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# Risk Analysis in Civil Construction Services Using Mobile Elevating Work Platforms

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**Abstract**

The use of vertical transportation equipment in Civil Construction, such as Mobile Elevating Work Platforms - MEWP had optimized activities, avoiding wasted time and simplifying. However, brings in addiction to risks inherent to mechanical equipment, the height factor, increasing the probability of accidents occurrences. The aim of this work was to identify the risks of accidents and nonconformities with the Brazilian legislation present in the activities using MEWP, in order to propose measures of control and systematization of the actions, to integrate accident prevention in construction sites. For this purpose, a checklist was developed and applied in a large Construction workplace located in the Metropolitan Region of Recife-Brazil. According to the data obtained, a list of control guidelines and safety measures was elaborated, identifying the responsibilities of users and operators in services using MEWP. It was observed that the irregularities found are due factors related to operation, maintenance and use inspection of the equipment and significant occurrence of irregularities such as absence of work area isolation, daily inspections and electrical grounding in motorized MEWP. These facts need for improvements making improvements on training and inspections to ensure the fulfillment of the safety standards and an accident-free work environment.

**Keywords:** mobile elevating work platforms, accidents prevention, civil construction

## 1. Introduction

The ILO (International Labor Organization, 2018) estimates that 2.78 million people die each year from work-related accidents and diseases. In addition to the immeasurable human loss, these events cause major economic damage to business and society, including reduced productivity and work capacity. According to the same institution, this cost corresponds to approximately 4% of the world's Gross Domestic Product (GDP).

## 2. Occupational Safety Associated with the Use of Lifting Equipment in Civil Construction

Civil Construction is considered one of the most dangerous work environments, due to the dynamics and variety of activities, external factors, equipment, and tools involved in the process (Kang et al., 2017).

From the increase in the height of the constructions, there is an increase in the use of auxiliary lifting equipment. According to Gehbauer et al. (2002), the use of mechanical means of transport in a building work contributes to the increase of productivity both by using less personnel in transport activities (due to ergonomic aspects and by enabling the application of this manpower in other activities) and by the possibility of working more efficiently, since there will be more effective availability of material to perform the activities.

At the same time, the increase in the height of the constructions made the execution of activities at height inevitable. To make these activities possible, the use of auxiliary lifting equipment has also increased. On the other hand, safety systems had often failed to keep up with this mechanization on construction sites, which creates new risk points within the production line. In other words, once misused, equipment and machinery can contribute to an increase in accidents and worker injury (Leverson, 2011).

Before the MEWPs, the construction industry relied almost exclusively on scaffolding and ladders to perform work at height. The implementation of the MEWP represented a great advance, promoting better safety conditions and increased productivity when used correctly (Flanagan, 2018).

The irregularities in lifting equipment are due, in part, to the pressures concerning the pace of production and

progress of a work site. It is common to observe the occurrence of improvisation due to the economy of time and money, leading to not very careful execution of inspection and maintenance operations, thus reducing the identification of imminent risks and increasing the probability of accidents occurring.

Other factors which contribute to the occurrence of accidents and incidents related to the use of this equipment are the lack of training and the lack of knowledge about the real risks of its use, without the due preventive and protective measures. According to Regulatory Standard No. 18 (Brazil, 2020), which regulates safety at work in the construction sector, professionals who operate transport equipment, must be trained in the specific equipment they will use. This action is a fundamental step for safe use and the conservation of a work environment free of risks, given the variety of existing equipment in the market today, as is the case of MEWP.

Given this context, it becomes evident the need for a Safety and Health at Work Management System—SHWMS since actions aimed at the elimination and/or reduction of risks in all processes and activities will had repercussions not only in the maintenance of the worker's health but also in financial planning, in reducing risks of embargoes and even in the enhancement of the company's image in the market (Vasconcelos, 2013).

Oliveira et al. (2010), complement by stating that an SHWNS provides a continuous improvement, rationalization, and reliability of processes and services, increased quality of life of workers, and increased competitiveness and profitability for the company.

### *2.1 Mobile Elevating Work Platform*

MEWP (Mobile Elevating Work Platform), replacing the term Aerial Work Platform (AWP) according to the new NR 18, is mobile equipment, with or without its means of propulsion, which has a work station, in the form of a basket or platform, and is supported at its base by a metal rod—called a boom MEWP (Figure 1)—or scissors (Figure 2), capable of lifting itself to reach an elevated point or workplace.

Figure 1. MEWP lance type

Source: The authors.

Figure 2. MEWP scissors type

Source: The authors.

The selection of the type of MEWP to be used in activity depends on factors such as access to the work area, available space, activity to be developed, and rescue procedures in case of emergency (International Powered Access Federation [IPAF], 2018).

The use of MEWP makes it possible to save time and increase the efficiency and safety of work at height when used correctly. For this to occur, there needs to be fine-tuning between management and planning, suppliers, performers, and operators (IPAF, 2018).

As with any mechanical equipment, the operation of the MEWP requires operator training, offered by the company or obtained in external courses, in the specific model of MEWP that will be used, proven by certificate. Moreover, the equipment itself must be inspected daily by the operator (in the items specified by the manufacturer) and had a preventive maintenance routine performed by specialized technical professionals, also with items specified by the manufacturer in the manuals. The inspections of this equipment had the objective to identify operation defects and correct them. Preventive maintenance also has the function of maintaining the integrity and ensuring a longer useful life of the MEWP. It is worth noting that the operation and maintenance manuals are considered an integral part of the equipment and must be present at its place of use (Sampaio, 1998; Brasil, 2018; Genie, 2007).

Maintenance is indispensable since the main causes of accidents that occur during the use of the work platform include equipment failures, as well as the lack of training of operators, failures in the recognition of risks, and, consequently, in the safety planning of activities (New Zealand Government, 2014).

The risks related to the MEWP also had a connection with the composition of its structure, such as risks of electric shock due to the current conducting metal structure; risk of explosion, since some models of MEWP had combustion engines; and the way it is used (tipping, collision) added to factors interconnected with the environment as the action of wind force and rain). These environmental factors may had a great influence on the load configurations of the MEWP, leading to tipping and even possible breakages, depending on the conservation conditions of the equipment and its geometric configuration. Omissions in this sense may cause accidents. Besides these, it is added the fact that the entire work process is performed at height, a factor that increases the risk of accidents (Bošnjak et al., 2012; Genie, 2007).

Construction sites are usually dynamic work environments, in constant transformation, with sometimes unplanned layouts and processes. Moreover, they are prone to adversities such as schedule delays, rework, and excessive workload, among other adversities that affect human work.

According to Daniellou, Simard and Boissières (2013), when human beings are placed in situations that are not compatible with their individual and collective properties, it can generate a decrease in their detection capacity and the performance of their actions, and an increase in the probability of errors, which can generate incidents or accidents.

The work platforms were developed to promote safety in work at height, but for this, those responsible for the selection, specification, and management of the platforms at a site must had knowledge of the risks associated with the use of this equipment and thus be able to control them. Planning is a fundamental step for the safe operation of aerial work platforms (Health and Safety Executive, 2014).

## 3. Results Materials and Methods

Initially, a literature review focused on the themes of occupational safety, construction, transport equipment in construction and aerial work platforms was performed, through textbooks, MEWP operation manuals, technical standards, and scientific articles available in research portals, such as the Portal de Periódicos da CAPES and the SCOPUS database through keyword combinations.

Subsequently, technical visits were made during the construction phase of work, to monitor the services with the use of MEWP and observe the safety conditions related to the performance of activities. The construction site studied in this research is the construction of a shopping center with a total built area of 295,000 square meters, in the metropolitan region of Recife-Brazil carried out during the period between 2010 and 2012. During the activities, the number of employees reached 6,924 and a total of 409 contractors were involved.

The first visit was of a reconnaissance nature for the structuring of the study to be conducted. According to what was observed in this first visit and based on Regulatory Standard 18 (NR 18), which contains recommendations for the use, operation, and maintenance of MEWPs, a checklist was created with twenty items, according to the method developed by Barkokébas et al. (2004), presented in full in the Appendix.

The checklist was applied to each one of the MEWP in operation found in activity, being numbered and registered through a spreadsheet with the identification number of the machine (numbering made by the leasing company for identification); the model of the MEWP, the name of the leasing company, the name of the operator of the equipment and the type of activity developed.

The structure of the checklist consists of the description of the item of the standard, followed by the classification CO (compliant) when the situation is by the standard; DES (non-compliant) when it does not meet the standard, and GIR (serious and imminent risk), when it can cause occupational accident or disease with a serious injury to the physical integrity of the worker (Barkokébas et al., 2004).

After structuring the collection elements, six visits were made to the construction site, to observe the activities with the use of MEWPs during the finishing activities of the work. It was applied the checklist developed in a total of 66 MEWP that were present at the site and in activity, of different models such as the spear and scissor MEWP. These visits were unannounced; to analyze what occurred in the use of the equipment during the construction process.

Besides the technical analysis, it was also performed documentary analysis, as well as information collection with equipment operators and technical managers. The data collection of the operators was done through observation of the work routine and verification of the availability of documents, based on the checklist prepared, with the collaboration of the company that supported the research and provided the existing documents. Information such as maintenance dates, machinery operation manual, and certificate of training for equipment operation, among other issues, were verified.

The data were treated and presented graphically, being analyzed by quantitative and qualitative indicators of the main situations found, making possible the direction and preparation of guidelines and safety measures for services using powered elevated platforms, focused on the elimination of potential causes of accidents.

## 4. Results

The results were divided into two parts: technical analysis and documentary analysis, as presented below.

### *4.1 Mobile Elevating Work Platform*

The data were treated and presented graphically, being analyzed by quantitative and qualitative indicators of the main situations found, making possible the direction and preparation of guidelines and safety measures for services using powered elevated platforms, focused on the elimination of potential causes of accidents.

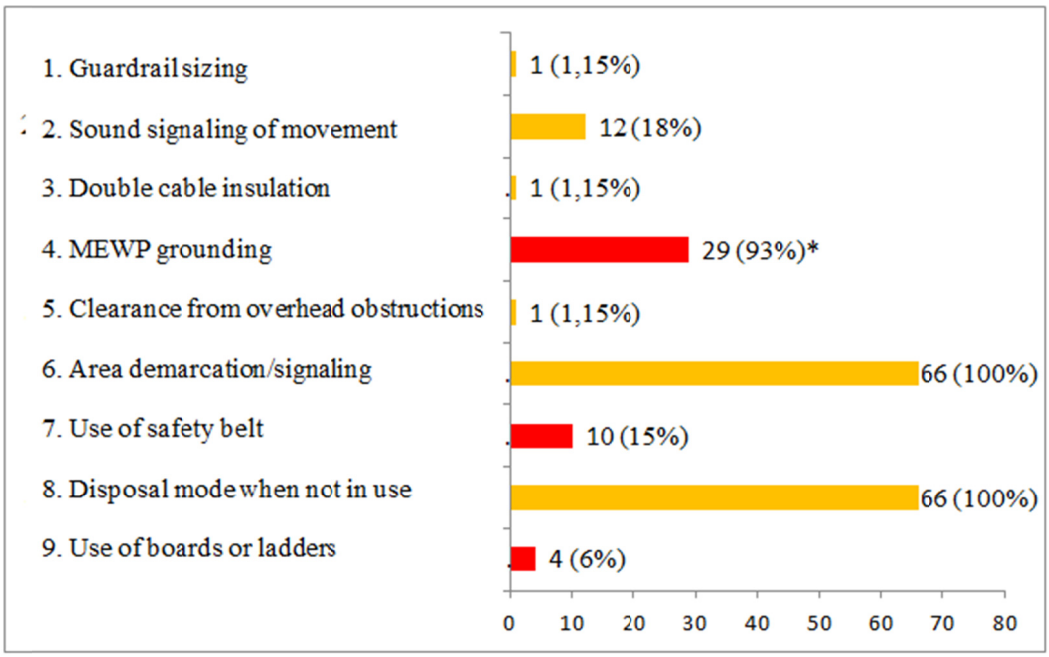


Figure 3. Quantitative indicator

Source: The authors.

Within this analysis, items in compliance with the standard represented 35.7%. The items in non-compliance accounted for 42.9%, and those representing serious and imminent risk were 21.4% of the total. Considering the sum of items in non-compliance with those considered serious and imminent risk, we had the total of items in non-compliance with the standard, which corresponds to 64.29% of the items. It is concluded then, from this analysis, that most items observed through the checklist do not meet the safety standard in force.

The qualitative indicator, unlike the quantitative indicator, allows a more specific observation of the safety situation studied, as shown in the graph in Figure 4. Thus, it is possible to quickly identify the disagreements and situations of serious and imminent risk with higher occurrences and then direct the corrective and preventive actions in order to obtain greater safety in services with the use of MEWP.

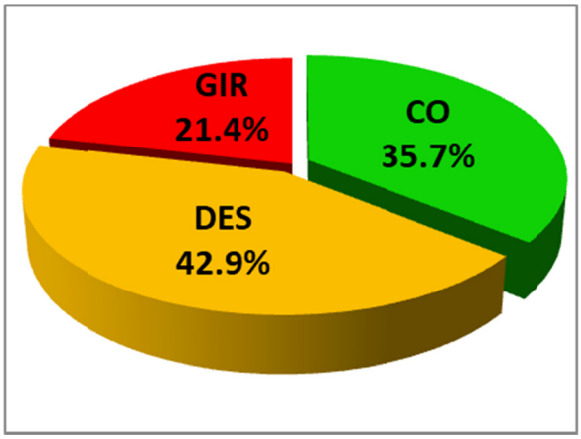


Figure 4. Quantitative indicator

Source: The authors.

*Note*. *Motorised MEWPs only.

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Figure 5. MEWPs stopped in working position without delimitation of work area

Source: The authors.

Regarding the items classified as serious and imminent risk, we observe an occurrence of non-compliance in 29 (44%) of the analyzed MEWPs (of the item related to electric grounding—item 4 (graph in Figure 4). It's important to point out that from the 66 MEWP, this item applied only to 31—quantities corresponding to the scissor MEWP, which are powered by electricity, being the other MEWP (of the boom) powered by combustion. This way, the occurrence of this item is considered alarming, because 93.5% (29 of 31 equipment) of the MEWPs were found in disagreement with the norm, without the presence of electrical grounding, representing a risk of a fatal accident.

Although the other items present lower occurrences in the sample space considered, it does not make them less dangerous or decrease their respective influences on the development of an accident.

In lesser frequency, situations were verified that configure situations of serious and imminent risk related to the non-use of the safety harness attached in 10 situations (15% of the MEWP) and the use of boards and ladders in the MEWP as an attempt to reach higher levels in 4 situations (6%).

*4.2 Documentary Analysis*

Each MEWP has recorded and written proofs that contribute to its correct operation and, consequently, greater safety in the work developed. The documental analysis encompasses the items of the norm that address the requirements concerning documentation (manuals, daily checklist, operator training, maintenance, etc.) and has the objective of highlighting the relevance of documental regularity in maintenance with the contribution to accident prevention.

The graph in Figure 6 presents the quantity of MEWP found in disagreement with the standard regarding the documental regularity of the machine. The disagreements arising from the documental analysis refer exclusively to the absence of the supporting document of the items evaluated in the checklist and do not necessarily configure a situation of imminent risk. Thus, the absence of a manual with records of daily verification of the equipment, for example, does not necessarily configure the absence of these checks, but the lack of records.

From the documental analysis, it was verified that disagreements were found in all items applied in the checklist. Field observations lead to believe that such occurrences are a consequence of negligence on the part of the company, taking as a basis the records for operation of the MEWP.

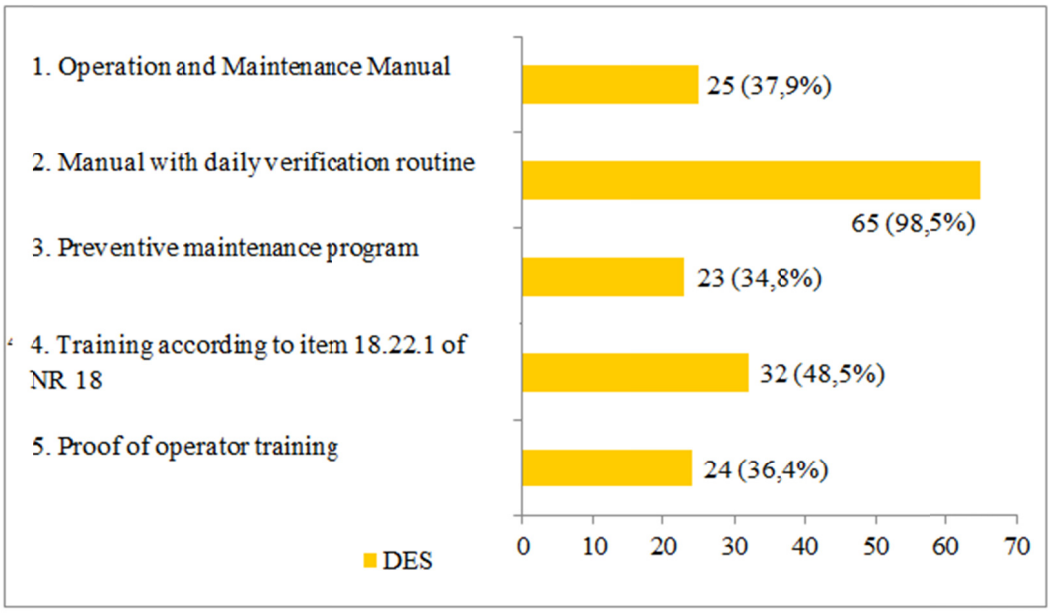


Figure 6. Qualitative indicator—documental analysis

Source: Authors.

Observing the results of this analysis, it can be seen that the highest number of disagreements was identified in item 2 of the chart in Figure 6, which deals with the daily verification. This verification consists of a series of items that should be checked before the operation of the MEWP to reduce the likelihood of occurrences during its operation, is important for the prior identification of possible irregularities or equipment defects, to avoid problems in the operation, interruption of activities and accidents.

The NR 18 requires the training of the operator for the development of activities with machinery, equipment, and various tools, aims for the operator to become familiar with the peculiarities of the equipment, learn to handle it, and use it for the proposed purpose without compromising the overall safety (operator and other workers involved) in the operation.

As it is equipment, the operation of MEWPs needs such prior training and should follow the requirements of NR 18 (BRASIL, 2018) which deals with the minimum content established by the manufacturer that the training should cover, addressing the basic principles of safety, inspection, and operation, in a manner compatible with the equipment to be used. At the end of the training, the operator receives a training certificate that contains the MEWP model for which this operator is able.

It was observed that some workers did not had the training certificate and others operated models different from those in their operator's license, which made them unfit to work with the machine they were operating.

For the analysis of this study, the situations were interpreted as follows: if the operator had a driver's license, but did not operate a model corresponding to his training, this operator was by item 5 (evidence of training), but was not following item 4 (he was considered trained but not qualified to operate the equipment under his responsibility); if the operator did not had a driver's license, he was in disagreement with both items.

It was verified that 24 (36.4%) of the 66 operators were not trained following item 18.22.1 of NR 18, since they did not present any type of training proof and 32 (48.5%) operators were using machines of models that did not appear on their certificate, being in this case, unfit to operate it.

The occurrence of these disagreements may be linked to factors such as the short deadline for delivery of the work, high turnover of construction workers, and lack of trained workers in the region, in addition to non-compliance with safety standards.

Employee turnover in an organization is an activity common to all sectors of the economy, and more pronounced in sectors in which the workforce has the low qualification and little experience (Brazil, 2015). Campos and Malik (2008) consider that high levels of turnover negatively impact the financial health of the company in addition to compromising productivity and product quality in the organization.

Among the construction workers, 8.3% had no level of education, 43.6% had only incomplete primary schools,

and 13.7% are complete (Brasil, 2015), which also hinders the process of training and availability of workers to operate the equipment.

Items 1 (operation and maintenance manual) and 3 (preventive maintenance programs) showed a relatively low number of occurrences (25 and 23 disagreements, respectively), but it is important to highlight their influence on the set of efforts to ensure safety in the operation of MEWPs.

The operation manual has the function of answering questions that may arise during the operation of the equipment, as well as bringing important recommendations of the manufacturer, being important its availability and access. Preventive maintenance is of great importance, not only to provide maximum useful life to the equipment but also to correct and prevent defects that endanger the integrity of its users.

### *4.3 Proposed Safety Guidelines for the Use of Powered Access Platforms*

NR 18 suggests that daily, before the beginning of the working day, a verification, and in a certain way, planning of the service is carried out with the use of the MEWP. It also establishes that it is the responsibility of the user (the company responsible for the work) to provide the operator (a worker who performs a certain activity using the MEWP) with the procedures manual for daily verification and lead your team in this action (item 3.2). Considering the information collected and the analysis of occurrences of regulatory non-compliance in work with the use of aerial work platforms, it was possible to detect the main points of risk generation in this type of service and draw the guidelines presented in Table 1.

Table 1. Suggested safety guidelines for services using MEWP

| |
|---|
| 1. Enable the worker to use the appropriate MEWP, as well as limit its use to trained professionals with permission to work at height. |
| 2. Document and keep the proof and history of training. |
| 3. RCarry out daily inspections before the start of activities, allowing workers access only after submission of a document proving the verification. |
| 4. Had the equipment manual (maintenance and operation) in the vernacular language in compartments in the equipment itself and ensure that it is known by all the workers involved. |
| 5. Define and respect criteria based on the limits provided by the manufacturer for using the MEWP due to unfavorable weather conditions, mainly related to wind speed and strength, storms, and lightning. |
| 6. Isolate and signalize the MEWP handling area, allowing only the workers involved in the process access to the machinery circulation area. |
| 7. Keep the MEWP folded in its base, when not in use, and turned off and protected from accidental operation to avoid accidents. |
| 8. Keep a safe distance from electrical networks according to voltage, as recommended in the manufacturer's manual, to avoid accidental energizing and electric shocks.. |
| 9. Provide adequate grounding for the machines, when necessary. |
| 10. Provide and supervise the use of the necessary PPE related to the operation of the MEWP according to the activity developed. |
| 11. Anchor the safety harness to the structure during the whole activity. |
| 12. Comply with the manufacturer's technical specifications concerning the application, operation, maintenance, and periodic inspections. |
| 13. Prepare a rescue plan for emergencies related to the use of the MEWP so that if any situation arises, the procedures and instructions can be carried out safely and effectively. |
| 14. Respect the high load limit in the MEWP compartment indicated by the manufacturer and had a visible identification plate with the respective limit and unit used. |
| 15. Ensure that the ground conditions are suitable for the safe operation of the machine. The ground must be stable, relatively level, and compacted. |
| 16. Ensure that all work at height involving a MEWP is planned and supervised. |
| 17. Implement a strict inspection and maintenance program, supervised by a legally qualified professional, to avoid accidents due to mechanical failure, with periodic inspections every three months or following the recommendations in the manual. |
| 18. Had periodic maintenance and inspections carried out by qualified professionals.. |
| 19. Only release the equipment when all evaluated items conform. |
| 20. Select a MEWP with the appropriate characteristics for the terrain and the activity to be developed, adapt it to the place where it will be used, and pay attention to the reach of the machine and overhead obstacles. |
| 21. Provide artificial lighting in the work front and the MEWP locomotion area in case of insufficient natural lighting. |
| 22. Had and sound an audible alarm on the MEWP, to communicate the operation in the procedures for lifting and lowering the basket, as well as during the movement of the MEWP. |
| 23. Had a suitable fire extinguisher. |

Source: The authors.

The proposal of these guidelines aims at the adoption of a routine of actions prior, practical and objective, to the beginning of activities with the use of MEWP, ensuring compliance with the minimum safety requirements in the operation of the equipment and consequently, making the activity safer and more efficient.

## 5. Conclusions

It is noticed that, for being relatively simple equipment to be operated, the use of MEWP presents many irregularities. The irregularities are caused by several factors, having as contributors actions in the operation, maintenance, and inspection of the equipment. We highlight the need for isolation of the work area of the platform, the disposal when not in use (it must be collected in its base), being these two irregularities found in all MEWP and the inspection regarding the filling of the daily checklist (irregularity present in 98.5% of the MEWP) containing items of the operation of the command and the verification of the existence of electrical grounding in the platform.

Such factors are due mainly to organizational failures, especially regarding the training of operators and the inspection by the technical managers to comply with the determinations of Brazilian standards regarding the work using MEWP. The correction of these aspects would bring a significant positive impact in reducing the risks present on the site since these items were the ones with the highest occurrence of non-compliances found.

Regarding the technical managers, failures were observed in the inspection regarding maintenance and daily checks, and the execution of services by the operators during the operation of the MEWPs. That is, in practice, basic items clearly defined by standard were not considered minimum prerequisites for the use of the equipment. Many machines did not have a checklist of checks.

Thus, it is necessary that workers are trained to use the equipment considering Occupational Safety issues and that there is monitoring and supervision of activities by the technical managers/company.

The development studied is a shopping and leisure center, with a total built area of 295,000 m² and 101,000 m² of shops (gross leasable area). The company has a socio-environmental commitment, having conquered the AQUA Certification (High Environmental Quality) for Sustainable Construction by applying sustainable practices with the implementation of 40,000 m² of green area, monitoring and air renewal, water saving through the capture of rainwater on the building's roof, collection of condensation water from the air-conditioning system, vacuum sewage, energy saving through the use of natural lighting, waste recycling system and composting.

In addition to environmental concerns, the company has a policy of Occupational Health and Safety—OHS to provide quality in the work environment and to promote an organizational culture focused on accident prevention. However, with the progress of the construction work and the expansion of activities, and as a consequence, the increase in the number of workers, reaching a peak of 6,000 workers performing services simultaneously, the occurrence of failures in management was noted, and consequently, compromising the safe performance of specific activities.

> "According to Llory and Montmayeu (2014), accidents, in the organizational approach, are the consequence of modes of operation often trivialized by organizations that accept safety deviations. In this way, the organizational safety culture of the company directly affects the occurrence of accidents at work."

In this context, although there is an organizational culture focused on the prevention and promotion of safety and health in the company's work environment, several irregularities related to the Brazilian legislation regarding MEWPs were verified. The irregularities found during the research, as well as the recommendations on the adequacy of the standards, were forwarded to the responsible technical professionals to facilitate the process of managing the identified risks.

It is concluded that the MEWPs are very useful tools within a construction site and can make some activities more practical and faster. However, their presence in a work environment brings risks, both for their operators and for other employees who circulate in the work. The application of guidelines and safety measures developed in this work can become a relevant tool in risk control and reduction of accidents, incidents, and non-compliance involving MEWP.

This article was limited to identify through field research, to identify the main irregularities related to the use of MEWP in a construction site Civil Construction and to propose guidelines to contribute to the execution and maintenance of safe work during the use of this mechanical equipment.

For a more generalist view, the proposed checklist can be applied to construction sites of different sizes, to result in more comprehensive guidelines. Another possibility for future research is one can deepen the perception of the risks of the operators and the verification the effectiveness of the control measures adopted.

Table 2. Checklist applied in the case study

| **Checklist for the use of Lifting Platforms** | | | | |
|---|---|---|---|---|
| **NR 18 - Mobile Elevating Work Platforms** | | | | |
| **Item** | *CO | *DIS | *SIR | *NA |
| **1. Minimum requirements and safety** | | | | |
| 1.2 Does the equipment had a safety device that ensures its perfect leveling at the work point, as specified by the manufacturer? | | | | |
| 1.2 Does the equipment had a guardrail that meets the manufacturer's specifications or the provisions of NR 18? | | | | |
| 1.2 Does the equipment had a control panel with an emergency stop button? | | | | |
| 1.2 Does the equipment had an emergency device to lower the worker and the platform to the ground in case of electrical, hydraulic, or mechanical failure? | | | | |
| 1.2 Does the equipment had an automatic sound signal system for ascent and descent? | | | | |
| 1.3 Does the MEWP had protection against electric shock utilizing double-insulated power cables? | | | | |
| 1.3 Is the platform electrically grounded? | | | | |
| **2. Operation** | | | | |
| 2.1 Are the MEWP operation and maintenance manuals written in Portuguese and available at the construction site? | | | | |
| 2.1.1 Does the operator had a procedure manual for the daily checking routine? Is it being applied? | | | | |
| 2.2 Is a safe distance maintained from obstacles, depressions, ramps, and other risk factors, as specified in the project or work order? | | | | |
| 2.3 Is the MEWP operation area delimited and signposted in such a way as to prevent workers from circulating? | | | | |
| 2.4 Are the climatic conditions favorable to the use of the MEWP? | | | | |
| 2.5 Do all workers in the MEWP use a safety harness connected to the equipment's guardrail or other specific device provided by the manufacturer? | | | | |
| 2.6 When not in use, does the MEWP remain retracted in its base, turned off, and protected against unauthorized operation? | | | | |
| **3. Maintenance** | | | | |
| 3.1 Does the owner maintain a preventative maintenance program following the manufacturer's recommendations and the equipment's usage environment? | | | | |
| **4. Capacity building** | | | | |
| 4.1 Is the operator trained according to the equipment he operates, following NR-18 requirements? | | | | |
| 4.1.1 Does the operator had a certificate of proof of capability to operate the MEWP? | | | | |
| **5 Final Provisions** | | | | |
| 5.1. Is it forbidden to use gangways, ladders, and other devices to reach greater height or distance on the MEWP? | | | | |
| 5.2 Is it forbidden to use the MEWP as a crane? | | | | |

*Note*. *CE = Compliant; DIS = Disagreement; SIR = Serious and Imminent Risk; NA = Not applicable.
Source: Authors, based on Brazil (2018)

## Dedication

We dedicate this paper to Professor Doctor Béda Barkokébas Junior (in memoriam).

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