Economise the Use of Space for Storing Pallets in a Warehouse

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Motivation:

Warehousing costs companies $300bn per year, globally. Building a warehouse can cost over $1200/m². Use of mathematical models can ensure the correct layout for the client.

1. Introduction:

In this analysis, we were requested to develop a strategy to economise the use of space for storing pallets in a warehouse.
This was restricted by the minimum width of an aisle that a forklift truck would need to operate in[1].

2. Assumptions:

- Static shelves.
- Rectangular pallets.
- Pallet size is the same.
- Same forklift used.
- The width of the aisle is a function of the size of the pallet and the forklift.
- 2D Modelling.

3. Defining Variables:

Independent Variables **(Inputs)**:

- Position of the door.
- Dimensions of the warehouse and aisle.
- Dimensions of pallets.
- Dimensions of forklift.

Dependent Variables **(Outputs)**:

- The layout of the warehouse.
- The percentage of used area/total area. (Warehouse space utilization)

References:
1. www.palletrackguru.com/forklift-aisle-widths
2. www.cisco-eagle.com/industries-served/order-fulfillment/the-typical-warehouse

4. Analysis:

We first looked at a snake path solution. This has an upper bound on the amount of space that can be used to store pallets of 2/3rds. Usually the efficiency drops below this in certain door locations, as demonstrated in the bottom example.

This solution is not time efficient, as the forklift needs to traverse the entire path twice to extract the furthest pallet. It also wastes space dividing the warehouse up into a grid of pallets. In addition, it uses unrealistic assumptions about how the forklift operates, mainly that the forklift it can operate within one pallet's worth of space.

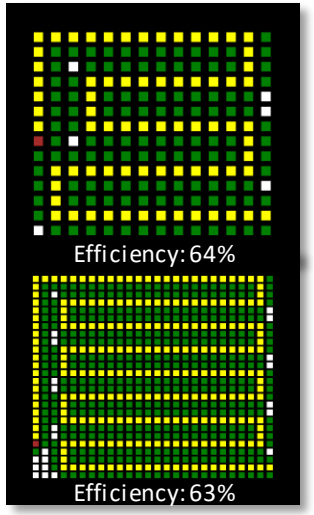

Figure 1: Example snake paths for moderately sized warehouses.

The second method we tried is less space-efficient, but far more time efficient.
It uses the concept of one main aisle and many perpendicular aisles in order to reduce the time to reach any pallet.
This solution has many advantages over the snake path: its applicability to non-rectangular warehouses, the reduced travel time of a forklift, and redundancy if one aisle is blocked.

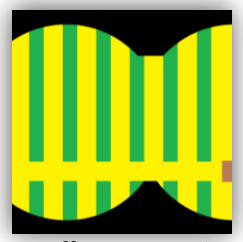

Figure 3: A strangely shaped warehouse.

Figure 4: The model failing. Red shows inaccessible aisles.

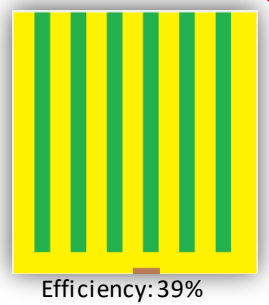

Figure 2: The model applied to an average[2] US warehouse.

5. Strengths and Weaknesses:

Pros:

- A low upfront investment with only the actual warehouse space required.
- The model is very suitable for storing identical pallets and optimizes the amount of pallets stored well, whilst not losing too much floor space for aisles.

Cons:

- Products and pallets must have similar dimensions as multi-sized pallets can't be stored in the same lane.
- None of our models are optimised for time which could cost more in the long run.

6. Elements for the Future:

With the limited time available, there were limits in what we could do with our model.
If we had more time, we would have made these improvements:

- Our model constructed the warehouse in a 2D world. If we considered a 3D world, we could utilise underpasses and the height of the roof of the warehouse to increase efficiency.
- Adding a second aisle, parallel to the main one, would solve the problem of a central obstruction rendering some aisles inaccessible (shown in red) as seen in figure 4.