before the start of this iteration.

- If the if condn on line 12 would not had hold, then it's trivial to see that before the start of the next iteration when $j = z+1$, the loop invariant still holds.

Termination: The inner loop terminates when $j = n+1$. By line 4, we know that n stores the no. of non-zero elements of matrix a, and hence also of matrix b. By loop invariant, we can say that $\forall K, 1 \leq K \leq n$, if a[K].col == i, then:

1) The corresponding transposed entry ⟨a[K].col, a[K].row, a[K].value⟩ has been correctly stored in the next available index of b[] (currentb)

∴ All the non-zero elements having column i in a[] have been transposed.

2) For all the non-zero elements in b having row i (i.e. column i in a), the elements are arranged in b[] such that their respective column indices are in ascending order. □

Outer loop invariant: At the start of each iteration of the outer loop when $i = c$, where $0 \leq c < a[0].col$, for all columns K, where $0 \leq K < c$, all the non-zero elements of a[] in these columns have been transposed correctly to their corresponding indices of b[] (a[K].col, a[K].row, a[K].value) in b[]. We ensure that the elements are arranged in ascending order of their row indexes.

Refined Outer Loop Invariant (ChatGPT)

- At the start of each iteration of the outer loop where $i = c$, $0 \leq c <$ a[0].col, the transpose of all non-zero elements in columns 0 to c-1 of matrix a[] have been correctly placed in b[] as triples ⟨row, col, value⟩,