compatible with the different parts of the site. In this sense, the variables try to reflect the organic structure of the site mentioned by Swuste et al. (2012), giving us on the one side general information of the site, and on the other side, specific information of the scenarios, which impact the overall valuation of a construction site. The aim of these risk variables is not provide all possible information of site. By contrast, our challenge is to build a structure to provide enough site information to propose adequate interventions fitted to the site, stage ejection and resources.

Fig. 1 shows the location of each risk variable on site, trying to cover all its different sections. As each section is not a "closed box" and each site has its own characteristics, intersections are plausible, but focusing each variable it is possible to obtain information from whole site. A number of 10 risk variables are chosen not as a close and exhaustive number, but a selection of 10 important ones capable to define the site risk. Moreover, the point is not trying to assess each single risk, but site risk. In doing so, we consider individually one single risk (falls from height) because its prevalence and representative of our site risk level, according to obtained evidences. Other risks could be present or not, and they are grouping together in other variable. Other risk variables represent barriers or other issues connecting with risk.

The composition of risk variables can be seen at Table 2 (scoring and aggregation rules are in Appendix C). Five of them are considered alarm variables (identified with an asterisk), i.e., they provide information about severe problems that need to be prioritised. Next each risk variable is explained in more detail:

*H&S plan compliance (RV1).* According to EU Directives, it is the main legal reference of H&S previsions that must be followed on site. This variable focusses on site stage. *General conditions of site (RV2).* This variable is referred to common areas of site, without looking at the current stage. This is one of the variables that the available tools do not consider explicitly. We consider important to disaggregate this information. *General conditions of the collective protections (RV3).* These conditions do not consider the current stage. It is needed to know the level of each collective protection on site (general and main stage) because they may require special treatment and actions. *Access* (*RV4*). It refers to the specific conditions of stage access, as a separate matter from those valued in the general conditions, because stage access frequently presents a different performance. *Falls from height* (*RV5*). This variable is the unique that includes a risk assessment and exclusively is composed by just this risk. This is because it is the most important risk on construction sites, always present at building construction and located at the top of risk on literature. It is measured at the current stage. We add, to the classical probability and severity items, four news items to improve the risk assessment with the specific site conditions. These items aggregate information for determining the needed intervention priorities.

*Other risks* (*RV6*). This variable identifies the coincidence of 11 risks at the current stage, and their influence on the risk of falls


**Fig. 1.** CONSRAT risk variables from site sections.

**Table 2**
Risk variables and their composition with CONSRAT references.

| Variable | Item | CONSRAT Ref.[b] |
|---|---|---|
| RV1. H&S plan[a] | – Compliance | 33 |
| RV2. General conditions | – Construction fence | 34 |
| | – Circulations, order, tidiness, illuminations | 35 |
| | – Safety signage | 36 |
| | – Safety of electrical installation | 37 |
| RV3. Collective protections[a] | – General collective protections | 38 |
| RV4. Access | – Access to main work stage | 39 |
| RV5. Falls of height[a] | – Height of fall | 40 |
| | – Level of failure | 41 |
| | – Exposure continuation | 42 |
| | – Probability | 43 |
| | – Severity | 44 |
| | – Intervention required | 45 |
| RV6. Other risks | – Identification of 11 more risks | 46–56 |
| | – Incidence with Falls of height | 57 |
| RV7. Process | – Adequacy | 59 |
| | – Process deviation | 60 |
| RV8. Collectives protections[a] | – Scaffolds. Adjustment to the phase and installation validation (Ad. & Val.) | 61–62 |
| | – Safety nets | 63–64 |
| | – Railing | 65–66 |
| | – Safety boarded. validation | 67–68 |
| | – Necessity more collective protections | 70 |
| RV9. Personal protections[a] | – Fall protection system | 71–72 |
| | – Need for more PPE | 74 |
| RV10. Auxiliary resources and machinery | – Scaffolds (Ad. & Val.) | 75–76 |
| | – Suspended scaffolds. (Ad. & Val.) | 77–78 |
| | – Horse scaffolds. (Ad. & Val.) | 79–80 |
| | – Portable ladders. (Ad. & Val.) | 81–82 |
| | – Others. (Ad. & Val.) | 83–84 |
| | – Lift truck. (Ad. & Val.) | 86–87 |
| | – Crane truck. (Ad. & Val.) | 88–89 |
| | – Fall protection for elevation resources. (Ad. & Val.) | 90 |
| | – Auxiliary resources for elevation system. (Ad. & Val.) | 91 |
| | – Concrete mixer. (Ad. & Val.) | 93–94 |
| | – Manual tool. (Ad. & Val.) | 95–96 |

[a] Alarm variables.
[b] See Appendix A for further information.

from height. With this variable we want to estimate the effect of having together these risks and their effect on falls from height. We consider all these risks grouped together in one single variable, because in building construction are secondary in relation with fall height risk. *Process* (*RV7*). It identifies whether or not the works sequence is adequate and it is performed according to the planned process. It tries to cover the need to undertake a task analysis as the literature has been claimed. *Collective protections* (*RV8*). It evaluates these protections at the current stage. It is composed by the adequacy, the assessment of the installation, and the need for more collective protections. *Personal protections* (*RV9*). It evaluates personal falling from height protection at tasks execution. It is composed, measured and valued with the same criteria than *RV8. Auxiliary resources and machinery* (*RV10*). This variable evaluates the adequacy to the phase and an assessment of the installation of different resources and machinery. It is composed of twenty items including auxiliary resources and construction machinery, elevation machinery and other machinery.

CONSRAT risk variables are measured within a zero-one interval. We then classify the observed value of each risk variable into three groups: Correct (from 0 to 0.33 included), acceptable (above 0.33 and below 0.66) and unacceptable (from 0.66 to 1.00). Valuation criterion (Appendix A) explains the rules to choose the different levels. The main criteria to choose between acceptable and unacceptable, the critical step, must bases in legal normative application. When it is not clear or insufficient, it must be rating according train technician criteria taking in account the elements that appear in mentioned valuation criteria.

### 3.2. CONSRAT validity evidences

#### 3.2.1. Relationships among CONSRAT variables

In order to address the empirical validation issue of CONSRAT, we have done an exploratory analysis of expected correlations. On first place, we have calculated the correlations among CONSRAT variables within.

As Table 3 shows, all correlations between risk variables have a positive sign and almost all of them are statistically significant ($p < 0.01$). The risk variable *RV*5 (Falls from height), and *RV7* (Process) present the highest coefficients with all risk variables. *RV*10 (Auxiliary resources and machinery) obtained the lowest coefficients and relationship between *RV*10 and *RV*8 (Personal protections) was non-significant.

Relationships between risk and organizational variables showed that *OV*1 (*complexity* of the project) and *OV*2 (size of site) obtained negative correlations with all risk variables. Correlations among *OV*1 and *OV*2 and variables of resources (*OV*4, *OV*5, *OV*8, *OV*9 and *OV*10) have significant positive coefficients in most cases, and a similar pattern was obtained for *OV7* (job planning and design). However, *OV*3 (stage characteristics) obtained a significant positive relationships with most risk variables. The other relationships between risks and organizational variables (*OV*4, *OV*5, *OV*8, *OV*9 and *OV*10) obtained a more homogenous behaviour. Most of the correlations in this case were negative. Results about OV intercorrelations showed that *OV*1 (more complexity of the project) is statistically significant correlated with *OV*2 (size of site), *OV*4 (promoter resources), and with *OV*8, *OV*9 and *OV*10 (resources on site, preventive resources of coordinator, and H&S plan). *OV*3 (stage characteristics) did not reach statistical significance with any other OV variables, while *OV7* (job planning and design) only obtained a significant correlation with *OV*8 and *OV*9.

#### 3.2.2. Relationships between CONSRAT and QRAM variables

Five of the nine Risk Levels (RL) of QRAM model to estimate correlations between CONSRAT variables were identified. It involves falls (F), contact with electricity (Ce), injured by falling/dropped/-collapsing objects (Fo), hit by rolling/sliding object or person (So), contact with machinery moving parts (M). The four remaining RL were discarded due to their very low risk level magnitude. The risk assessment with QRAM was carried out without consider climate. All correlations between CONSRAT risk variables (RV) and QRAM risks levels (RL) were positive and mainly statistically significant ($p < 0.01$) (Table 4). Specifically *RV*5, falls of height, obtained highest coefficient of 0.92 ($p < 0.01$) with QRAM RL falls of QRAM. A similar behaviour was found between *RV*5 and the rest of RL variables (F, Ce, Fo, So, M). A column with the average of all RV (SRI) was added in the middle of Table 4.

## 4. Discussion and conclusions

The main objective of this paper is to develop a new assessment tool that consider construction site as a unit of analysis, and the main idea that potential risk synergies may exist when individual risk elements are together on site. Consequently, the construction site risk is greater than the simple addition of the different risk levels identified from a hierarchy of events. Adequate convergent validity evidences for CONSRAT has been obtained using QRAM

**Table 3**
Correlation matrix among CONSRAT variables.

| | RV1 | RV2 | RV3 | RV4 | RV5 | RV6 | RV7 | RV8 | RV9 | RV10 | OV1 | OV2 | OV3 | OV4 | OV5 | OV6 | OV7 | OV8 | OV9 | OV10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RV1 | 1 | | | | | | | | | | | | | | | | | | | |
| RV2 | ,49** | 1 | | | | | | | | | | | | | | | | | | |
| RV3 | ,58** | ,71** | 1 | | | | | | | | | | | | | | | | | |
| RV4 | ,42** | ,68** | ,55** | 1 | | | | | | | | | | | | | | | | |
| RV5 | ,69** | ,64** | ,71** | ,59** | 1 | | | | | | | | | | | | | | | |
| RV6 | ,38** | ,36** | ,35** | ,35** | ,55** | 1 | | | | | | | | | | | | | | |
| RV7 | ,66** | ,65** | ,73** | ,58** | ,83** | ,56** | 1 | | | | | | | | | | | | | |
| RV8 | ,38** | ,46** | ,55** | ,31** | ,60** | ,39** | ,52** | 1 | | | | | | | | | | | | |
| RV9 | ,46** | ,45** | ,64** | ,34** | ,66** | ,31** | ,61** | ,47** | 1 | | | | | | | | | | | |
| RV10 | ,28** | ,29** | ,33** | ,27** | ,33** | ,29** | ,34** | ,17* | ,31** | 1 | | | | | | | | | | |
| OV1 | –,47** | –,35** | –,34** | –,29** | –,31** | –,06 | –,42** | –,24** | –,12 | –,15 | 1 | | | | | | | | | |
| OV2 | –,06 | –,40** | –,35** | –,31** | ,05 | ,17* | –,11 | –,03 | –,20* | –,13 | ,41** | 1 | | | | | | | | |
| OV3 | ,39** | ,24** | ,36** | ,23** | ,39** | ,25** | ,53** | ,17* | ,40** | ,31** | –,12 | ,07 | 1 | | | | | | | |
| OV4 | –,36** | –,41** | –,23** | –,22** | –,10 | –,12 | –,15 | –,06 | –,01 | –,16 | ,43** | ,38** | ,16 | 1 | | | | | | |
| OV5 | –,26** | –,20* | –,33** | –,13 | –,05 | ,15 | –,12 | –,04 | –,06 | –,01 | ,27** | ,37** | ,08 | ,46** | 1 | | | | | |
| OV6 | –,22** | –,20* | –,18* | ,05 | –,01 | ,03 | –,04 | ,03 | ,01 | ,07 | ,07 | ,19* | ,17* | ,40** | ,33** | 1 | | | | |
| OV7 | –,16 | –,20* | –,26** | ,07 | ,02 | –,06 | –,20* | –,35** | ,02 | –,05 | ,22** | ,10 | –,10 | ,14 | ,12 | ,21* | 1 | | | |
| OV8 | –,40** | –,36** | –,28** | –,14 | –,21** | –,04 | –,22** | –,33** | –,10 | ,05 | ,53** | ,28** | ,04 | ,47** | ,32** | ,34** | ,38** | 1 | | |
| OV9 | –,54** | –,59** | –,60** | –,43** | –,40** | –,34** | –,50** | –,28** | –,24** | –,27** | ,51** | ,38** | –,13 | ,46** | ,48** | ,32** | ,36** | ,44** | 1 | |
| OV10 | –,34** | –,34** | –,37** | –,32** | –,21** | –,18* | –,23** | –,22** | –,10 | –,03 | ,44** | ,44** | –,02 | ,35** | ,40** | ,38** | ,08 | ,47** | ,50** | 1 |

* p < 0.05.
** p < 0.01.

for correlation comparison. On one hand, a positive and statistically significant relationship between all CONSRAT risk variables (RVs) within and with QRAM risk levels (RLs) was expected, with different magnitudes depending of each risk variable composition. On the other hand, different relationship patterns between RVs and RLs with CONSRAT organizational variables (OVs) were expected depending of the OV type. In general, for OVs that express complexity (*OV*1, *OV*2, *OV*3, *OV*6 and *OV*7) a positive relationship with RVs and RLs was expected, in the sense than more complexity increase risk. With OVs that express resources (*OV*4, *OV*5, *OV*8, *OV*9 and *OV*10) a negative relation with RVs and RL was also expected, in the sense that more resources decrease risk. And finally, lower coefficients or even non-significant relationships between RLs and OVs than with RVs and OVs were expected, because the most general site assessment that entails RVs.

Results of correlations among RVs confirm expected results, so adequate evidences about all RVs could be representative to site risk level have been obtained; though RVs are assessing different risk site areas. Particularly, RV5 (falls from height) and *RV7* (Process) results are mainly demonstrative in our context of building construction sites, that are indicative of site level risk. These two variables showed statistical significant correlations ($p < 0.01$) with all other VRs and RLs, and may justify they election of variable composition. For its part, RV6 (Other risks) also reached significant correlations with all others RVs and RL, despite their coefficients are lower than with RV5, that shows its adequacy and adequate behaviour. The lowest coefficients of RV10 with the others RVs, although significant, show certain independent relationship, as for example, with *RV*8 (Personal protections). In this case, the site can have a good fall protection system, but also have inadequate machinery, or vice versa.

Obtained correlations among RVs and OVs are important empirical evidences about the CONSRAT internal consistence (not psychometric one). Correlations between RVs and OVs agree in general with our expected results, but not in all cases. Significant relationships of variables *OV*1 and *OV*2 with most of RVs are negative, that means more complexity may be related with lower risk. These results could be interpreted in the sense that probably more complex projects with bigger sites have more resources to control their risks. In fact, positive correlations from both *OV*1 and *OV*2 to resources' OVs (*OV*4, *OV*5, *OV*8, *OV*9 and *OV*10) confirm this prevision and explain previous results. A similar behaviour for both *OV*7 and *OV*6 than *OV*1 and *OV*2 with RVs (although with lower coefficients) may think in similar motivations because the similar correlations with OVs of resources. Correlations of *OV*3 on RVs agree with expected results. These evidences give support to the strength of OV structure to assess stage complexity and its possible relation with risk. On the other hand, expected results among resources variables (*OV*4, *OV*5, *OV*8, *OV*9 and *OV*10) on RVs were also obtained. Especially adequate behaviour between the OVs related with prevention (*OV*8, *OV*9 and *OV*10) was showed, with the best behaviour of *OV*9 (preventive functions) to RVs. These results are indicative of content validity of the tool, and in addition of the importance of resources, especially the preventive functions of the structure, over the complexity of site.

Intercorrelations between OVs showed an adequate expected behaviour. All correlations between different dimensions of site complexity (*OV*1, *OV*2, *OV*6 and *OV*7) are positive and most of them significant, except *OV*3 that has a different pattern because the specific characteristics of the stage that could not be coincident with site complexity in each stage. These results can be interpreted as these variables assess different characteristic of complexity. And taking into account the sample, composed by building constructions, these OVs assess characteristics that have a similar behaviour. For example, among the significant correlations ($p < 0.01$), more complexity of the project (*OV*1) are related with more size (*OV*2) (0.41), and job planning and design (*OV*7) (0.22). More com-

**Table 4**
Correlations between CONSRAT variables and QRAM risk levels.

| | RV1 | RV2 | RV3 | RV4 | RV5 | RV6 | RV7 | RV8 | RV9 | RV10 | SRI | OV1 | OV2 | OV3 | OV4 | OV5 | OV6 | OV7 | OV8 | OV9 | OV10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F | ,61** | ,49** | ,68** | ,52** | ,92** | ,53** | ,75** | ,57** | ,66** | ,37** | ,85** | –,18* | ,06 | ,36** | ,02 | ,01 | ,07 | ,04 | –,14 | –,28** | –,16 |
| Ce | ,47** | ,73** | ,61** | ,53** | ,55** | ,32** | ,58** | ,29** | ,44** | ,23** | ,64** | –,16 | –,27** | ,26** | –,41** | –,22** | –,21* | –,05 | –,21* | –,39** | –,28** |
| Fo | ,22** | ,17* | ,16 | ,26** | ,47** | ,66** | ,45** | ,37** | ,13 | ,32** | ,39** | –,10 | ,33** | ,07 | ,04 | ,35** | –,08 | –,13 | –,10 | –,17* | ,01 |
| So | ,42** | ,34** | ,45** | ,44** | ,60** | ,36** | ,56** | ,27** | ,42** | ,25** | ,56** | –,10 | ,01 | ,37** | ,03 | –,02 | ,06 | ,04 | ,17* | –,17* | ,09 |
| M | ,38** | ,11 | ,28** | ,07 | ,46** | ,34** | ,36** | ,31** | ,29** | –,11 | ,33** | –,14 | ,30** | –,13 | ,23** | ,06 | ,21** | –,01 | –,02 | –,21* | –,01 |

* p < 0.05.
** p < 0.01.

plexity also implies more works on site, more workers among others. But *OV*1 and *OV*6 (Internal organization structure) do not have a similar pattern with no significant results, like *OV*1 and *OV*7. These results could be interpreted as a lack of proportion among the complexity of site and the complexity of its organization and planning. More big or complex sites do not have more subcontracting or more complexity of contracting as it could be expected; so, a possible excess of these two issues in small sites.

The obtained correlations between dimensions of resources (*OV*4, *OV*5, *OV*8, *OV*9 and *OV*10) showed more consistent results than previous of complexity. Most correlations are positive and significant ($p < 0.01$) and have higher values (ranging from 0.33 to 0.50). According with these results, these resources variables show internal coherence although they assess different characteristics. Furthermore, positive and significant correlations among OVs of resources and OVs of complexity fitted the expected behaviour because sites with more complexity in general have more resources. OVs expected intercorrelations are indicative of the adequate structure of these variables and show the broad possibilities of the tool.

Discussing the values of correlations among RVs (CONSRAT) and RLs (QRAM), important convergent validity evidences are obtained as most of them are significant ($p < 0.01$) and positive as expected. Correlations with the Site Risk Index (SRI) are also significant and positive as expected with all RLs, and also for the five alarm RVs (*RV*1, *RV*3, *RV*5, *RV*8, *RV*9). As it was also expected, the best coefficient is obtained for variables that assess the same risk (i.e., *RV*5 and RL_F). In more detail, RL_F (falls) obtained the highest values with *RV*5 (Falls, 0.92), *RV*7 (Process, 0.75), *RV*3 (General collective protections, 0.68), and *RV*9 (Personal fall protection, 0.66). It is important to highlight the strong positive relationship between RL_F and *RV*7 that shows the relevance of the process (adequacy and deviation) in relation to the existence of fall risk and let us to focus on check what happens in the sequence of tasks that is associated with high levels of risk. For its part, relationship between RL_F and both *RV*3 and *RV9* connects the general collective protections and personal protections with risk of falls in main work. All these RVs strongly correlated with RL_F can directly focus the problem involved and try to correct in the genesis. Other relations are relevant too, as for example the relationships of RL_F with *RV*1 (H&S plan compliance) (0.61) or with *RV*8 (Collective protections on stage) (0.57).

As some RLs are in part assessed in some RVs, they obtain significant ($p < 0.01$) and positive correlations. For example, RF_Ce (contact with electricity), obtained the highest coefficients with *RV*2 (general conditions; 0.73), RL_Fo (injured by falling/dropped/-collapsing objects) obtained higher coefficients with *RV*6 (other risks, 0.66) and RL_So (hit by rolling/sliding object or person) with *RV*3 (general collective protections; 0.45). Other important strongly correlation is between all RLs and *RV*7 (process) positive and significant ($p < 0.01$) in cases, and with high coefficients (Ce 0.58, Fo 0.47, So 0.56 and M 0.36). We interpret these results, as the case of fall (RL_F), in the sense that *RV*7 is a strong predictor of future risks, capable to anticipate them just checking the adequacy of the process without need of risk manifest. These results probably imply to reconsider this variable as one more of alarm variables. Similar behaviour showed *RV*5 (Falls) with all RVs, with positive sign ($p < 0.01$), with biggest coefficients with RL_F, RL_So (0.60), RL_Ce (0.55), RL_Fo (0.47), and RL_M (0.46). According to these results, *RV*5 could be an adequate indicator capable to advance information of the general risk level on site. These results pointed out that RVs could contribute to assess overall site risk level, which was one of the important goals of this study. They also lead to conclude that, in this type of building sites, one can use falls from height as unit of measure or an indicator of general site risk, as it correlates with the major of rest important risks on CONSRAT as well as on QRAM used for validation. RVs are capable to detect the appropriateness of safety barriers (Ale et al., 2008) as well as accident precursors or leading indicators (Grabowski et al., 2007; Hinze et al., 2013b; Toellner, 2001).

In general, a different behaviour than the relationships between RVs and OVs was expected. For example, RF_F (falls) shows a significant positive correlation with *OV*3 (Stage characteristics), that is strongly coherent, because stage characteristics are directly affecting this risk. The same pattern happened between RL_F and *OV*9 (preventive functions), more integration of preventive functions implies low risk levels, with a negative and significant coefficient (−0.28, $p < 0.01$). A similar relationship is found between *OV*9 and the rest of RLs, significant and negative with different magnitude coefficients. Correlation between RL_F and *OV*1 is negative and means that the complexity of the project impacts negatively on fall risk (the same behaviour than *OV5* on *OV1*) that can be explained by the existence of more resources (mainly as the commented relationship with *OV*9). For its part, RL_Ce obtained a significant correlation with 7 OVs, with best results with resources OVs, mainly with *OV*4 (promoter resources, 0.41), *OV*9 (preventive functions, 0.39), *OV*10 (H&S plan adequacy, 0.28), and *OV*8 (coordinator resources, 0.21). In all cases resources has an impact to better risk conditions.

Finally, regarding to practical application, CONSRAT requires a simpler assessment process than QRAM and is easier to be carried out by any technician with previous basic training. And the most significant difference between CONSRAT and QRAM or other similar tools of risk assessment is that CONSRAT considers site risk elements, agents and resources, having an overview of "the construction site" and its environment. It can be used both as a tool for previously risk assessment, and to verify the site risk level regularly. In this sense, it can be considered as an active leading indicator or predictor (Grabowski et al., 2007; Hinze et al., 2013b). It can be used as a site safety audit. It can also be used as many times as desired in order to monitor and assess proposed improvements.

This instrument tries to meet the lack of tools for analysing the construction site as unit of analysis, with own identity characteristic that affect risk. CONSRAT adopts a site risk approach through the building of several variables to assess the main live conditions, complexity factors and organizational structure characteristics which are related to risk. It makes possible a subsequent analysis of the relationships among those variables, therefore, to guide potential intervention programs to enhance safety and health.

## 5. Limitations and future challenges

CONSRAT has been designed to assess building construction sites and organizational structures in the European environment. Other environments or site types may need an adaptation of the tool contents. Although CONSRAT has elements to enhance the objectivity of the assessment, it is necessary provide previous training for inspectors. Law knowledge and experienced technical criteria are imperative to correct manage this tool. CONSRAT has been design to easily collect data while visiting the sites. As a future extension, we programme to build an application for mobile devices to further inspections on site. Finally, we point out that CONSRAT is an easy manage instrument to assess site risk and mainly oriented to focus intervention on most important issues capable to affect risk, including material conditions as well as complexity or resources specific of construction sites.

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## Appendix A. Form to be filled out

### CONSRAT

| Item Number | Classification of items. Rating level. Scoring criteria. |
|---|---|
| | **A. General information and organizational factors** |
| | **i. Identification dates** |
| **1.** | **Identifier**: nº_____, address_____________________________ |
| **2.** | **Company name** ________________________________________<br>Contractor, or subcontractor in the case that the contractor does not have workers on site<br>In case of some contractors or subcontractors. chose:<br>The bigger one, with more of its own workers on site.<br>The principal (that has subcontractors). |
| **3.** | **TIN**__________________<br>Of the company selected in item 2 |
| **4.** | **Date of the visit to the site**________ |
| | **ii. Construction site characterisation** |
| **5.** | **General characterisation.** Rating: **1**☐**2**☐ Scoring: See App. B<br>1 - New construction<br>2 - Reform and extensions. Others Works at existing building |
| **6.** | **Building Configuration.** Rating: **1**☐**2**☐**3**☐**4**☐**5**☐**6**☐ Scoring: See App. B<br>1- Isolated Single family house<br>2 - Infill single family house<br>3 - Services Building<br>4 - Isolated multi-family<br>5 - Infill multi-family<br>6 - Other uses |
| **7.** | **Number of floors.** Rating: **1**☐**2**☐**3**☐**4**☐**5**☐ Scoring: See App. B<br>1- Ground floor (GF)<br>2 - GF+1-2<br>3 - GF+3-5<br>4 - GF+5<br>5 - Infrastructure |
| **8.** | **Procedure construction typology.** Rating: **1**☐**2**☐ Scoring (0-1)<br>1 - Traditional. Conventional construction methodologies, systems, resources and materials<br>2 - Alternative. Unconventional procedures, systems or resources (prefabrication, slenderness, etc.) |
| **9.** | **Administrative documentation.** Rating: **1**☐**2**☐ Scoring (0-1)<br>1 - Minor work. Construction site without technical project<br>2 - Major work. Construction site with technical project |
| | **ii. a. Stage of the work** |
| **10.** | **Main work stage.** Rating: **1**☐**2**☐**3**☐**4**☐**5**☐**6**☐**7**☐**8**☐**9**☐ Scoring: See App. B<br>1 - Interior works<br>2 - Installations<br>3 - Brickwork<br>4 - Flat roof<br>5 - Facade works<br>6 - Pitched roof<br>7 - Excavation<br>8 - Foundation and structure<br>9 - Demolitions |
| **11.** | **Secondary work stage.** Rating: **1**☐**2**☐**3**☐**4**☐**5**☐**6**☐**7**☐**8**☐**9**☐ Scoring: See App. B<br>1 - Interior works<br>2 - Installations<br>3 - Brickwork<br>4 - Flat roof<br>5 - Facade works<br>6 - Pitched roof<br>7 - Excavation<br>8 - Foundation and structure<br>9 – Demolitions |
| **12.** | **Number of works.** Rating: **1**☐**2**☐ Scoring (0-1)<br>1 - One main work<br>2 - More than one work |
| **13.** | **Employer location assignments.** Rating: **1**☐**2**☐**3**☐**4**☐**5**☐**6**☐**7**☐**8**☐**9**☐ Scoring: See App. B<br>Where are most of the workers at the main work on site?<br>1 - On the field<br>2 - Interior floor<br>3 - Perimeter floor or roof<br>4 - On the floor at auxiliary resources in use<br>5 - Outdoor, on machine in use<br>6 - Outdoor, on auxiliary resources in use (platform, scaffold)<br>7 - Outdoor, on auxiliary resources to set up<br>8 - On machine or installation to set up |

### iii. Promoter characterisation

14. **Type of promoter.** Rating: **1**☐**2**☐**3**☐ Scoring: See App. B
1 - Private/Individual promoter
2 - Professional
3 - Public/Official administration

15. **Designation of health and safety coordinator.** Rating: **1**☐**2**☐ Scoring: See App. B
1 - No. There isn't any document to demonstrate the designation
2 - Yes. It's documented at construction site (incidents book, any documentation of administration or professional college)

16. **Documented work of the H&S coordinator.** Rating: **1**☐**2**☐**3**☐ Scoring: See App. B
1 - No/there is not datum. There is not evidences or nobody now
2 - Yes, but not systematic. There are some documentation instructions at any format
3 - Yes, systematic at incidents book

17. **Type of contracting.** Rating: **1**☐**2**☐ Scoring: See App. B
Number of construction firms that contract directly with the promoter
1 - Only one contractor
2 - Some contractors

18. **Special environmental conditions.** Rating: **1**☐**2**☐ Scoring: See App. B
1 - No
2 - Interferences like: Electrical, public spaces, streets or buildings at perimeters or party walls, slopes or evenness, etc.

19. **Locality. Municipal term ____________________**

### iv. Constructor characterisation

20. **Type of constructor.** Rating: **1**☐**2**☐**3**☐ Scoring: See App. B
Selected at item two
1 - Self-employed
2 - Self-employed with workers at his charge
3 - Company (SA,SL,COP, UTE)

21. **Constructor's Role.** Rating: **1**☐**2**☐**3**☐ Scoring: See App. B
Selected at item two
1 - Subcontractor
2 - Contractor
3 - Promoter-constructor

22. **Number of companies at construction site**____________
Total number, including all companies and self-employed workers

23. **Subcontracting.** Rating: **1**☐**2**☐ Scoring (0-1)
Is there subcontracting on site?
1 - No
2 – Yes

24. **Level of subcontracting.** Rating: **1**☐**2**☐**3**☐ Scoring: See App. B
1 - Contractor (no subcontracting)
2 - First level of subcontracting
3 - Second level of subcontracting

25. **Control and register of subcontracting.** Rating: **1**☐**2**☐**3**☐ Scoring (0-0.5-1)
Is there a subcontracting book, if it is required
1 - Not required
2 - Yes
3 – No

26. **Number of workers of constructor on site**__________
Of the constructor selected at item two. The most important contractor or subcontractor

27. **Total number of workers on site __________**
All workers from all companies and self-employed workers

28. **Site management structure.** Rating: **1**☐**2**☐**3**☐**4**☐**5**☐**6**☐ Scoring: See App. B
Refers to site structure, explained by the interviewee on the visit with regular presence and assistance to the construction site.
1 - Nobody in charge
2 - Worker with some functions
3 - Site foreman
4 - Business owner
5 - Site foreman and site manager
6 - Site foreman, site manager and prevention technical

29. **Preventive functions of the structure.** Rating: **1**☐**2**☐**3**☐**4**☐ Scoring: See App. B
This means the level of knowledge and implication in prevention
1 - It's not assumed, there isn't nobody in charge of preventive topic
2 - It's assumed but on secondary way
3 - It's assumed within with principal activity
4 - It's assumed and documented in an organised way

30. **Preventive resource.** Rating: **1**☐**2**☐**3**☐ Scoring (0-0.5-1)
1 - Nobody/ does not apply
2 - Assigned to a worker
3 - Assigned to one site foreman or qualified technician

### v. Health and safety plan adequacy

31. **Presence at construction site of H&S plan.** Rating: **1**☐**2**☐ Scoring: See App. B
Is the document physically at the construction site?
1 - No
2 – Yes

32. **Appropriateness of the previsions of the H&S plan**. Rating: **1**☐**2**☐**3**☐**4**☐Scoring: See App. B
The question refers to the general conditions and specific conditions of the current phase of the site at the time of the visit
1 - There isn't H&S plan or its previsions are unknown. Interlocutors at site don't know anything of contents of H&S plan
2 - The previsions in H&S plan aren't applicable to the site or there are critical mistakes.
3 - Appropriate previsions, no critical mistake. Possible errors don't affect systems and general protections, personal protection equipment (PPE) or collective protection (CP) specifically for the stage when they protect for serious risk
4 - Complete and appropriate in previsions. No deficiency

## B. Risk factors on site

### i. Health and safety plan compliance

33. **Compliance with the H&S plan or regulations in case.** Rating: **0**☐**1**☐**2**☐**3**☐**.** Scoring: See general valuation
**0** Full and appropriate compliance. The phase is compliant with the H&S plan or general and specific regulations (implantation, circulations, CP, PPE)
**1** Appropriate, no critical mistakes. Possible failure but it does not affect systems and general protections, personal protection equipment (PPE) or collective protection (CP) specifically for a phase where they protect against serious risk
**2** Deficient, with critical mistakes. The H&S plan or regulations fail to affect systems and general protections, personal protection equipment (PPE) or collective protection (CP) with serious risk
**3** Nothing, very deficient failure. There is no record of compliance with any aspect of the H&S plan or regulations

### ii. General conditions valuation

34. **Construction fence. 0**☐**1**☐**2**☐**3**☐. Rating and scoring: See general valuation
35. **Circulations/order and tidiness/Illumination. 0**☐**1**☐**2**☐**3**☐. Rating and scoring: See general valuation
36. **Safety signage. 0**☐**1**☐**2**☐**3**☐. Rating and scoring: See general valuation
37. **Safety of electrical installation and cable. 0**☐**1**☐**2**☐**3**☐. Rating and scoring: See general valuation
38. **General collective protections. 0**☐**1**☐**2**☐**3**☐. Rating and scoring: See general valuation

### iii. Stage conditions valuation

### iii. a. Access

39. **Access. 0**☐**1**☐**2**☐**3**☐. Rating and scoring: See general valuation
This refers to the main stage or workplace, independently of general circulation conditions

### iii. b. Falls from height

40. **Height of fall.** Rating: **0**☐**1**☐**2**☐**3**☐. Scoring: See general valuation
This refers to the primary phase or workplace
**0** There is no height or it is controlled. There is no exposure or it is controlled by a preventive system, design, work stage, etc.
**1** From 0 to 2 metres (exclusive)
**2** From 2 to 6 metres (exclusive)
**3** More than 6 metres

41. **Level of failure.** Rating: **0**☐**1**☐**2**☐**3**☐. Scoring: See general valuation
**0** Complete appropriate. Risks are controlled by forecasted resources
**1** Appropriate, without critical failures. There are minor failures, but with overall compliance with the conditions
**2** Deficient, with critical failures. Important failures of protection systems that could affect the safety of users or of protection
**3** Very deficient. There is no protection system or it is very deficient, it may create a false perception of protection increasing risk

42. **Continuity of exposure.** Rating: **0**☐**1**☐**2**☐**3**☐. Scoring: See general valuation
**0** None, controlled or there is no exposure
**1** Punctual or sporadic
**2** At some stages of the process
**3** Permanent

43. **Probability.** Rating: **0**☐**1**☐**2**☐**3**☐. Scoring: See general valuation
**0** Very low probability
**1** Low probability
**2** Medium Probability
**3** High Probability

44. **Severity.** Rating: **0**☐**1**☐**2**☐**3**☐. Scoring: See general valuation
**0** No severity
**1** Minor, slight injury
**2** Medium, serious injury
**3** Severe, serious injury or frequent death

45. **Intervention required.** Rating: **0**□**1**□**2**□**3**□. Scoring: See general valuation
**0** Intervention is not necessary
**1** No critical improvements are necessary
**2** Corrections and critical improvements are necessary
**3** Immediate intervention is necessary

### iii. c. Other risks concurrence. In general 1= No risk, 2=Yes, there is risk.

46. **Falls on the same level/Slip.** Rating and scoring: See dichotomist valuation
47. **Fall of objects.** Rating and scoring: See dichotomist valuation
48. **Collapses or cave-ins.** Rating and scoring: See dichotomist valuation
49. **Cuts, hits, pricks.** Rating and scoring: See dichotomist valuation
50. **Hit by a vehicle, crushing, entrapment.** Rating and scoring: See dichotomist valuation
51. **Projections.** Rating and scoring: See dichotomist valuation
52. **Burns.** Rating and scoring: See dichotomist valuation
53. **Electricity contact shock.** Rating and scoring: See dichotomist valuation
54. **Overexertion.** Rating and scoring: See dichotomist valuation
55. **Hygienic risk exposure.** Rating and scoring: See dichotomist valuation
56. **Other risks**. (Hygienic, prick with connecting rod, electrical interferences). Rating and scoring: See dichotomist valuation
57. **Incidence of falls from height risk.** Rating: **0**□**1**□**2**□**3**□. Scoring: See general valuation
**0** None
**1** Punctual or sporadic
**2** Occasional occurrence, sometimes
**3** Permanent

### iii. d. Process valuation

58. **Type of process.** Rating: **1**□**2**□**.** Scoring: See dichotomist valuation
**1** Traditional. The sequence and resources involved in the activities are common at construction sites
**2** Not traditional. Sequence, resources or construction systems are not common or habitual
59. **Adequacy of the process.** Rating: **0**□**1**□**2**□**3**□. Scoring: See general valuation
**0** Very appropriate. The sequence of operations and resources and resources provided in the H&S plan are adapted to the site typology as needed
**1** Appropriate for site conditions. Some dysfunction in the process is possible, but globally the process is appropriate
**2** Inappropriate for site conditions. The process is not appropriate for the phase or the construction site
**3** Nothing or inappropriate. Process is completely inappropriate for construction site
60. **Process deviation.** Rating: **0**□**1**□**2**□**3**□. Scoring: See general valuation
**0** There are no deviations. It is complying with the process forecast in the H&S plan
**1** There are some deviations, but they are not critical. It is mostly complying with the process forecast in the H&S plan
**2** There are critical deviations. There are some critical deviations in the forecast process
**3** There are critical and permanent deviations. The deviations are important and continuous

### iii. e. Collective protections. CP.

61. **Scaffolds. Adjustment to the phase.** Rating and scoring: See dichotomist valuation
62. **Scaffolds. Installation validation. 0**□**1**□**2**□**3**□. Rating and scoring: See general valuation
63. **Safety nets. Adjustment to the phase.** Rating: **1**□**2**□. Scoring: See dichotomist valuation
**0** Appropriate. It is the CP necessary for the work stage and the risks.
**1** Inappropriate. It is not an appropriate CP for the work stage and the risks or typology of the site.
64. **Safety nets. Installation validation. 0**□**1**□**2**□**3**□. Rating and scoring: See general valuation
65. **Railing. Adjustment to the phase.** Rating and scoring: See dichotomist valuation
66. **Railing. Installation validation. 0**□**1**□**2**□**3**□. Rating and scoring: See general valuation
67. **Safety boarded. Adjustment to the phase.** Rating and scoring: See dichotomist valuation
68. **Safety boarded. Installation validation. 0**□**1**□**2**□**3**□. Rating and scoring: See general valuation
69. **Number of items CP**: **0**□**1**□**2**□**3**□**4**□**5**□**6**□**7**□**8**□
70. **Need for more CP specific to the phase.** Rating: **1**□**2**□. Scoring: See dichotomist valuation
**1** No, it is not necessary. It is enough that they are installed, independently of the adjustment
**2** Yes, more CP is needed, in addition to that which is already installed

### iii. f. Personal protection equipment. PPE

71. **Fall protection system. Adjustment to the phase.** Rating: **1**□**2**□. Scoring: See dichotomist valuation
**1** Appropriate. The system is adapted to the edge that needs protected (harness, connector, lifeline, anchorage) Independently from the installation
**2** Not adapted. The fall protection system is not adapted to the edge or there is no protection system.
72. **Fall protection system. Installation validation.** Rating and scoring: See dichotomist valuation
73. **Number of PPE items: 0**□**1**□**2**□
74. **Need for more PPE specific to the phase.** Rating: **1**□**2**□. Scoring: See dichotomist valuation
**1** No, it is not necessary. It is enough that they are installed, independently of the adjustment
**2** Yes, more CP is needed, in addition to that which is already installed

### iv. Auxiliary resources and machinery

### iv. a. Auxiliary resources

75. **Scaffolds. Adjustment to the phase.** Rating and scoring: See dichotomist valuation
76. **Scaffolds. Installation validation. 0☐1☐2☐3☐.** Rating and scoring: See general valuation
77. **Suspended scaffolds. Adjustment to the stage.** Rating and scoring: See dichotomist valuation
78. **Suspended scaffolds. Installation validation. 0☐1☐2☐3☐.** Rating and scoring: See general valuation
79. **Horse scaffolds/work platform. Adjustment to the phase.** Rating and scoring: See dichotomist valuation
80. **Horse scaffolds/work platform. Installation validation.** Rating and scoring: See dichotomist valuation
81. **Portable ladders. Adjustment to the phase.** Rating and scoring: See dichotomist valuation
82. **Portable ladders. Installation validation. 0☐1☐2☐3☐.** Rating and scoring: See general valuation
83. **Other. Adjustment to the phase.** Rating and scoring: See dichotomist valuation
84. **Other resources. Installation validation. 0☐1☐2☐3☐.** Rating and scoring: See general valuation
85. **Number of AR items: 0☐1☐2☐3☐4☐5☐**

### iv. b. Elevation resources

86. **Forklift truck/dumbwaiter. Adjustment to the phase.** Rating and scoring: See dichotomist valuation
87. **Forklift truck. Installation validation. 0☐1☐2☐3☐.** Rating and scoring: See general valuation
88. **Crane truck. Adjustment to the phase.** Rating and scoring: See dichotomist valuation
89. **Crane truck. Installation validation. 0☐1☐2☐3☐.** Rating and scoring: See general valuation
90. **Fall protection system for elevation work resources.** Rating and scoring: See dichotomist valuation
91. **Auxiliary resources for elevation system**. 0☐1☐2☐3☐. Rating and scoring: See general valuation
(Supporting cable, operating ropes, unloading platforms, etc.)
92. **Number of ME items: 0☐1☐2☐3☐4☐**

### iv. c. Other machinery

93. **Concrete mixer. Adjustment to the phase.** Rating and scoring: See dichotomist valuation
94. **Concrete mixer. Installation validation. 0☐1☐2☐3☐.** Rating and scoring: See general valuation
95. **Manual tool. Adjustment to the phase. 1☐2☐.** Rating and scoring: See dichotomist valuation
96. **Manual tool. Installation validation. 0☐1☐2☐3☐.** Rating and scoring: See general valuation
97. **Number of OM items: 1☐2☐**

**Valuation criteria to fill the form**

**General Valuation criteria**

| Rating | Criteria | Scoring |
|---|---|---|
| 0. | Complete and appropriate. It is well installed, reliable, independent for the worker that used it | 0 |
| 1. | Appropriate, without critical failures. There are some minor failures, but in overall compliance with the conditions | 0.33 |
| 2. | Deficient, with critical failures. Failures are significant and could affect safety resources, installation or the user or other persons in a partial way | 0.66 |
| 3. | Very deficient. There are no resources or failures are significant and are affecting safety resources, installation, the users or other persons in a continuous way | 1.00 |

**Dichotomous valuation criteria**

| Rating | Criteria | Scoring |
|---|---|---|
| 1. | Adequate for the work, construction phase or type | 0 |
| 2. | Not adequate for the work, construction phase or type | 1 |

## Appendix B. Organisational variables, items composition, rating scales, scoring and aggregation rules

| Variable | Item composition and rating scales[a] | Item scoring[b] | Variable aggregation rules |
|---|---|---|---|
| OV1. Complexity of project | **General characterisation** | | Mean |
| | New construction | 0 | |
| | Reform and extensions. Others Works at existing building | 1 | |
| | **Building Configuration** | | |
| | Isolated Single family house | 0 | |
| | Infill single family house | 0.2 | |
| | Services Building | 0.4 | |
| | Isolated multi-family | 0.6 | |
| | Infill multi-family | 0.8 | |
| | Other uses | 1 | |
| | **Special environment conditions** | | |
| | No | 0 | |
| | Interferences like: Electrical, public spaces, streets or buildings at perimeters or party walls, slopes or evenness, etc. | 1 | |

**Appendix B** (*continued*)

| Variable | Item composition and rating scales[a] | Item scoring[b] | Variable aggregation rules |
|---|---|---|---|
| OV2. Size of site | **Number of floors** | | Direct item scoring |
| | Ground floor (GF) | 0 | |
| | GF+1-2 | 0.25 | |
| | GF+3-5 | 0.50 | |
| | GF+5 | 0.75 | |
| | Infrastructure | 1 | |
| OV3. Stage characteristics | **Main work stage** | | Mean |
| | Interior works | 0 | |
| | Installations | 0.125 | |
| | Brickwork | 0.25 | |
| | Flat roof | 0.375 | |
| | Facade works | 0.50 | |
| | Pitched roof | 0.625 | |
| | Excavation | 0.75 | |
| | Foundation and structure | 0.875 | |
| | Demolitions | 1 | |
| | **Main work stage** | | |
| | Interior works | 0 | |
| | Installations | 0.125 | |
| | Brickwork | 0.25 | |
| | Flat roof | 0.375 | |
| | Facade works | 0.50 | |
| | Pitched roof | 0.625 | |
| | Excavation | 0.75 | |
| | Foundation and structure | 0.875 | |
| | Demolitions | 1 | |
| OV4. Promoter resources | **Type of promoter firm resources** | | Direct item scoring |
| | Private/Individual promoter | 0 | |
| | Professional | 0.5 | |
| | Public/Official administration | 1 | |
| OV5. Constructor resources | **Type of construction firm resources** | | Mean |
| | Self-employed | 0 | |
| | Self-employed with workers at his charge | 0.5 | |
| | Company (SA,SL,COP, UTE) | 1 | |
| | **Resources depending of Constructor's Role** | | |
| | Subcontractor | 0 | |
| | Contractor | 0.5 | |
| | Promoter-constructor | 1 | |
| | **Site management structure** | | |
| | Nobody in charge | 0 | |
| | Worker with some functions | 0.2 | |
| | Site foreman | 0.4 | |
| | Business owner | 0.6 | |
| | Site foreman and site manager | 0.8 | |
| | Site foreman, site manager and prevention technical | 1 | |
| OV6. Internal organization structure | **Type of contracting**. | | Mean |
| | Only one contractor | 0 | |
| | Some contractors | 1 | |
| | **Number of companies at construction site** | | |
| | Just 1 | 0 | |
| | From 2 to 3 | 0.33 | |
| | From 4 to 6 | 0.66 | |
| | More than 6 | 1 | |
| | **Level of subcontracting** | | |
| | Contractor (no subcontracting) | 0 | |
| | First level of subcontracting | 0.5 | |
| | Second level of subcontracting | 1 | |

(*continued on next page*)

**Appendix B** (*continued*)

| Variable | Item composition and rating scales[a] | Item scoring[b] | Variable aggregation rules |
|---|---|---|---|
| OV7. Job planning and design | **Number of works** | | **Mean** |
| | One main work | 0 | |
| | More than one work | 1 | |
| | **Employer location assignments** | | |
| | On the field | 0 | |
| | Interior floor | 0.1425 | |
| | Perimeter floor or roof | 0.285 | |
| | On the floor at auxiliary resources in use | 0.4275 | |
| | Outdoor, on machine in use | 0.57 | |
| | Outdoor, on auxiliary resources in use (platform, scaffold) | 0.7125 | |
| | Outdoor, on auxiliary resources to set up | 0.855 | |
| | On machine or installation to set up | 1 | |
| | **Total number of workers at site** | | |
| | To 3 | 0 | |
| | From 4 to 6 | 0.2 | |
| | From 7 to 10 | 0.4 | |
| | From 10 to 20 | 0.6 | |
| | From 20 to 30 | 0.8 | |
| | More than 30 | 1 | |
| | **Ratio of number of workers of principal constructor over total workers at site** | | |
| | Less than 0.25 | 0 | |
| | From 0.25 to 0.5 | 0.25 | |
| | From 0.5 to 0.75 | 0.5 | |
| | More than 0.75 | 1 | |
| OV8. Coordination resources | **Designation Health and safety coordinator** | | Mean |
| | No. There isn't any document to demonstrate the designation | 0 | |
| | – Yes. It's documented at construction site (incidents book, any documentation of administration or professional college) | 1 | |
| OV9. Preventive functions | **Documented work H&S coordinator** | | Mean |
| | – No/there is not datum. There is not evidences or nobody now | 0 | |
| | – Yes, but not systematic. There are some documentation instructions at any format | 0.5 | |
| | – Yes, systematic at incidents book | 1 | |
| | **Preventive functions of the structure** | | |
| | – It's not assumed, there isn't nobody in charge of preventive topic | 0 | |
| | – It's assumed but on secondary way | 0.33 | |
| | – It's assumed within with principal activity | 0.66 | |
| | – It's assumed and documented in an organised way | 1 | |
| OV10. Health and Safety Plan | **Presence at construction site of H&S plan** | | Mean |
| | No | 0 | |
| | Yes | 1 | |
| | **Appropriateness of H&S plan's previsions** | | |
| | There isn't H&S plan or its previsions are unknown. Interlocutors at site don't know anything of contents of H&S plan | 0 | |
| | The previsions in H&S plan aren't applicable to the site or there are critical mistakes | 0.33 | |
| | Appropriate previsions, no critical mistake. Possible errors don't affect systems and general protections, personal protection equipment (PPE) or collective protection (CP) specifically for the stage when they protect for serious risk | 0.66 | |
| | Complete and appropriate in previsions. No deficiency | 1 | |

[a] Higher values in any scale signal more complexity and more resources.
[b] Item scales: from 0 to 1, where 0 means less complexity or resources, and 1 the maximum level of complexity or resources.

## Appendix C. Risk variables item composition and aggregation rules

| Variable | Item composition | Item scoring[b] | Variable aggregation rules |
|---|---|---|---|
| RV1. Health and Safety Plan [a] | – Compliance with the H&S plan or regulations in case | 0–0.33–0.66–1.00 | Direct item scoring |
| RV2. General conditions | – Construction fence<br>– Circulations/order and tidiness/Illumination<br>– Safety signage<br>– Safety of electrical installation and cable | 0–0.33–0.66–1.00<br>0–0.33–0.66–1.00<br>0–0.33–0.66–1.00<br>0–0.33–0.66–1.00 | Mean |
| RV3. Collective protections[a] | General collective protections | 0–0.33–0.66–1.00 | Direct item scoring |
| RV4. Access | Access | 0–0.33–0.66–1.00 | Direct item scoring |
| R5. Falls of height | – Height of fall<br>– Level of failure<br>– Continuation of exposure<br>– Probability<br>– Severity<br>– Intervention required | 0–0.33–0.66–1.00<br>0–0.33–0.66–1.00<br>0–0.33–0.66–1.00<br>0–0.33–0.66–1.00<br>0–0.33–0.66–1.00<br>0–0.33–0.66–1.00 | Mean |
| RV6. Other risks | – Falls on the same level/Slip<br>– Fall of objects<br>– Collapses or cave–ins<br>– Cuts, hits, pricks<br>– Hit by a vehicle, crushing, entrapment, projections<br>– Burns<br>– Electricity contact shock<br>– Overexertion<br>– Hygienic risk exposure<br>– Other risks<br>– Incidence of falls from height risk | 0–1<br>0–1<br>0–1<br>0–1<br>0–1<br>0–1<br>0–1<br>0–1<br>0–1<br>0–1<br>0–0.33–0.66–1.00 | Mean between the percentage of identified risks items and incidence of falls item |
| RV7. Process | – Adequacy of the process<br>– Process deviation | 0–0.33–0.66–1.00<br>0–1 | Mean |
| RV8. Collectives protection[*] | For each protection:<br>– Adjustment to the phase<br>– Installation validation<br>In general:<br>– Need for more CP specific to the phase | <br>0–1<br>0–0.33–0.66–1.00<br><br>0–1 | Mean of adjustments and installations Choose the highest value between these two means and the need for more CP |
| RV9. Personal protection[*] | For each fall protection system:<br>– Adjustment to the phase<br>– Installation validation<br>– Need for more PPE specific to the phase | <br>0–1<br>0–0.33–0.66–1.00<br>0–1 | Mean of adjustments and installations Choose the highest value between these two means and the need for more PEE |
| RV10. Auxiliary resources and machinery | For each resource and machinery:<br>– Adjustment to the phase<br>– Installation validation | <br>0–1<br>0–0.33–0.66–1.00 | Mean of adjustments and installations Choose the highest value between them |

[a] Alarm variables.
[b] Item scales: from 0 to 1, where 0 means less complexity or resources, and 1 the maximum level.

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