

Influence of Design on the Thermal Environment of Public Transport Transit Facilities

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Abstract

Rural urban migration is a phenomenon which is experienced in many developing countries; the result is an increase in populations across urban centers which further translate into overpopulation. In Mombasa, Kenya, there is a growing concern over comfort in particular thermal comfort due lack of response to the hot and humid climatic conditions in the design of transit facilities. The objective was to investigate thermal environment conditions in transit facilities. Field surveys were carried out to investigate the thermal environment conditions of ferry transit facilities. The study was conducted for two days at two terminals mainly the Island and the Mainland terminal at the Likoni area of Mombasa in the month of July 2012. The study consisted of two methods, namely, thermal environment measurement and thermal comfort questionnaire. Wind and thermal inertia measurements were taken and a total of 100 questionnaires were administered, 50 per terminal. The study found that there was approximately 70 % dissatisfaction rate in thermal comfort at the mainland transit facility and a 20% dissatisfaction rate in the island transit facility. Poor ventilation levels were also observed in the mainland transit facility. It was recommended that solar passive cooling techniques be used to cool the thermal environment.

Keywords: *Urban centers, Public transport, Thermal environment, Congestion, Passive cooling*

1. Introduction

Rural urban migration is a phenomenon which is experienced in many developing countries. The reason being, inhabitants of rural areas seek better opportunities in urban centres. The result is an increase in populations across urban centres which further translate into congestion in these areas. The city therefore is likely not to be able to sustain the burden of overpopulation and therefore deterioration of cities occurs. One such area of a city which is likely to deteriorate is in public transport.

Public transport plays a key role in the functioning of a city; this is because as our urban centres continue to grow public transport is increasingly becoming a necessity due to the need for movement. People need to make the switch from one mode of transport to another due to the complexity of the transport system in our urban centres. Transit facilities are therefore important to make the switch easier and seamless. In Kenya, the need for transit facilities is on the rise as populations in urban centres increase and urban centres develop. It is estimated that over 650 thousand people use public transport daily in Nairobi alone, the capital city of Kenya.



Fig 1.0 Maps of Africa, Kenya and Mombasa



Fig 2.0 Island and Mainland Terminal

At the Likoni ferry terminal in the hot and humid coastal town of Mombasa, The Kenya Ferry Services Ltd which operates ferries on a single route with two terminals namely the mainland and island terminals carries over 250 thousand passengers a day.

The terminals are linked to bus stations. Therefore people transit from one mode to another. The problem is that: the design of ferry transit facilities in Mombasa do not respond to the thermal comfort requirements for the hot and humid climate of the region. The pragmatic objective of the designs of the ferry transit facilities was probably to realize mass passenger

low with less attention being paid to the quality of the environment. Evidence of thermal discomfort can be seen when the transit facility is congested. Some cases of people fainting

have been reported inside the transit facility likely due to congestion and the poor thermal environment. The objective was to investigate the thermal environment conditions in ferry transit facilities.

2. Methods

To investigate thermal environment conditions in transit facilities. Field surveys were carried out in the month of July 2012 for two days on two ferry terminals namely island terminal and mainland terminal.



Fig 3.0 Island transit facility



Fig 4.0 Mainland transit facility

The aim was to:

- To establish the temperature distribution across the terminals.
- To take measurements of the indoor and outdoor air temperature as well as surface temperatures of the transit facilities.
- To establish the indoor and outdoor humidity of the transit facilities.
- To measure wind speeds and observe wind direction across the terminals.

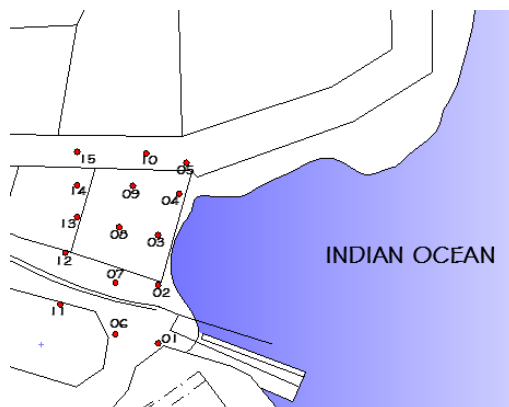


Fig 5.0 Numbers indicating the positions where measurements were taken to find the temperature distribution within the Island transit facility site.

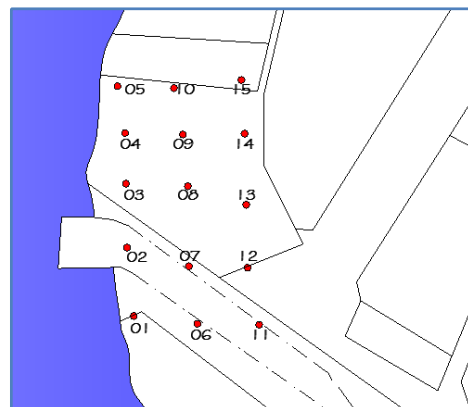


Fig 6.0 Numbers indicating the positions where measurements were taken to find the temperature distribution within the Mainland transit facility site.

To establish the temperature distribution across the site (Fig 3 and 4): Air temperature was recorded every 20 minutes for 2 hours in 15 different locations. The study was carried out between 1pm and 3pm at the island terminal and mainland terminal for two days.

To determine the differences between the indoor and outdoor air and surface temperatures: Temperatures were recorded between 1-3 pm because this is the highest recorded temperature for the region. The air and surface temperatures of the indoor and outdoor walls

were taken three times in intervals of one hour for two days between the hours of 1pm and 3pm.

To establish the indoor and outdoor humidity: Relative humidity was recorded every 20 minutes for 2 hours in 15 different locations. The study was carried out between 1pm and 3pm at the island terminal on the first day and mainland terminal on the second day.

To measure wind speeds and observe wind direction: Wind speeds were measured for 5 minutes after every 30 minutes in selected areas around the transit facility. Two flags on both sides of the ferry terminals were strategically placed to monitor wind direction.

The data recorded was further checked against physiological responses of the users so as to establish the thermal satisfaction rate. Users were asked to answer a number of questions about their comfort levels by use of questionnaires. This method involved a survey of a small percentage of the user population of these transit facilities to acquire the general thinking of the majority.

3. Results

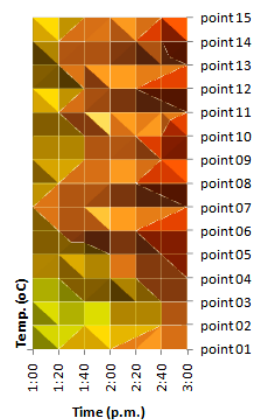


Fig 7.0 Island transit facility temperature recordings

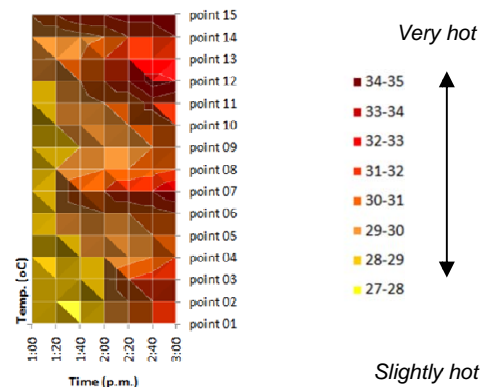


Fig 8.0 Mainland transit facility temperature recordings

3.1 Temperature analysis

The Mainland transit facility recorded high indoor temperatures compared to the island transit facility. This may have been attributed to the shade of the indoor environment and lack of a solid wall in the island transit facility. This allowed wind movement through the facility and significantly cooled the indoor environment.

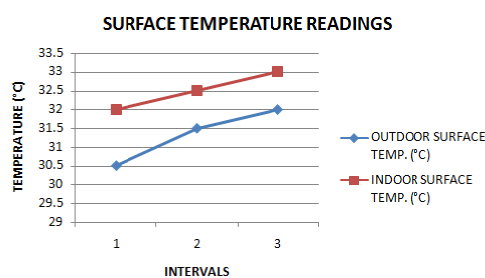


Fig 9.0 Surface temperature readings mainland transit facility



Fig 10.0 Mainland transit plan

Poor air movement between transit A and B resulted in less ventilation and therefore increase in temperature.



Fig 11.0 Island indoor



Fig 12.0 Mainland Transit A



Fig 13.0 Mainland Transit B

3.2 Humidity analysis

The study showed a relatively higher humidity in the outdoor environment than the indoor environment in both the mainland and island terminals.

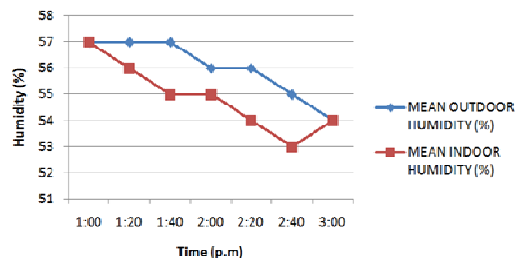


Fig 14.0 Humidity island transit facility

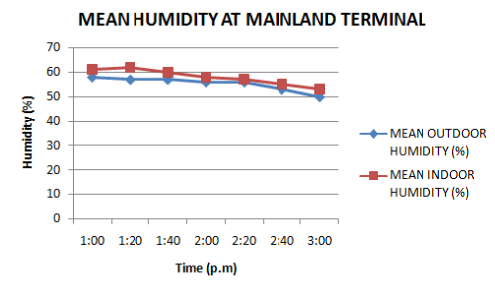


Fig 15.0 Humidity island transit facility

3.3 Wind analysis

The air velocity inside the mainland transit facility recorded low speeds of less than 5m/s. This was an indication of poor ventilation levels. The openings at the waiting area were not sufficient to allow sufficient air to cool the interior through natural ventilation. Discomfort arose when the mainland transit facility was fully occupied and wind speeds were less than 5m/s.

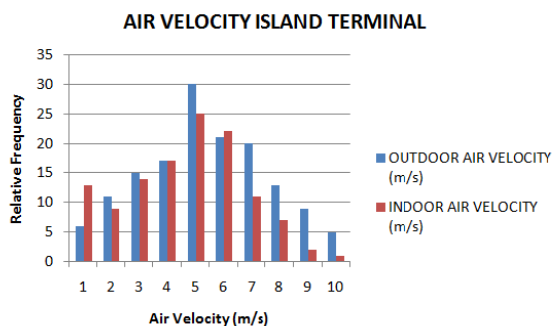


Fig 16.0 Air velocity island transit facility

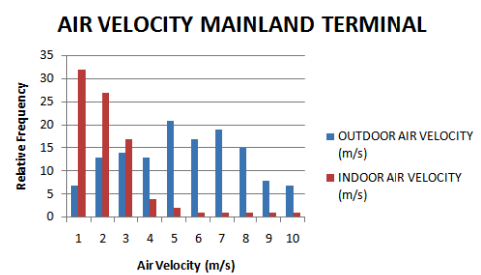


Fig 17.0 Air velocity Mainland transit facility

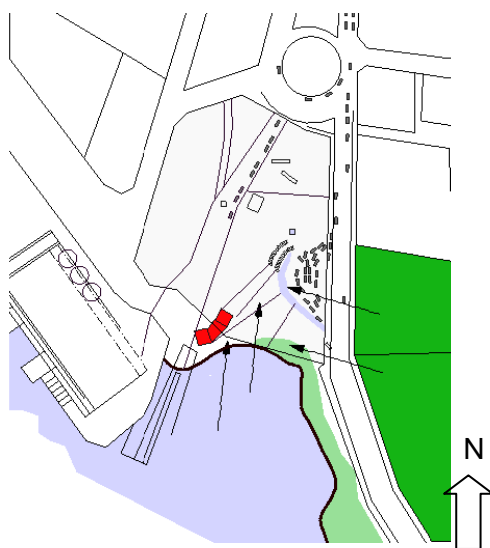


Fig 18.0 Prevailing winds island transit

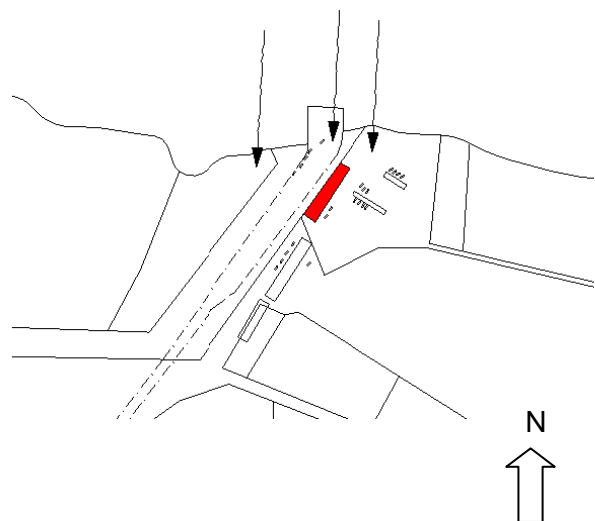


Fig 19.0 Prevailing winds Mainland transit

3.4 Questionnaire analysis

Humphreys and Auliciemes investigated the thermal neutrality of the human body. It was defined as the temperature at which the person feels thermally neutral "comfortable". From the questionnaire analysis the neutral temperature accepted by users was between 27 - 31°C.

There was approximately 70 % dissatisfaction rate in the thermal comfort of the mainland transit facility and a 20% dissatisfaction rate in the island transit facility. This was attributed to warmer temperatures indoors in the mainland transit facility. The Island transit facility did not have any solid walls and therefore the shades provided air ventilation adequate to cool the indoor environment.

4. Discussion

4.1 Neighborhood

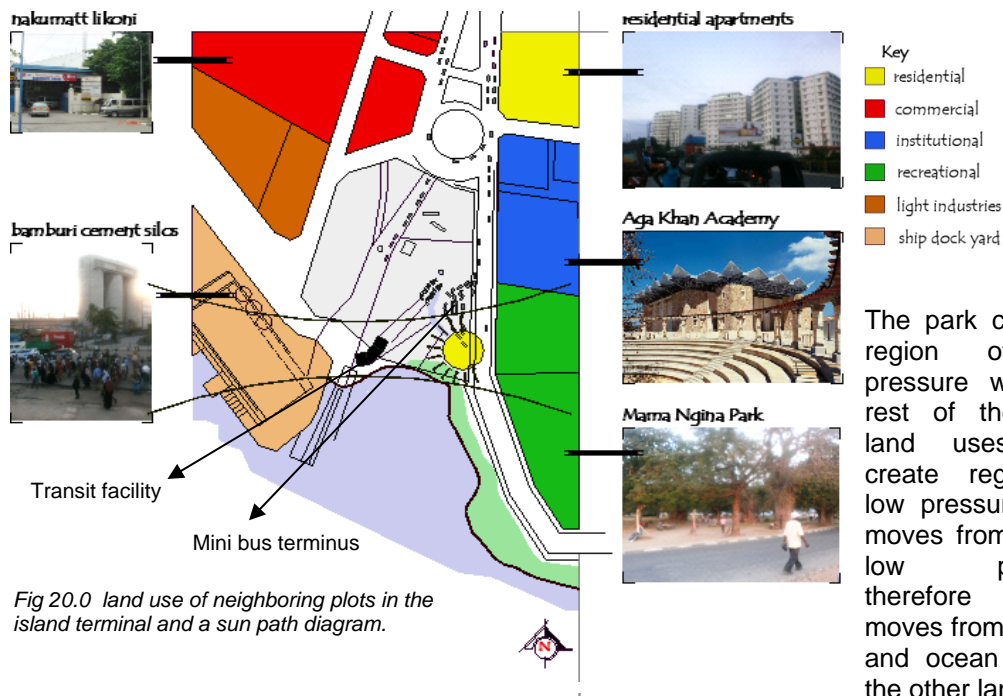


Fig 20.0 land use of neighboring plots in the island terminal and a sun path diagram.

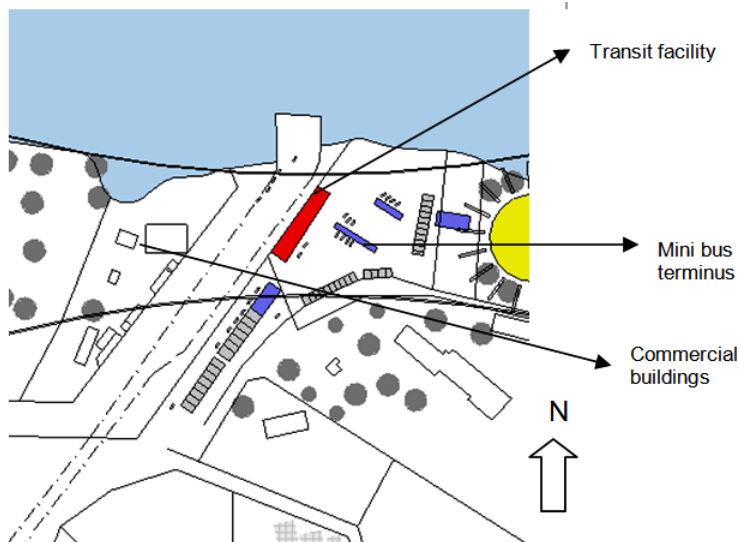


Fig 21 Neighborhood and a sun path diagram in the mainland terminal.

4.2 Neighborhood and Configuration

Sun path and Orientation

Both buildings are oriented north east. The orientation could have been the result of designing the building by following the configuration of the plots and not the sun path forces. This can be seen in fig 21 where the transit facility is designed in line with the road's configuration.

Wind movement

Land and sea breezes were the major source of air velocity into the facility. The mainland terminal however had its prevailing winds not sufficiently reaching the waiting area. The walls acting as boundaries at the staircases blocked the sea breeze during the day.

4.3 Planning

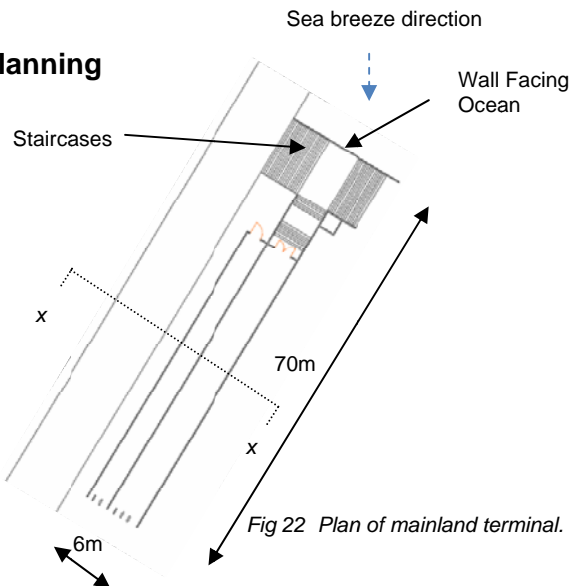
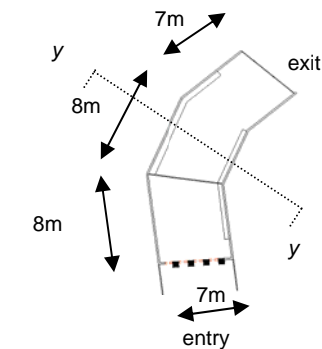


Fig 22 Plan of mainland terminal.



NB m=meters

Fig 23 Plan of island terminal.

Both plans are rectilinear, with the island's terminal rectilinear shapes forming a slight curve. The mainland terminal is enclosed with walls while the island terminal is more of an open plan with steel bars acting as boundaries in place of a wall. The mainland terminal consists of a long narrow waiting area and path shown in fig.22. Although wind movements are faster in narrow cross sectional areas according to the Venturi effect, it was noted that when the facility was filled with users, the congestion resulted into reduced wind velocity.

4.4 Volumetric aspects and boundary layers

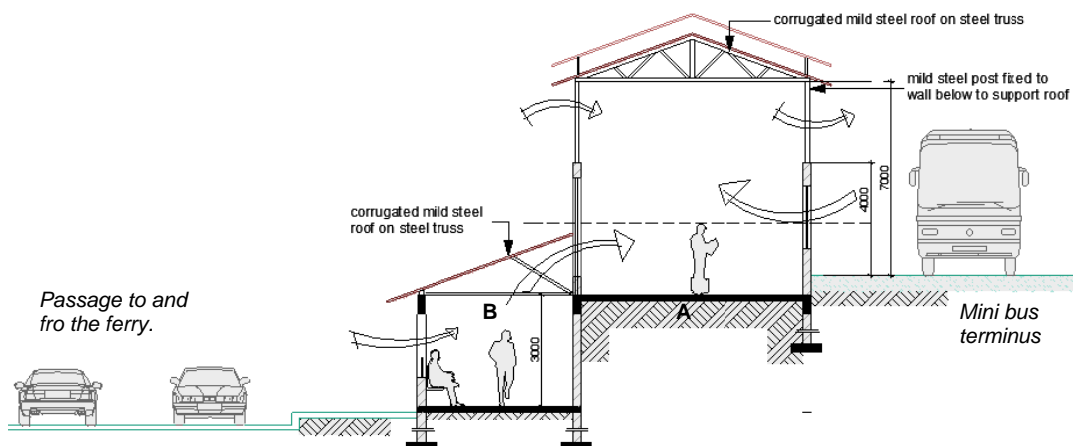


Fig 24 section x-x: mainland transit facility

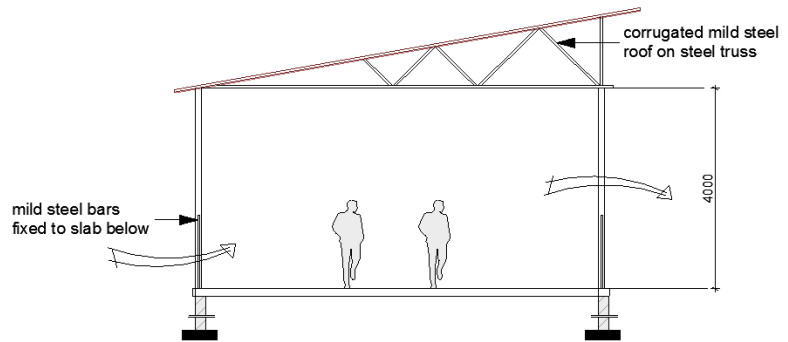


Fig 25 section y-y: island transit facility.

It was noted in the mainland terminal (fig.24) that wind movement from space 'B' to space 'A' resulted in thermal discomfort in space 'A'. As the warmer air rises, it enters into space 'B' as this is the boundary layer for air exchange between the two spaces. The area below the dotted line in space 'A'(fig 24) received less airflow than the upper area above the dotted line. Therefore the airflow was not enough to cool space 'A'.

In the island transit facility, the airflow was at comfortable rates according to 80% of the users. This was attributed to the open nature of the design in terms of open vertical planes rather than a solid wall.

5. Summary of findings

5.1 Thermal environment of the mainland terminal

The indoor environment of the mainland terminal recorded higher heat levels than the island terminal. This was attributed to:

- There was poor air exchange rate to cool the indoor environment.
- Air circulation in the lower part of the transit building was poor compared to the upper parts of the building as shown in fig 25.
- Intense heat from the surrounding environments.
- Poor openings strategies.
- Higher surface temperatures were observed due to the longer side of the rectilinear shape being exposed to solar radiation because of the buildings orientation.
- The narrow design to increase the wind movement indoors doors not work due to the large number of users that congest the area.

5.2 Thermal environment of the island terminal

The indoor environment of the transit facility recorded lower temperatures compared to the surrounding. This was attributed to:

- Lack of solid wall surfaces to block the incoming and outgoing winds unlike the mainland transit facility.
- A larger and wider surface area of the transit facility allows passengers to spread.
- This area has more greenery than the mainland terminal

6. Conclusions and Recommendation

6.1 Conclusions

Thermal sensations differed among individuals, even in the same environment, however all respondents preferred shades. From the results of the thermal comfort survey, the temperature level that was comfortable was 27-31 °C. Levels above or below were deemed to cause discomfort. But it was noted that people in different areas may have different thermal sensations or preferences even under the same climate conditions.

Lin and Matzarakis (2007) Vehicles boarding the ferry increased the temperature level of the region. The asphalt surfaces of the road were also the major cause of high temperatures around the transit facilities.

More openings should be designed on the north-south facades rather than east-west facades as observed in the mainland transit facility. This is to enable land and sea breezes to enter the facility without any obstructions.

The two facilities lacked high and low pressure points. Courtyards can act as high pressure points so that wind moves to the warmer surfaces from the courtyards.

Areas which received less airflow such as space 'B' (fig.25) can be raised because wind velocity increases with increase in height.

Air plenums can be created to avail airflow to areas which had limited wind movements

6.2 Recommendations

It was recommended that solar passive cooling techniques be used to cool the thermal environment if prevailing winds are above 5m/s. The following was an important consideration: Implications in design:

- Building orientation should have a strong correlation with wind direction and sun radiation.
- The double ventilated façade is essential for cross ventilation.

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