Ergonomic Design of Taho Cart with Shock Absorber System

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Abstract

Taho is a delicacy made of fresh tofu commonly retailed in the Philippines, where vendors are usually forced to empty their supply in a few hours as the quality of taho deteriorates due to uncontrolled heat transfer and vibration-produced during peddling. This study aims to construct a prototype that will minimize quality deterioration of taho as well as to provide ease in retailing of taho. Carts are the usual vehicle for street vendors. Consequently, the prototype is loosely based on the design of the carts readily available in the market with key improvements such as coil springs on the auxiliary wheel and the addition of polyethylene foam for heat insulation. The results show that the cart design appears to have small fluctuations of temperature than manual operation. In contrast, the vibration frequency seems to be minimal throughout the assessment. In contrast, the quality of taho in terms of physical appearance is comparatively similar to both strategies due to it being beyond the study's scope. The prototype exhibited comparatively better results than its manual counterpart, alleviating the payload from tension, which creates a higher tilt and movement readings in terms of frequency and acceleration while achieving temperature being preserved throughout the interior of the system.

Keywords
Ergonomic design, shock absorber system, taho cart

1. Introduction
Taho is made from fresh tofu, usually mixed with highly concentrated brown sugar or vanilla syrup and paired with gelatin-based edible pieces known as "sago." It is typically retailed using an aluminum container with ropes tied around it that act as support when carried by the vendors daily. This delicacy often energizes the consumer due to its sugar content that provides a unique taste similar to drinks such as coffee. However, tofu is a reasonably sensitive ingredient whose quality can quickly deteriorate, so vendors are forced to empty their daily supply in less than a few hours as soon as they start peddling. This is seen as the tofu excretes a liquid extract that resides at the top of the edible material. The quality of the tofu also relies on the ambient temperature of the surroundings (Kong, Chang, Liu, & Wilson, 2008). This implies that as the ambient temperature increases, the quality of the tofu decreases. The taho being peddled will depend on its quality, as most consumers prefer a gel-like texture. Vendors are forced to toss the liquid extract before serving their taho to cater to the consumers' liking.

1.1. Objectives
With these factors in mind, researchers conducted this study to prolong the timeframe of peddling taho before its quality completely deteriorates and improve the ergonomics and comfort of the vendors. This research will cover the

concept of design, fabrication, and testing of a taho cart with added key improvements to meet the objectives of this study.

The standard method of selling taho is to use an aluminum container carried by the vendors throughout the day. The aluminum containers are designed economical-wise in mind. Hence, its design exposes the tofu from the fluctuations of ambient temperature. Vendors usually carry the aluminum container using their shoulders, which generates a vibrational effect as they peddle their product. The whole setup typically weighs approximately 50 kilograms (Baes, 2017), which may harm the vendor's shoulders in the long run. Vendors are usually seen to toss the watery extract produced during peddling since most consumers prefer gel-like texture rather than watery texture. The watery extract is made due to the vibrational effect during peddling and the effect of ambient temperature fluctuations. Since the main ingredient of taho is sensitive to these factors, vendors should empty their daily stock in 5 hours soon as they started.

Since improving the ergonomics and comfort of the vendors is considered an objective, researchers concluded to use a method that requires little effort in terms of physical capacity. Carts are usually seen as the widely acceptable vehicle for street vendors. Hence, the design will be based on a bicycle cart. The dangers of the cart-operated method are comparatively low compared to the standard method. The initial design was drafted with the use of drawing software such as AutoCAD and Fusion360. Following the initial design was not prioritized as the sizes used in constructing the cart will heavily depend on the standard sizes available in the market. Key improvements to meet the criteria of the objectives will be added. A shock absorber system will be installed to limit the vibrational effect during peddling. In the conventional design, the heat of the taho may pass through the steel wall through conduction at a standard rate. Double-wall stainless steel containers tend to store the heat for a prolonged period, but the same heat transfer process is considered throughout. Polyethylene foam was used as another leverage to reduce the effect of fluctuating ambient temperature on the product.

2. Methods

To start the prototype design process, the researchers determined which key improvements are to be added to meet the criteria of the objectives of the study. Short goals are to be met; to minimize the vibrational effect on the product, minimize the impact of heat transfer of ambient temperature, and improve the ergonomics and safety of the vendors.

The researchers also determined which devices can meet the criteria of the objectives and are widely available in the market and their cost-effectiveness. The most commonly used device to minimize the vibration frequency of a moving vehicle is a shock absorber, while the widely used device to insulate heat transfer is polyethylene foam. The design is then based on carts as it is the most commonly used vehicle by street vendors and is widely available in the market.

After understanding which key improvements were to be added, the researchers evaluated its structural integrity as it is the most important aspect to be considered when designing in general. The researchers considered are the weight of the aluminum containers when it is at total capacity and the cart itself. The total load will be carried by two installed shock absorbers, whereas the total load should be less than the load that two shock absorbers can hold. The dimensioning of the prototype design will heavily depend on the size of the aluminum containers used. Since the size of the aluminum containers does not affect the product quality, the size will then be based on the aluminum containers used in the standard method retailing taho.

The cart was drafted with the aid of drafting applications such as AutoCAD and Fusion360. The initial design assisted the researchers in selecting the best materials for the prototype in terms of selecting materials, satisfying the objectives, and the structural integrity was the priority. Cost-effectiveness also comes into play in materials selection.

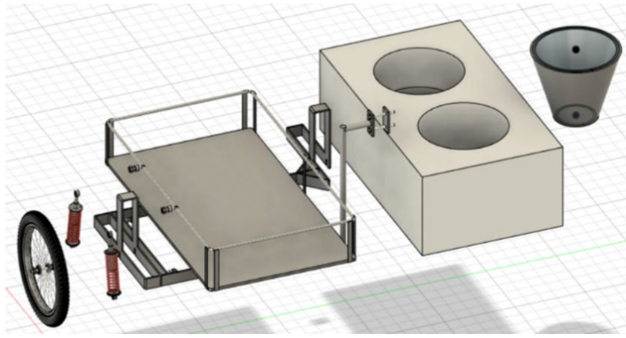

Figure 1. Overview design of the cart

In the ergonomic design of the taho cart, as shown in Figure 1, the shock absorbers used will heavily depend on the vibrational analysis from frequency and velocity of people walking (Pachi & Ji, 2005) alongside the calculated induced load earlier. The commonly used and widely available insulation foam in the market was chosen as it was assumed to be enough to minimize heat transfer of the ambient temperature with the condition that the whole interior of the cart should be covered. Two shock absorbers were used to eliminate all the possible vibration-induced due to road profile and the suspension fork installed on the bicycle of the cart.

Testing will be limited to urban areas where there is a high presence of cemented roads and a high quantity of gravel rocks. The location will be ultimately decided based upon the vendor's discretion, one of which will affect their business model. Their goal is to create profit regardless of the materials and prototype presented for. The testing occurred during a global pandemic. Hence, city guidelines such as wearing face masks and proper physical distancing were prioritized, and the limitation of only one of the researchers will conduct the testing.

Sensors were used throughout the experiment to automate and ensure the accuracy of the data gathering. A DS18B20 temperature sensor and an MPU-6050 accelerometer-gyroscope sensors were used since those are widely available sensors in the market that satisfy the method of data gathering. Both sensors are within the accepted accuracy and improved with the help of Arduino to automate the data gathering.

Two data gathering methods will be conducted: (1) standard taho peddling and (2) cart-operated taho peddling. Sensors were used in both ways to ensure that the accuracy range will be similar. The standard taho peddling was performed earlier, and the test concluded within 3 hours. To ensure the compatibility of the two methods in terms of testing, cart-operated taho peddling should also conclude within 3 hours.

3. Results and Discussion

Two parameters are taken into consideration: the amount of vibration for which the taho will be enduring, as well as the temperature at which the taho will be preserved throughout the testing. Regarding the payload's weight, it is assumed that the materials used in the design will carry their total weight. The quality of weld and materials used were sufficient in fabricating the cart. Temperature is one of the deciding factors when and if the taho is undergoing quality deterioration. Based on the temperatures achieved in the comparison shown in Figure 1, the cart achieved higher temperature readings. The testing is timed within a 2 ½ -hour (9000 seconds) period.

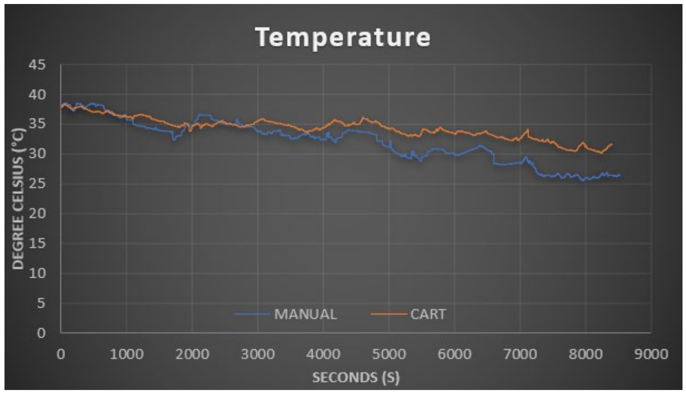

Figure 2. Graph comparison of Manual vs. Cart

As seen in Figure 2, the orange line represents the cart-operated method resulting in a higher temperature reading than the line in blue, which means the standard peddling method. The placement of the temperature sensor, in this case, located in the attachment of the cylindrical containers generated data based on its area of location as well as the relation of temperature differences between an ambient environment versus the cylindrical container. These factors were discussed in the succeeding sections to further explain some key elements leading to data gathering.

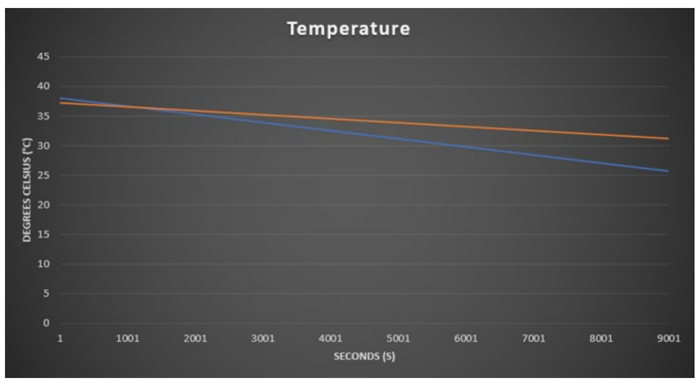

Figure 3. Curve-fitting graph of Figure 2

As shown in Figure 3, a graph method called curve-fitting was made to substantiate additional information regarding the evaluation of temperature of both methods. Similar to Figure 2, the orange trendline represents the prototype cart design while the blue trendline represents the manual retailing operation.

The temperature sensor is attached to the steel walls of the payload. The sensor is situated upright and in close contact with the cylindrical sheet metal as shown in Figure 4. For us not to damage the quality of the container, the researchers decided to test the attachment as the testing moves forward, and based on the results, it outputted similar data on both categories of testing. The exact orientation and placement of the temperature sensor were done on both aspects of the testing, may it be during manual operation or the testing of the prototype.

Figure 4. Sensor location in the cart

The span of the tests conducted was within two days. The first test was conducted in a manual operation where the payload is situated on the vendor's shoulder. The second test was conducted using the proposed cart design, where the buckets are inserted in the cart. The ambient temperature was measured to be 32°C on both tests. These ambient temperature readings were considered in relation to the payload and the surrounding's Arithmetic Mean Temperature Difference (AMTD), where the mathematical considerations are in between two temperature regions, one hot, in this case, the payload, and one cold region, in this study is the surroundings.

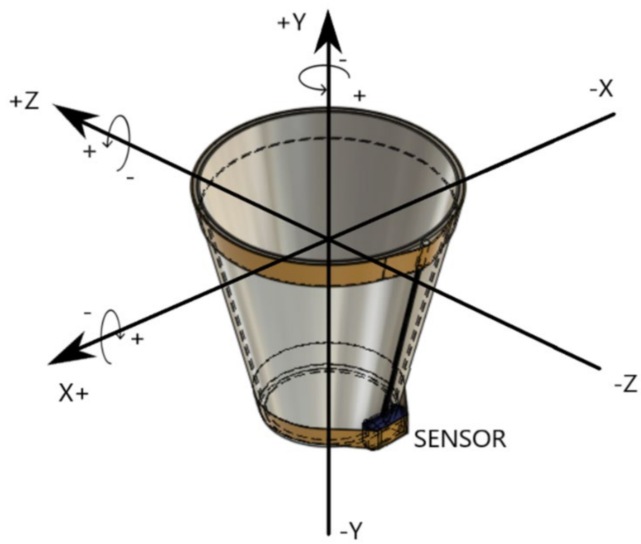

Figure 5. Accelerometer & Gyroscope Direction and Rotation

Vibration is a contributing factor for the deterioration of the taho. When the taho is receiving fluctuating vibration frequencies, its surface texture becomes agitated and may result in the breaking up of the surface. This, in turn, deteriorates the quality of the taho.

The graphs shown are the results and comparison of the tests done in manual operation versus when used with the proposed cart design. The accelerometer readings show values when the sensor picks up sudden acceleration in the system. The Gyroscope, on the other hand, detects tilt on specified planes under observation. In this study, we compared the difference in tilt and sudden accelerations in the system on the X, Y, and Z-axis in manual operation versus the proposed cart design as shown in Figure 5.

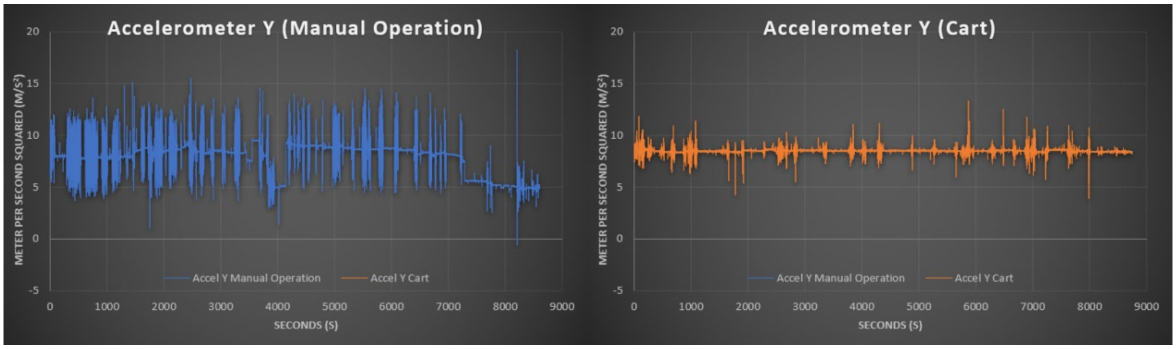

Figure 6. Y-Acceleration of Manual-operated vs. Cart-Operated

Figure 6 shows the Y-axis of the test with the upward and downward movement of the payload. The data shows the frequent fluctuations in the movement of the system under observation. In the graph for the accelerometer, we can set 9.8 m/s2 as the point of origin or the point where the aluminum can is stationary and not involved in any upward or downward movement; this is because of the constant gravity and normal force the aluminum can experiences. Any value higher than 9.8 m/s2 shows the acceleration at which the aluminum can experience a sudden upward motion. Any value below 9.8 m/s2 shows the sudden downward movement the aluminum can experience during the experiment.

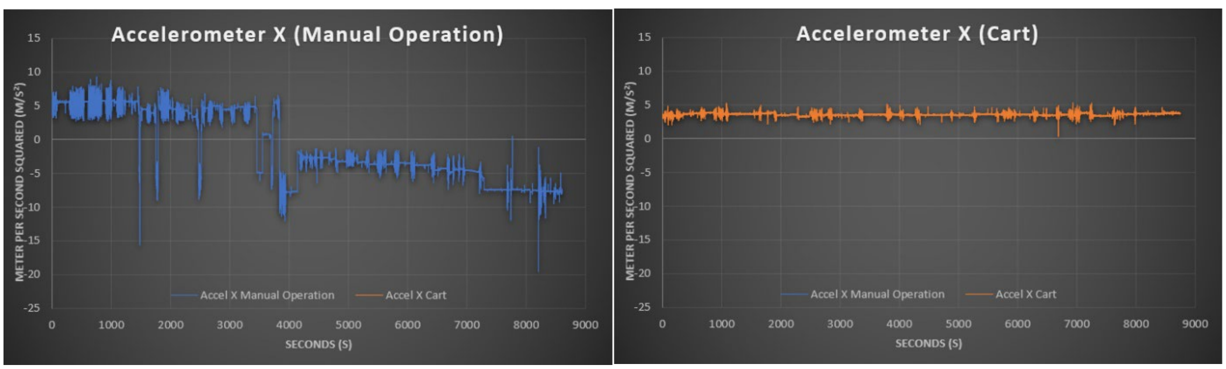

Figure 7. X-Acceleration of Manual-operated vs. Cart-Operated

Figure 7 shows the X-axis of the test about the forward and backward motion of the system. Since the vendor almost always does forward motion (walking forward) due to the nature of the manual operation and when using the cart, wherein almost no reverse movement is done, we can see that values are higher than 0 m/s2. Negative values for the manual testing may indicate rotation of the aluminum container while traversing, thus inverting the orientation of the sensor and direction of the acceleration, as seen in the graph. The graph shows that there were more frequent fluctuations in movement, thus giving erratic data points when in manual operation compared to when using the proposed cart design. Usage of the cart then shows the elimination of any erratic data points gathered during the manual process. The cart supporting the aluminum can is situated in support of the cart, which provides normal force opposing the weight of the payload.

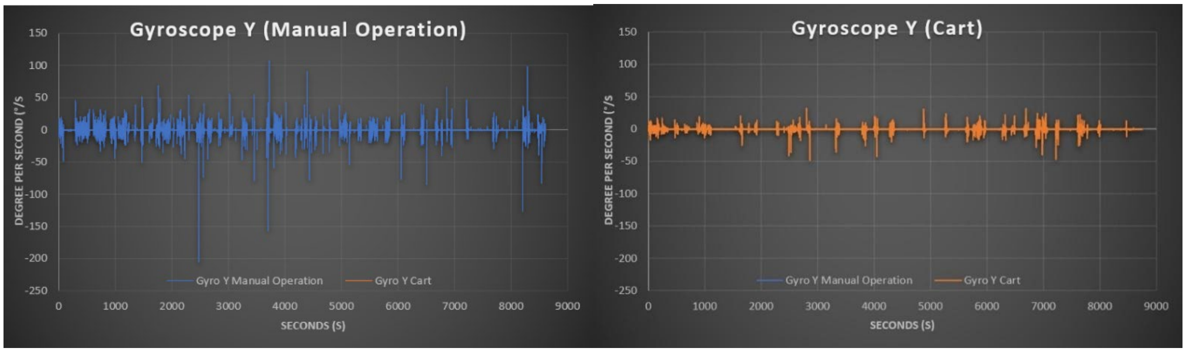

Figure 8. Angle disposition (Y-axis) of Manual-operated vs. Cart-Operated

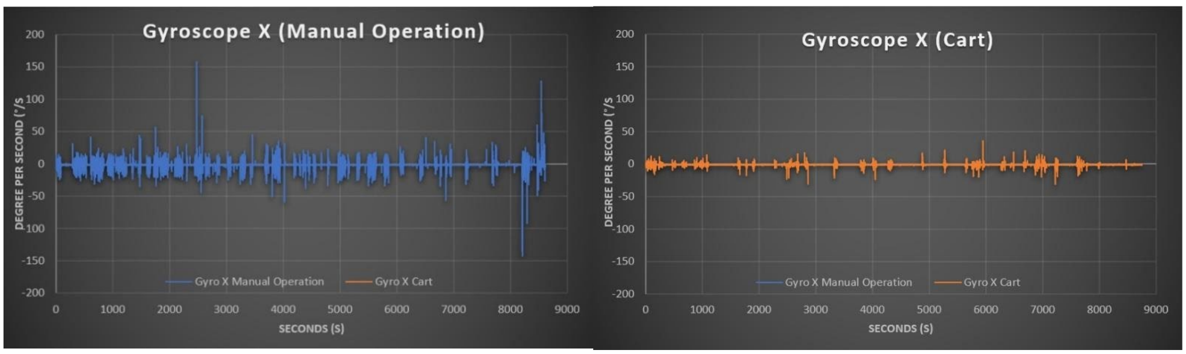

Figure 9. Angle disposition (X-axis) of Manual-operated vs. Cart-Operated

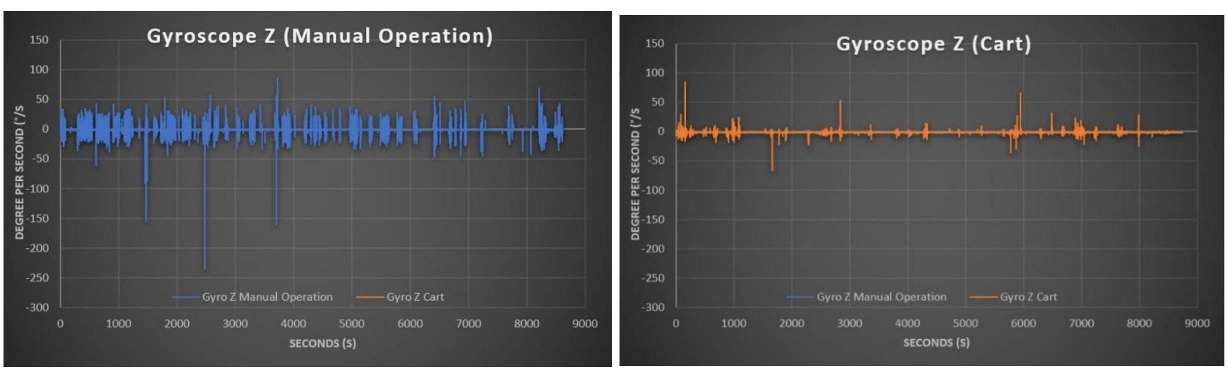

Figure 10. Angle disposition (Z-axis) of Manual-operated vs. Cart-Operated

As for the graph of the Gyroscope, as shown in Figures 8 to 10, since it is in degrees/second, it simply indicates the tilt of the aluminum can concerning the orientation of the sensor, provided that one knows the axis at which where the pitch, yaw, and roll movements are.

The result shows that manual operations tend to produce higher fluctuations in movement compared to the use of a cart. Tension forces are relieved in the system when transitioned to the proposed design because it does not rely on the vendor's shoulders for support. The payload is situated in support of the cart, which provides normal force opposing the weight of the payload.

The system consists of two 320mm coil springs at the auxiliary wheel located at the right side of the cart. The spring system carried the impact force of the cart when driving, especially when encountering speed-decreasing elements such as speed bumps and potholes. The output of the proposed cart design was in direct relation to the inclusion of coil springs for the system. Based on road selection, the road was purely asphalt filled with few amounts of gravel, including speed bumps and potholes. The payload weighs fifty (50) kilograms, whereas including the vendor's weight and other auxiliary elements would total one hundred and forty (140) kilograms. This translates that the springs should support up to the same amount of the load or higher. Based on the springs' specifications, a single 320mm coil spring can carry an average load of 300 kilograms. The cart design proposes using two coil springs at the auxiliary wheel where it dissipates the load of the system. The dimensions also suggest that the track of the design is kept at a minimum for it to avoid deflection along with the point where the load is placed.

The road selected is within the limits of the testing. Based on the data, both manual operation and the use of the proposed cart design were operated under the same conditions.

4. Conclusion

The objective of the research is to design and fabricate a taho cart with key improvements such as a vibration damping system to reduce the vibrational effect to the product and a heat insulation system to reduce the effect of ambient temperature on the product as well as to improve the ergonomics and safety of the vendors.

The researchers observed two parameters that were discussed in this study: temperature and vibration. Based on the prototype, the fabrication techniques were adequate in accommodating the payload and cruise through a usual route traveled by the vendor. The researchers adapted the widely-used cart design by street vendors, adding key improvements to accommodate the given parameters. Cost-effectiveness was also prioritized by utilizing the available aftermarket parts such as coil springs and the cart itself to alleviate the vibration-induced road conditions. Using a double-walled cylindrical aluminum container alongside polyethylene foam covering the whole interior of the cart, heat transfer due to ambient temperature changes was minimized. The data presented in this study is sufficient to assess the difference between manual-operated and cart-operated methods properly. Based on the data acquired, the manual-operated method produces higher fluctuating values than the cart-operated method. The accelerometer graphs show that the cart-operated method has minimal vibrational frequency mainly due to the added key improvements such as shock absorber. The temperature graphs show that the prototype cart achieved higher temperature readings which means that heat was preserved through an extended period while achieving lower values in terms of tilt and movement inside the system. The prototype exhibited comparatively better results than its manual counterpart, alleviating the payload from tension, which creates a higher tilt and movement readings in terms of frequency and acceleration while achieving temperature being preserved throughout the interior of the system.

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