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EVALUATION OF THE EXPOSURE OF WHEELCHAIR USERS TO MECHANICAL VIBRATIONS: A COMPARATIVE STUDY OF MANUAL AND MOTORIZED CHAIRS ON PUBLIC FLOORS

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Abstract. *Frequently users of wheelchairs are subject to vibrations due to soil irregularities. In many cases these vibrations can reach high levels and lead to damage to health of these users. Thus the goal of this work is to evaluate the exposure of wheelchair users to vibrations, who are continuously under these vibrations in their routine. This work was performed through vibration measurements carried out in two wheelchairs, one manual and the other motorized. The evaluations were performed according to the ISO-2631, where the limits of vibration levels and maximum exposure times were analyzed. The worst case was related to the stone pavement and motorized chair with a maximum exposure time of one hour and a half. This work presents a scientific and social approach, since the experiments developed and their results can be used by wheelchair manufacturers, which can lead to improvements in wheelchair transportation.*

Keywords: *Vibrations, Wheelchair users, Exposure.*

1. INTRODUCTION

The individual who have some difficult or impossible to walk due to illness, injury or disability need of a wheelchair as a mean of locomotion. The use of this technology allows the individual to overcome his limitations and perform much of the activities imposed on him. The constant use of the wheelchair can lead to long-term complications. These complications may be related to excessive exposure to vibration.

According to the ISO-2631, there are two types of exposures to vibration, the hand-arm vibration and the whole-body vibration. The last is more appropriate for wheelchair users. Whole-body vibration can lead to serious health problems for the human being, such as spinal injuries and gradual degeneration of muscle and nervous tissue.

Human exposure to vibration can be evaluated through standard measurements on the surfaces or tools that transmit these vibrations to the human body. This work has the objective of measuring and evaluating the vibrations received by users of wheelchairs on public floors, according to their routines.

As will be shown, there are differences in vibration levels for different types of chairs. There are also pavements with large irregularities such as stone pavement, whose high levels of vibration determine tiny exposure time limits.

2. THEORETICAL FOUNDATION

2.1 Wheelchair and pavements

A wheelchair is used by individuals with difficulty of locomotion, and can be moved manually or electronically by the occupant or pushed by someone. Due to the time users stay in wheelchairs, comfort and stability are important to their health. The exposure of vibration is one of the factors that can lead to health risks, based on the irregularities of the ground and low absorption of vibrations by the chair. The concern with human exposure to vibration is recent, there are few researches related, and the existing ones are not clear or objective.

Three different pavements were selected for this work (Fig. 1). The criterion of selection was the predominance in cities.



Figure 1. Selected pavements: Asphalt; Paver and Stone Paving. Adapted from Neri (2013).

2.2 Human exposure to vibration

According to ISO 2631-1, there are two types of exposure to vibration of the human body, the hand-arm, which is transmitted through the handling of tools or machines and the whole body, which is transmitted through the body support surfaces. The most pertinent in the case of the wheelchair users is the whole-body vibrations, transmitted by the wheelchair when transiting by the pavements.

For vibration analysis, the human body can be modeled as a biomechanical system, which approximates a mass-spring-damper system in the frequency range 1 to 80 Hz for whole body vibrations, as illustrated in Fig. 2 (GRIFFIN, 1990).

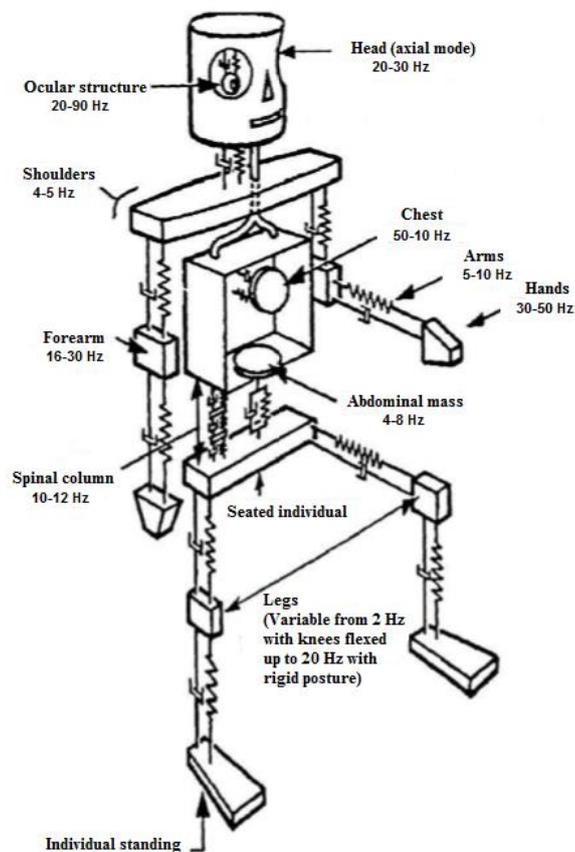


Figure 2. Sensitive frequencies in various regions of the human body. Adapted from Gerges (2005).

The vibrations transmitted to the human body may be along the x -, y - and z -axes, with distinct characteristics, as illustrated in Fig. 3. The combined effect is equal to the sum of the partial effects given the parts of the body that are

subject to these vibrations (XIMENES, 2006). In most studies related to whole body vibration, the predominance of higher vibrations levels is in the z-axis direction, due to the greater tendency of movement to occur vertically (SEIDEL, 2005).

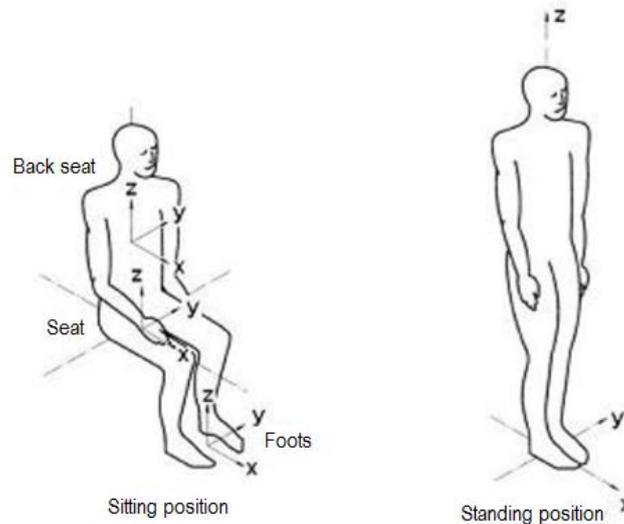


Figure 3. Body space axes systems. Adapted from ISO 2631-1 (1997).

2.3 Measurement of vibrations according to ISO 2631-1 1997

Measurements are necessary to evaluate the human exposure to vibrations in wheelchair users, which must be performed under normal driving conditions, without modifications in the wheelchair and the user himself as a driver.

The primary variable used to characterize the vibration is acceleration, measured in root-mean-square (rms). This acceleration must be weighted, characterized in all three axes, resulting in a weighted rms acceleration for each axis. After that, the overall value of the weighted acceleration is determined according to:

$$a_w = \sqrt{\sum_i (W_i a_i)^2}, \quad (2.1)$$

where a_w is the weighted acceleration, W_i is the weighting factor and a_i the acceleration measured on each axis.

The ISO 2631-1 recommends that when the vibration intensity is similar on two or more axes (x, y and z), a vector resulting from these three axes must be calculated. The vector resulting from the total acceleration is determined according to:

$$a_v = \sqrt{k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2}, \quad (2.2)$$

where a_{wx} , a_{wy} e a_{wz} are the accelerations r.m.s weighted for each orthogonal axis and k_x , k_y e k_z are multiplicative factors, which are: 1.4, 1.4 and 1, respectively.

The limits for the weighted total acceleration for different times of exposure to vibration are shown in Fig. 4. In this graph, the dashed lines B.1 divide the exposures in three zones. For exposures below the lines, health risks are not clearly documented. The zone between the lines is designated as the precautionary zone or caution zone and above the lines, health risks are likely.

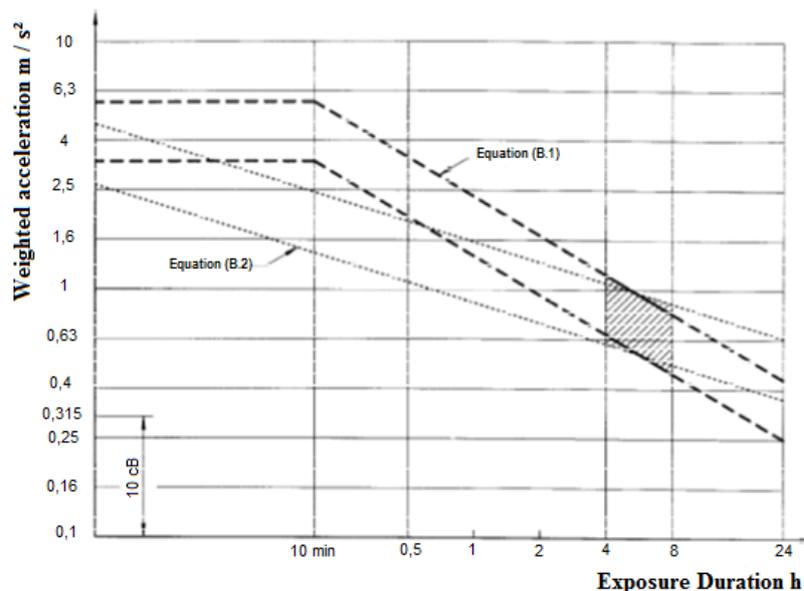


Figure 4: Graph that relates effects to health in relation to intensity and time of exposure. Available in ISO-2631-1.

3. EXPERIMENTAL PROCEDURE

It was used three accelerometers of ENDEVCO and model 256-100, to measure the accelerations, one for each axis (x -, y - and z -axes). In order to measure these acceleration, it was developed a device to fix the accelerometers in each direction. The device created called "cushion" (Fig. 5) incorporates the three accelerometers in its interior. This device was designed to not interfere in the wheelchair driving, as well as in the user's seat. So, this device was placed underneath the user and the measurements were carried out. Measurements were made through a digital signal analyzer connected to a laptop, that were transported by another person to the side of the wheelchair during the measurements.

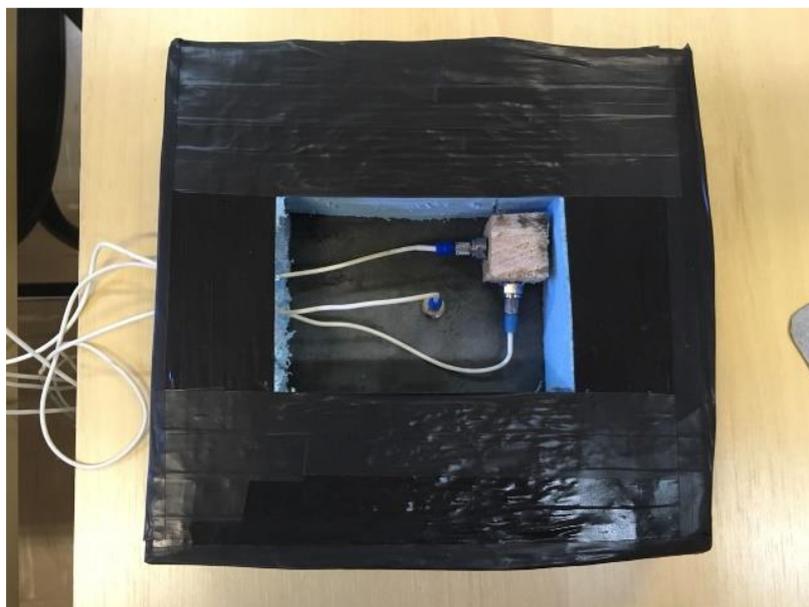


Figure 5: Cushion device.

As the research involves human beings, the approval of the university ethics committee is required. The approval number is 21098719.0.0000.5547.

A total of 10 measurements were performed with a total time of 240 seconds. The measured frequency range was 1 to 80 Hertz, which characterizes the frequencies sensitive to the human body. The data were measured in a 1/3 octave band by the FFT analyzer.

Two types of wheelchairs were evaluated, one manual and other motorized. For each type of wheelchair, the vibrations were measured on three types of floor: asphalt, paver pavement and stone pavement. Beyond the floors and wheelchair types, it was also evaluated the influence of the user weight in the total vibration, by measuring three users with different masses. The mass of each user is shown in Tab. 1.

Table 1: User characteristics in measurements.

Identification	Gender	Age	Mass (kg)	Height (m)	Body mass index
A	M	25	26	1,10	21.49
B	M	36	62	1,64	23.05
C	M	49	90	1,77	28.75

Figures 6 and 7 show the pictures of the measurement setup.



Figure 6: Image collected during asphalt measurement.



Figure 7: Image collected during paver pavement measurement.

Through the processing of signals from the transducers and the application of the Fourier transform, the acceleration values for each of the frequencies were obtained for each axis. The data were exported in text files <.txt> and processed in routines developed in the MATLAB program according to the equations and weights established by ISO-2631 (1997). A routine was written in the Matlab environment to process the measured data and compute the vibration total value of weighted acceleration of each case, in accordance to equations (2.1) and (2.2) of the ISO 2631-1.

4. RESULTS

The maximum time allowed for human exposure to vibration in each case was analysed. The resulting vibration spectrum was generated for each of the measurements. The worst case can be visualized in Fig. 8, and the best case, or the one that had lower rates of vibration can be visualized in Fig. 9.

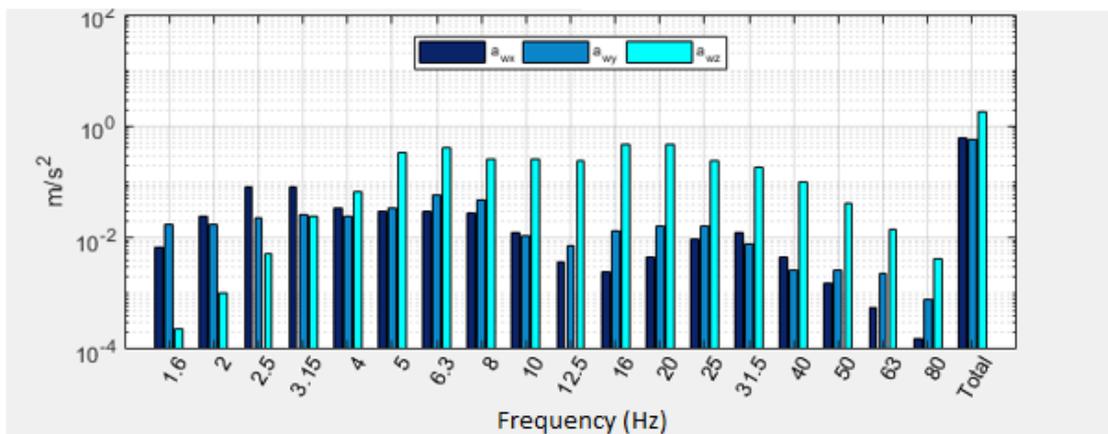


Figure 8: Resultant vibration spectrum: Stone Paving and Motorized wheelchair.

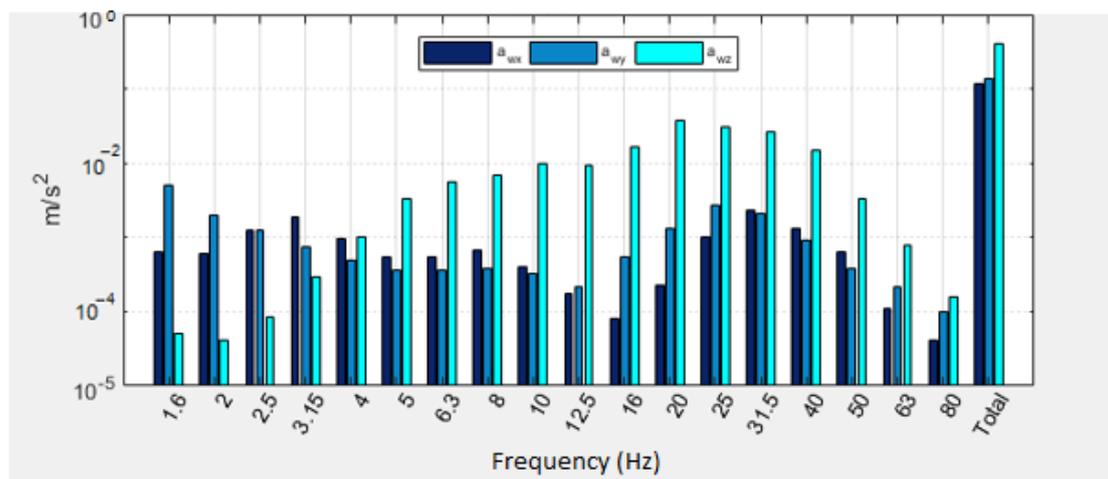


Figure 9: Resultant vibration spectrum: Asphalt and Motorized wheelchair.

It was verified that the worst case evaluated was for the stone pavement and with the motorized wheelchair. The result was 2.1 m/s^2 , which relates to a maximum exposure time of approximately 1 hour and 30 minutes. On the other hand, the best result was the configuration asphalt with the motorized chair, which the limit of exposure time was 8 hours to the measured vibration (0.5 m/s^2).

The worst and best case check can be visualized in Fig. 10, in red and blue, respectively.

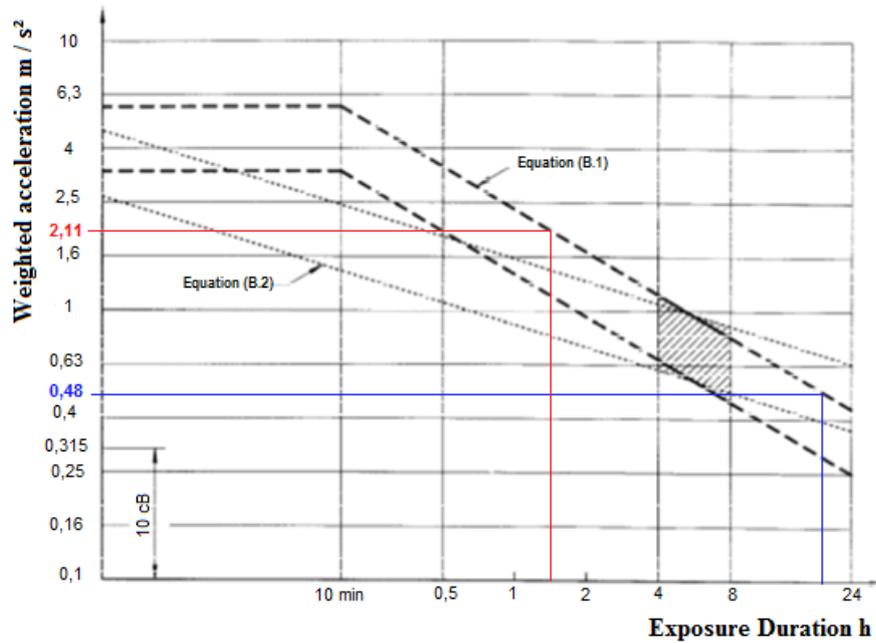


Figure 10: Worst and best case Check. Modified from ISO 2631-1.

The comparison between the manual and motorized chairs can be seen in Fig. 11. There is a small difference between the two seats, where the manual tends to damping more the vibrations during the routes.

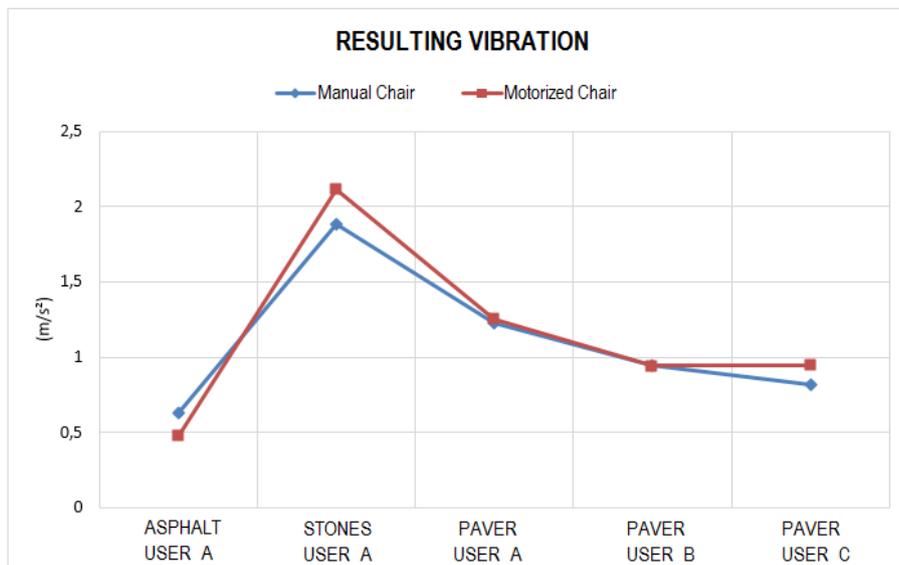


Figure 11: Comparison of results for wheelchairs.

Another comparison is about the mass of the wheelchair user, whose results are shown in Fig. 12. In this, the pavement analysed was the paver sidewalk. A slight downward trend can be observed, that is, the greater the mass of the wheelchair the lower the vibration received by the user.

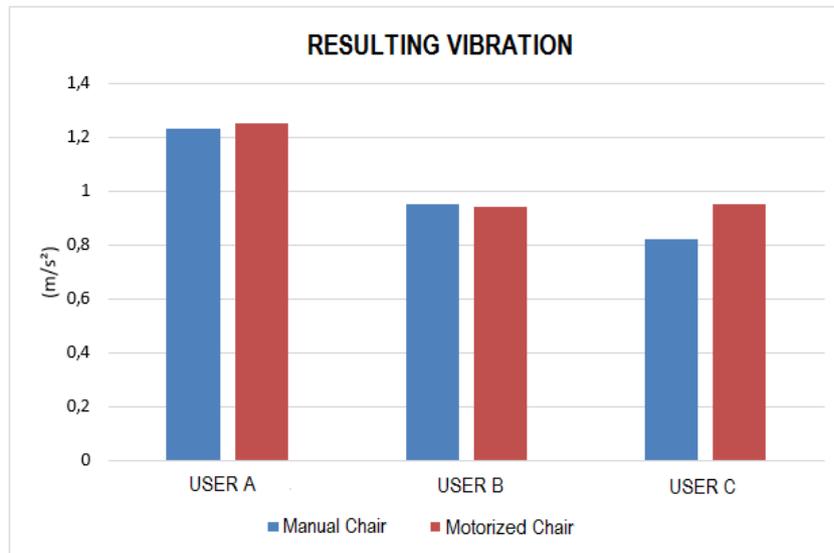


Figure 12: Comparison of results for the mass of the wheelchair user on the paver pavement.

As can be seen in Fig. 11, the highest vibration values were found in stone paving, so the shortest exposure times are related to this type of pavement. A total of 1 hour and 30 minutes for the motorized chair and 1 hour and 45 minutes for the manual.

The lowest measured vibration levels are connected to the asphalt, where the exposure times for the motorized and manual wheelchair were 19 hours and 30 minutes and 12 hours respectively. According to the standard in case of exceeding these exposure limits, health risks are likely.

In comparison to results for wheelchairs, the overall manual had a better performance in absorbing the vibration levels than the motorized, the complexity and set of distinct frequencies of the latter may have led to inferior performance.

Regarding measurements on the paver sidewalk, the maximum exposure times were between 4 and 7 hours of exposure. In this pavement, the influence of the weight of the wheelchair in the two wheelchairs was evaluated through the graph of Fig. 12. It is difficult to say if there is or not influence of the mass of the user by the measurements carried out, a slight tendency is noticed that the larger the mass of the user, the lower the vibration levels received by him. But the number of participants is small to say with conviction.

5. CONCLUSIONS

With the present research it was possible to improve the knowledge about vibrations in wheelchairs and the effects they can cause to the human body. It has been found that wheelchair users, which are mostly using the wheelchair, can suffer complications if they exceed time limits in relation to each selected floor.

The worst case was related to the stone pavement, for reasons of greater irregularity and inconstancy, followed by the paver and then asphalt. Regarding the mass of the wheelchair according to the trajectory analyzed in the paver sidewalk, no significant effect on the vibration exposure was found.

Future projects can be based through this to withdraw information and provide as an example some type of component for the chair, which would aim at reducing exposure to vibration of users. Another idea for further work is the elaboration of a new prototype wheelchair, which would give importance to this area of vibrations, which deserves to be highlighted due to the impacts on human health.

6. ACKNOWLEDGEMENTS

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