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How to identify ground slot patterns in inland terminals to increase storage capacity of containers – a combination of metaheuristic and simulation

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Abstract

There are many studies on the layout of container yards at maritime terminals. These layouts are based on the 20-foot ground slot (TGS), as 20-foot and 40-foot containers predominate. In contrast, inland intermodal terminals (e.g., rail-road terminals) handle various container sizes (e.g., 20-, 30-, 40-, and 45-foot). The TGS is, therefore, not always suitable for inland intermodal terminals. Thus, finding the optimal ground slot size(s) for intermodal terminals is very relevant. However, we did not find any studies concerned with this question. This work uses a metaheuristic to find suitable ground slot patterns for inland intermodal terminals, develops a model in Python to analyze these patterns in a short time, and an agent-based discrete-event simulation in Anylogic, including additional crane movement to free containers with other containers stacked above, vehicles and, trains for more detailed analysis. Our preliminary results show that the average height of containers can be reduced by up to 0.96. Thus, the limited space can be used more efficiently using adjusted ground slot patterns. Similarly, the average space use can be reduced by up to 13 %.

Keywords: Inland Terminal; Container; Storage Capacity; Metaheuristic; Simulation

1. Introduction

Inland intermodal terminals play a vital role in shifting freight transport to rail. This makes them crucial for the sustainable supply of urban regions. However, intermodal transport is often considered to be time-consuming and costly (Cimili et al., 2022). Therefore, terminal operators need to ensure that terminal operations run smoothly.

A key challenge for terminals is the efficient temporary storage of containers and other intermodal transport units. Space is typically restricted by other infrastructure and should be used as efficiently as possible economically to avoid additional costs and environmentally to avoid soil sealing. Additionally, the space is restricted upwards due to the maximum stacking height of containers, container handling equipment (e.g., cranes), and the need to extract containers from the bottom of a stack. Therefore, the design of the storage area, including the ground slots, i.e., the exact area within which containers are stored, is essential.

At (maritime) terminals, containers are usually stored in blocks. As illustrated in Figure 1, the block's heights are measured in tiers, their length in bays, and their width in rows. Thus, a container's position can be found using bay(s), row, and tier (Ambrosino and Xie, 2023).

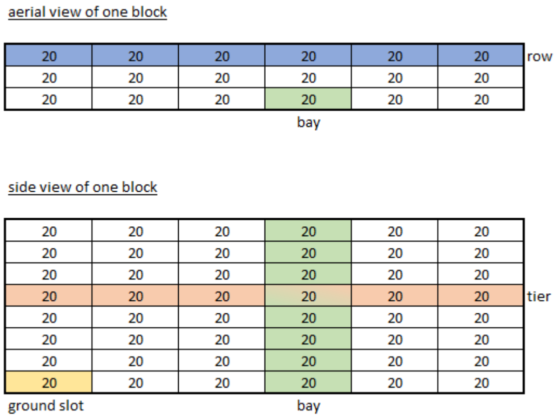


Figure 1. Ground slots pattern with TGS

At maritime terminals, bays are usually 20, sometimes 40 feet long, as 20-foot and 40-foot containers predominate. Bays with a size of 40 feet can either accommodate one 40-foot container or two 20-foot containers.

In contrast to maritime terminals, inland terminals have to manage a wide range of container types with different sizes (e.g., 20’, 24’, 41’, 45’), which are usually stored in mixed blocks, i.e., containers of different sizes in one block (Posset et al., 2020). As a result, 20-foot ground slots (TGS), typically found in maritime terminals, are inadequate for many inland terminals.

Therefore, intermodal inland terminals are often partitioned differently, e.g., horizontally, according to the length of a rail car (Boysen et al., 2013).

Thus, instead of blocks consisting of several bays with TGS found at maritime terminals, mixed blocks in intermodal terminals consist of only one bay. The bays’ ground slot length is specific. However, it is not standardized. Depending on its length, each ground slot can host one or more containers of different sizes.

Subdividing large storage spaces into smaller units (e.g., blocks) is particularly relevant for handling them when cranes are operated manually, as is common in inland terminals. The smaller units are needed to pinpoint a specific container`s current or future location, to either remove or move it (from) there.

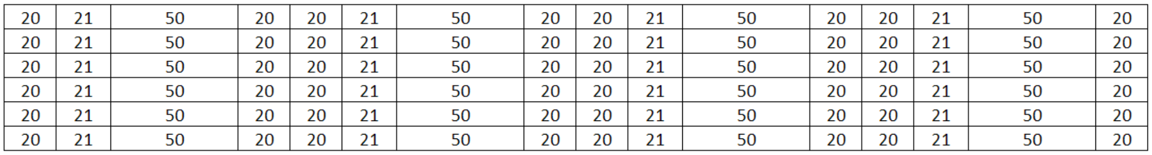
Minimizing the space required for a given number of intermodal transport units is one of many challenges terminals face. In addition, the slot size must allow for smooth operation, e.g., efficient crane movements, and facilitate easy access to particular containers, even if other containers are stacked on top of them. This access is only possible in combination with reasonable stacking rules (e.g., Kim and Ryu, 2022; Kim et al., 2008).

There are different possibilities to find a suitable ground slot size. Inland terminals could e.g., focus on the largest size of containers handled.
For example, in an inland terminal handling containers with a maximum size of 45 feet, the ground slot size could be set to 45 to accommodate containers of all sizes handled at the terminal. For example, a ground slot of 45 feet can host

- two 20’ containers (space not used: 5’),
- one 20’ and one 24’ container (space not used 1’),
- one 30’ container (space not used 15’) or
- one 45’ container (space not used 0’).

However, depending on the mix of container sizes, space may be wasted if, e.g., many 30-foot containers are handled. Thus, there could be better slot sizes than 45 feet. Additionally, not all blocks (and thus, ground slots) necessarily have to be of the same length.

Diverse ground slot patterns (as shown in Figure 2) could mitigate the problems caused by the variety of container sizes handled in inland intermodal terminals.
In the example shown in Figure 2, not all the ground slots are the same size. One or more containers of a total size that is equal to a specific slot’s size or smaller can be placed on this slot. In the example, the ground slot pattern is 20’-21’-50’-20’. Thus, half the slots are 20-foot slots, and a quarter are 21-foot and 50-foot slots. Consequently, all slots can accommodate at least one 20-foot container, half of all slots can accommodate at least one 21-foot container, and only a quarter can accommodate containers larger than 21 feet (e.g., 30’ 45’).
As the composition of containers of a given size changes over time, the ground slots should use the given space as efficiently as possible for anticipated container sizes while remaining robust to possible changes in the future composition of container sizes.
The challenge, however, is not only that the proportion of containers of certain types and sizes fluctuates over time, but also that, once the ground slot pattern has been decided upon, it is hardly possible to change it without incurring immense transaction costs.
Therefore, we develop a risk-free two-step approach, including a metaheuristic, to provide promising ground slot patterns. We also develop an agent-based discrete-event simulation model to test those ground slot patterns in a dynamic setting for an exemplary case study terminal. A ground slot pattern is defined by the slot sizes dividing the storage space into smaller units.



20	21	50	20	20	21	50	20	20	21	50	20	20	21	50	20
20	21	50	20	20	21	50	20	20	21	50	20	20	21	50	20
20	21	50	20	20	21	50	20	20	21	50	20	20	21	50	20
20	21	50	20	20	21	50	20	20	21	50	20	20	21	50	20
20	21	50	20	20	21	50	20	20	21	50	20	20	21	50	20
20	21	50	20	20	21	50	20	20	21	50	20	20	21	50	20

Figure 2. Aerial few of section of ground slot pattern with slot sizes 20'-21'-50'-20' and six rows

2. State of the art

Several authors have discussed yard layout planning for maritime terminals. One issue tackled, e.g., by Gupta et al. (2017) or Lee and Kim (2013), is how container blocks are laid out in relation (e.g., vertical, parallel) to the quay. Boysen et al. (2013) surveyed intermodal inland terminals, specifically railway yards. They only found a few papers on yard layout for rail-rail terminals and some simulation studies for rail-road terminals looking at general terminal layouts (e.g., number of tracks and location of terminals within a port). To the best of our knowledge, no more recent literature on this topic is published.
Additionally, we did not find any account of what other units are feasible or reasoning on why the slots need to be equal in size in the literature.

Closer to our topic, Zhou et al. (2020) divide blocks into segments of different sizes, however, ground slots are constant at 20-foot (TGS).

Thus, for maritime terminals, the block size, length position and various other aspects are discussed in the literature. Nevertheless, the size of the ground slots themselves (20`) is not discussed. TSG are, however, often not feasible at inland intermodal terminals because of the various container sizes.
In this work, we therefore investigate how to achieve an optimal combination of different ground slot sizes (ground slot patterns) to efficiently store the various container types at inland intermodal terminals and allow for smooth operations.

3. Method

The proposed approach comprises initial data processing, a fast metaheuristic, and detailed simulation.

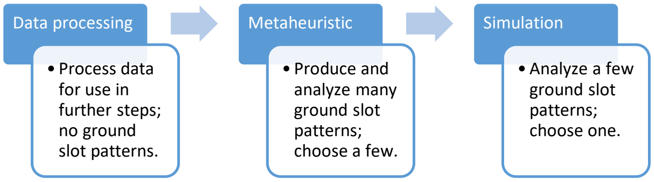


Figure 3. The method in three steps.

In the first step, we remove redundant data points from the needed real-world data from the case study terminal and prepare the format for use in steps 2 and 3.

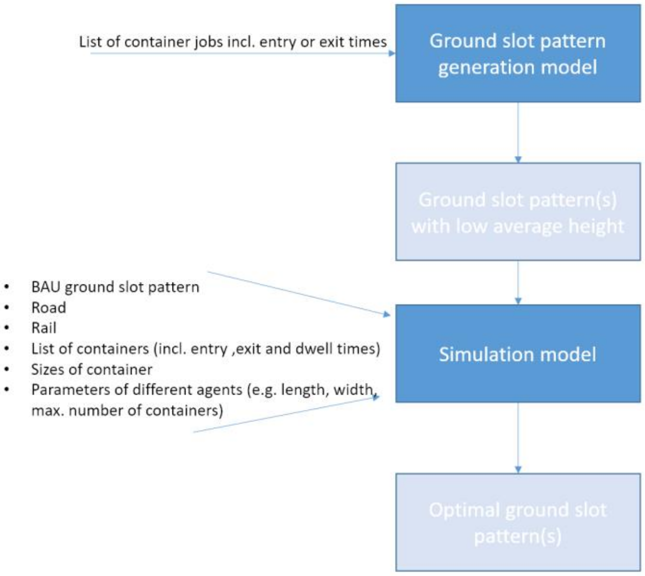


Figure 4. Overview of method and data input

In the second step, we use metaheuristics to generate possible ground slot patterns based on static information (e.g., number of containers per container size and period) and evaluate them using information on container arrival and departure times. Based on this information, ground slot patterns, ensuring enough space for containers, and meeting volume restrictions are created.
In the third step, a detailed hybrid agent-based discrete-event simulation is developed to analyze the

previously created ground slot patterns in more detail under dynamic conditions. Within the simulation model, the focus is broadened from a pure space utilization-based evaluation to include additional effects such as crane movement and maximum container stack height or delayed trains.

3.1. Data processing

The real-world data used is a list of containers entering and leaving the terminal over one year, including such information as size, entry or exit times, and whether or not the container was dropped off/picked up by train or truck. A list, thus, looked like follows:

Table 1. Example of real-world data format.

Container id	Size	Entry Time	Exit Time	In by Train	Out by Train
1	20	Day1 11:00	Day 2 10:00	YES	NO
2	30	Day1 12:00	Day 8 17:00	YES	NO
3	45	Day1 15:00	Day 10 11:00	NO	NO
4	24	Day3 08:00	Day 22 18:00	YES	YES

The real-world data was processed to be used in the following steps in order to get a list of crane jobs sorted by time, which was especially relevant for the initial ground slot pattern generation.

Table 2. Example of real-world adapted data format (Container jobs).

Time	In/ Out	Container id	Size	In by Train	Out by Train
Day1 11:00	In	1	20	YES	NO
Day1 12:00	In	2	30	YES	NO
Day1 15:00	In	3	45	NO	NO
Day 2 10:00	Out	1	20	YES	NO
Day3 08:00	In	4	24	YES	YES
Day 8 17:00	Out	2	30	YES	NO
Day 10 11:00	Out	3	45	NO	NO
Day 22 18:00	Out	4	24	YES	YES

3.2. Initial Pattern Generation

In the following we describe how the ground slot patterns which can be tested using the agent-based simulation are generated.

The patterns were generated and selected using a classical metaheuristic, the Genetic Algorithm. This method builds a first generation from a large number of possible patterns and then combines, modifies, and optimizes them to produce new generations of patterns in each subsequent iteration of the algorithm. Furthermore, the algorithm is not limited regarding the number of slots within a ground slot pattern (e.g., the number is four in the example illustrated in Figure 2). In this work, we use a number of four, but larger sizes are possible using this method.

We defined “good” ground slot patterns as those with low average heights and “bad” solutions as those with high average heights of containers in the terminal. The average height is an important indicator, as it implicitly indicates how much space is “wasted” in between containers. The height is also restricted by the equipment used to handle containers (e.g., overhead cranes). In general, lower average height shows better use of space and promises easier access to containers and, thus, easier handling. We define the average height in terms of the number of used slots divided by the number of all ground slots. For example, if there are five ground slots in two rows (5 x 2 = 10 ground slots) with four tiers, there are 5 x 2 x 4 = 40 slots available. In case 7 of these slots are used, the average height is calculated as 7 / 10 = 0.7. In another example, if all 40 slots are in use, the average height is 40/10 = 4. In this calculation, we do not differentiate between slots that are partly used (e.g., a 45’ slot used by one 30’ container) and those that are fully used (e.g., a 20’ slot used by a 20’ container).

In order to obtain the values of the objective function (i.e., the average height) for each ground slot pattern, a model was developed in Python programming language to simulate the movement of all containers in the terminal in a simplified way over a year. A simple heuristic was developed to decide each container’s location. In contrast to the detailed simulation model described in Section 3.3, this model does not include the capacity and the movement of cranes, including additional crane movement to free containers with other containers stacked above vehicles and trains. Nevertheless, it can accurately calculate the average height of the containers in the terminal.
Depending on the duration of the selected time period, the algorithm needs a few milliseconds to a few seconds to do this.

Finally, the most promising ground slot patterns that showed the best objective function values (i.e., the lowest average height) were forwarded for further detailed analysis in an agent-based discreet event simulation.

3.3. Simulation Analysis & Numerical Experiments

To analyze the ground slot patterns found in the previous step in a dynamic environment, we developed a simulation model.
The agent-based simulation model consists of five agent types: containers, slots, cranes, trucks, and trains. The logic modules of the simulation model consist of numerous elements of the process modeling and some of the material handling library by Anylogic, which can only reach their full potential with additional logic coded in Java. The model is based on 20 parameters and eight datasets.
In the current versions, we simulate 2.600.000 seconds, which is approximately 30 days. We varied the number of inbound and outbound jobs retrieved from real-world data (see Table 2), which occur before the simulation starts, to get a better picture of how different starting conditions affect the results.

To make the model as flexible as possible, roads, rails, and ground slot patterns are computed programmatically using a dataset and parameter input (see Figure 4). Thus, different terminal spaces can easily be integrated into the existing model.

The terminal dimensions, trains, and trucks are generated according to real-world data from our case study terminal. According to this, we assume a length of 600 meters and space for six containers, four rails for trains, and one road for trucks. Vehicles are generated at a specific moment in time by three different sources representing trains, trucks with inbound containers (i.e., at least one container to be dropped off), and trucks without inbound containers. If necessary, vehicles wait until other vehicles leave the terminal to enter. Within the terminal, vehicles wait for one of two overhead cranes to unload inbound containers and load outbound containers. The cranes use a simple heuristic to decide on the next container to move. In contrast to the size, type of vehicle, and arrival time, which are taken from real-world data, the crane movements are decided upon within the simulation.

Another heuristic, based on the heuristic used in the previous step (described in 3.2), determines where containers are stored within the terminal. Similarly, to crane movements, the decision where (i.e., in which slot) a specific container is stored is made within the simulation, as historical real-world data cannot be used because of the new yard layout (ground slot patterns). There are some variations to this heuristic depending on the scenario setting. First, there are three options regarding the stacking of containers: stacking is mandatory whenever possible, only performed if necessary, or in between those extremes. Second, we introduce notional zones affecting the placement of containers. The heuristic always tries to place a container in the emptiest zone first. Thus, the number of zones influences the distribution of containers across the terminal.

As it is possible that there is no space for inbound containers, trucks with containers that cannot find a free slot leave the terminal (e.g., to a parking space or any other destination) and return after a given time. In contrast, trains wait until there is space for all inbound containers. After containers are unloaded and loaded, the vehicles leave the terminal. However, trains wait for their preassigned exit time to conform to timetables.

Within Anylogic, agents can be connected to each other by links. For example, each container can be linked to its inbound and its outbound vehicle (truck/train) and vice versa. Similarly, containers can be connected to their slots when they arrive at the terminal storage. This allows for smooth communication between the agents. In addition, storage slots are connected to their neighbors, e.g., a ground slot is connected to the slot in the next tier, as well as to slots on the left and on the right. This makes it easy to check whether or not a given slot can be used (e.g., if a slot in tier 2 is empty, no container can be placed in tier 3 at this slot).

Within the model, the entry time of vehicles and containers is determined by the input data. However, the dwell time of each container is drawn from a distribution of real-world dwell times. The dwell time is relevant regarding the decision of which vehicle should pick up a specific container. For example, a truck will pick up the container with the highest exit time (sum of enter time and dwell time), which is leaving the terminal by truck.

To evaluate the robustness of the ground slot patterns, they are tested in a number of scenarios.

Table 3 presents an overview of the values that are varied within the experiment.

The ground slot patterns vary regarding the size of the single ground slots within the patterns. Three ground slot patterns are taken from the previous step (3.2), while the business as usual (BAU) ground slot pattern represents the current division of the container yard in our case study terminal. The number of notional zones shows how many parts the storage space is divided into. For the preliminary experiment, we chose one and three to analyze if a division had an effect at all. The number of container jobs before the start indicates how many container jobs (i.e., containers entering or leaving the terminal) have been performed at the model start. For example, at "number of container jobs before start" equals 30, a maximum of 30 containers are in the terminal. However, as it is possible that containers not only entered but also left the terminal, the number could also be lower (see Table 2). To use a random rule, the values chosen are increasing and a multiple of 30 (30, 30*2^3, 30*2^7, 30*2^10).

Table 3. Parameters and their values for the simulation experiment. *Business as Usual

Parameter	Values
Ground slot pattern	1,2,3, BAU*(4)
Number of notional zones	1,3
Number of container jobs before start	30,240,3840,30720

3.4. Case Study

For our analysis, we use real-world data from an Austrian intermodal inland terminal. The terminal is shown in Figure 5 from an aerial view. We consider eight possible container sizes, with the smallest container being a 20-foot container and the largest a 45-foot container. The terminal space has a fixed maximum length of 1968.5 feet (= 600 meters) and space for six rows of containers. Thus, there is space for 236220 (1968.5 x 6 x 4) feet of container. The number of containers leaving and entering the terminal fluctuates on a given operating day. Incoming container numbers are roughly between 10 and 500 containers per day, while outgoing container numbers are roughly 20 to 400 containers per day. On an average day, approximately 170 containers enter and exit the terminal.

Figure 5. Aerial view of the case study terminal

In order to facilitate non-automatic crane handling, the ground slot pattern complexity is kept to a maximum number of four, i.e., a maximum of four different ground slot sizes, which are repeated. We consider four tiers. Thus, each slot can host at least four containers of the same size stacked above each other. However, containers of different sizes cannot be stacked (e.g., a 30-foot container cannot be stacked on top of a 40-foot container).

We consider two rail-mounted gantry cranes as well as one road for trucks and four rail tracks for trains that transport containers. Trucks and trains enter the terminal to deliver and/or pick up containers, which are moved by overhead gantry crane either transferred directly to an onward train or truck by gantry crane or are temporarily stored at the terminal.

4. Preliminary Results & Discussion

In this section, we present preliminary results from the initial layout generation and the experiments with a number of scenarios of the simulation analysis presented in Table 4. Each scenario is replicated three times; thus, results are preliminary.

Three ground slot patterns from the generation phase were forwarded to the simulation analysis.
These are:

- Ground slot pattern 1: 20’-21’-50’-20’
- Ground slot pattern 2: 23’-20’-46’-20’
- Ground slot pattern 3: 52’-20’-21’-21’

In addition, the business-as-usual (BAU) layout (Ground slot pattern 4) was analyzed.

In our preliminary analysis, we focused on three output values: the average height, i.e., the number of full slots divided by the number of all ground slots (see Section 3.2 for further explanation), the average number of containers in the terminal, and the rate of space used, i.e., the percentage of the total 236220 feet available that is used by containers.

Figure 6 shows how the different scenarios perform regarding the average height. It is apparent that the BAU ground slot pattern 4 performs the worst with regard to average height (i.e., pattern 4 shows high average heights in all scenarios). This may be explained by the pattern generation itself, as new ground slot patterns were scored on their average height in step 2 (Section 3.2). Patterns 1,2 and 3 also perform better in this aspect in the dynamic simulation, regardless of other values.

Table 4. Simulation scenarios.

Scenario	Number of zones	Number of container jobs	Ground slot pattern
1	1	30	1
2	1	30	2
3	1	30	3
4	1	30	4
5	1	240	1
6	1	240	2
7	1	240	3
8	1	240	4
9	1	3840	1
10	1	3840	2
11	1	3840	3
12	1	3840	4
13	1	30720	1
14	1	30720	2
15	1	30720	3
16	1	30720	4
17	2	30	1
18	2	30	2
19	2	30	3
20	2	30	4
21	2	240	1
22	2	240	2
23	2	240	3
24	2	240	4
25	2	3840	1
26	2	3840	2
27	2	3840	3
28	2	3840	4
29	2	30720	1
30	2	30720	2
31	2	30720	3
32	2	30720	4

For example, scenarios 9 – 11, as presented in Figure 4, show average heights of 0.9 to 1, while scenario 12 shows an average height of over 1.7. We find the lowest average height in scenario 17 (0.27, pattern 1) and the highest in scenario 32 (1.91, pattern 4). In six out of eight scenarios, pattern 4 shows an average height of 1 and over, while patterns 1 and 2 show a height of 1 and over in total three, respectively, two times (pattern 1 in scenarios 13, 25, and 29, Pattern 2: Scenarios 14 and 30). Pattern 3 never reaches an average height of 1. The largest decrease of 0.96 from the BAU pattern to a new pattern can be found for pattern 3 in scenario 31 (average height: 0.95) compared to the BAU scenario 32 (average height: 1.91).

Figure 6. Average height

Figures 7 and 8 show how many containers were, on average, in the terminal (Figure 8) and how much space these containers used (Figure 7). We find that both values are influenced by the number of jobs before the simulation and less by the patterns. We can assume that there were generally more containers in the terminal to start with, with higher numbers of jobs.

The number of containers in scenarios 1 – 8 and 17 – 24, where the maximum number of containers before start is 240, stays between 300 and 400. All other scenarios (9 – 16 and 25 – 32) show an average number of containers between 500 and 750. In these scenarios, the number of container jobs is either 3840 or 30720.

The largest difference between the BAU pattern and other patterns regarding the average space used can be found in scenario 29 and 30, both scenarios show a decrease of roughly 13 % in average used space compared to the BAU scenario 32.

The number of notional zones – which regulates the distribution of containers in the terminal – does not seem to have an effect, while ground slot patterns do not strongly influence the number of containers at the terminal. For scenarios that differ only in the number of zones, we find that in some cases, the scenario with two zones performs better in all aspects, e.g., scenarios 1 and 17, while in others, the scenario with one zone performs better, e.g., scenarios 8 and 24.

Ground slot patterns 3 and 4 have a higher space use, especially when the number of container jobs is high. A possible explanation for this is that those ground slot patterns allow for (more) larger containers in the terminal.

Figure 7. Average space used

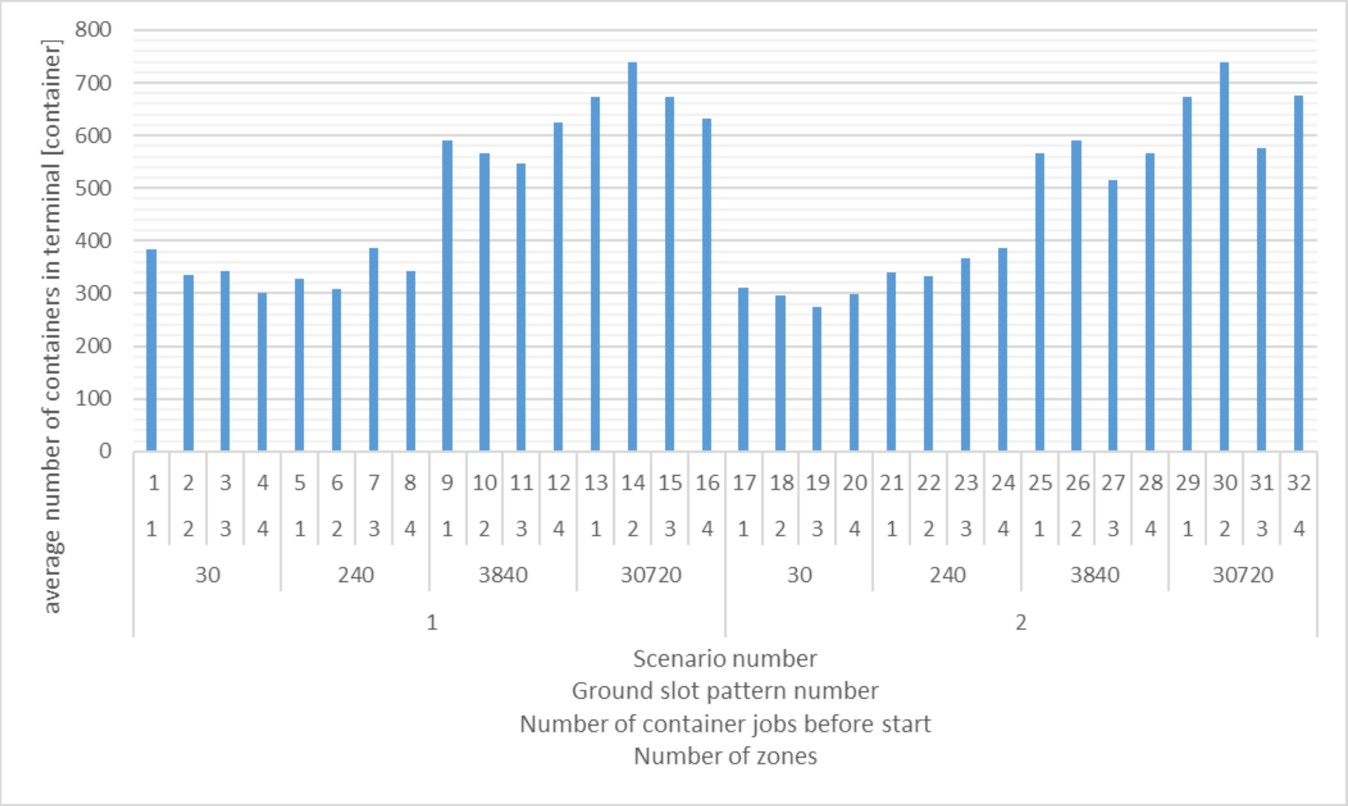


Figure 8. Average number of containers in the terminal

5. Conclusion & Outlook

We find that the generated ground slot patterns perform better in some aspects compared to the BAU ground slot pattern, while all provide lower average heights. However, especially ground slot pattern 3 performs similarly to the BAU pattern in most other aspects. To decide on an optimal ground slot pattern, more tests and scenarios are necessary.

In further work, we want to:

- Analyze more values (e.g., crane utilization, average waiting time for trucks, etc.).
- Analyze if we can determine further "good" ground slot patterns using the metaheuristic with adapted input data and include these ground slot patterns in our analysis.
- Analyze all (three) ground slot patterns found by the metaheuristic in detail with different scenarios and additional replications.
- Test how the results change with different heuristics for determining a space/slot for containers within the terminal.
- Increase the time simulated from one month to six months and beyond.
- Vary the input regarding train and truck arrivals, including the mix of container types and the number of inbound and outbound containers.

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References

Ambrosino, D. and Xie, H. Optimization approaches for defining storage strategies in maritime container terminals. Soft Comput 27, 4125–4137 (2023). https://doi.org/10.1007/s00500-022-06769-7

Boysen, N., Fliedner, M., Jaehn, F., and Pesch, E. (2013). A survey on container processing in railway yards. *Transportation Science*, 47(3), 312-329.

Cimili P., Voegl J., Hirsch P., and Gronalt M. (2022).,Automated damage detection of trailers at intermodal terminals using deep learning. Proceedings of the 24th International Conference on Harbor, Maritime and Multimodal Logistic Modeling & Simulation(HMS 2022). , 003 . DOI: https://doi.org/10.46354/i3m.2022.hms.003

Gupta, A., Roy, D., de Koster, R., and Parhi, S. (2017). Optimal stack layout in a sea container terminal with automated lifting vehicles. *International Journal of Production Research*, *55*(13), 3747–3765. https://doi.org/10.1080/00207543.2016.1273561

Kim, K. H., Park, Y. M., & Jin, M. J. (2008). An optimal layout of container yards. *OR Spectrum*, 30, 675-695.

Kim, T., & Ryu, K. R. (2022). Deriving Situation-Adaptive Policy for Container Stacking in an Automated Container Terminal. *Applied Sciences*, 12(8), 3892.

Lee, B.K. and Kim, K.H. Optimizing the yard layout in container terminals. *OR Spectrum* **35**, 363–398 (2013). https://doi.org/10.1007/s00291-012-0298-z

Posset, M., Gronalt, M., Peherstorfer, H., Schultze, R. C., and Starkl, F. (2020). *Intermodal Transport Europe*. Universität f. Bodenkultur Wien

Zhou, C., Wang, W., and Li, H. (2020). Container reshuffling considered space allocation problem in container terminals. *Transportation Research Part E: Logistics and Transportation Review*, *136*, 101869.