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METHOD FOR DESIGNING MACRO AND MICRO LAYOUTS FOR STORAGE AND TEMPORARY FACILITIES IN RESIDENTIAL PROJECTS BASED ON TAKT PLANNING

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ABSTRACT

Logistics is considered a key element for the successful adoption of takt planning. However, there are few practical studies that demonstrate how the issue of material storage should be approached. This topic becomes more relevant when considering that takt planning, as well as other lean-based methodologies, has a greater focus on reducing inventories. Therefore, this paper presents a method for designing macro and micro storage layouts in residential construction projects to support takt planning implementation. Using the design science research methodology, the study relies on the application of two-dimensional and three-dimensional cells to represent storage areas, supported by estimated data from a case study and secondary data of similar projects. The primary goal of the method is to optimize space usage in alignment with takt demands, thereby reducing waste and promoting production efficiency. The results highlight the method's accuracy in determining the occupancy rates of different storage areas for the various materials required to meet the project's takt demand. As recommendations for future research, the study emphasizes the integration of digital tools, such as BIM, to facilitate spatial visualization and the exploration of generic algorithms for layout optimization.

KEYWORDS

Takt Planning, WorkFlow, Construction logistics, Residential Projects.

INTRODUCTION

Logistic planning is crucial for Takt planning, as inadequate equipment sizing, storage space, or movement planning can create bottlenecks and disrupt the takt plan (Lehtovaara et al., 2020; Reck & Fireman, 2023; Tommelein & Emdanat, 2022; Vatne & Drevland, 2016). The immediate impact is the disruption of activity flow, as continuous work depends on the precise delivery of materials at the right time and place (Tetik et al., 2021; Heinonen & Seppänen, 2016). The absence of materials when needed causes delays that not only affect the directly involved task but can also trigger a cascading effect throughout the subsequent production wagons, jeopardizing overall planning and increasing external variation (Lehtovaara et al., 2019). Additionally, workers often spend time retrieving materials or creating supply solutions

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on-site, deviating from planned tasks and reducing productivity (Seppänen & Görsch, 2022). These effects counteract Lean-based systems by increasing waste and inefficiency.

Examples highlighted in the literature emphasize the impact of such interruptions. In the case study presented by Tetik et al. (2021), delays in door deliveries directly impacted the completion of work packages, generating rework and additional costs. Moreover, large materials such as gypsum panels and shower cabins, when not properly coordinated, required manual handling and caused site congestion (Tetik et al., 2021). The lack of planning and communication between management teams and suppliers was also identified as a recurrent cause of interruptions, aggravating logistical issues and process variability (Riekki et al., 2023).

Another significant aspect of logistics and takt planning is that the lean vision of reducing inventories becomes increasingly challenging for construction companies, whether due to the complexity of projects, the reduction in the size of sites available for construction or interruptions in the supply chain. Recent supply chain studies show that companies across different sectors experience severe supply chain disruptions approximately every 3.7 years (Mckinsey, 2020). One strategy to address this issue is the appropriate application of material buffers, either on-site (Riley & Sanvido, 1997) or in distribution centers (Elfving et al., 2010; Tetik et al., 2019).

Centralizing material processing in off-site distribution centers, as highlighted by Tetik et al. (2021) and Elfving et al., (2010), enables preprocessing and kit creation, reducing on-site movements. Also, Heinonen & Seppänen (2016) integrate this centralized solution with small-batch deliveries directly to workstations. These approaches reduce unnecessary movements on-site and facilitate just-in-time delivery, ensuring materials are delivered precisely when and where they are needed.

When using distributed on-site storage, it is essential to carefully plan delivery and preparation areas, along with the positioning of materials near workstations, to ensure efficient access and reduce transportation waste. Heinonen & Seppänen (2016) pointed out that buffers on-site should be sized to avoid congestion, while Lehtovaara et al. (2019) emphasize the need to consider backlog areas for materials that cannot be immediately moved to work locations. Riekki et al. (2023) underline that achieving synchronized flows using digital tools, such as 4D BIM models, to integrate real-time information and synchronize manufacturing, transportation, and assembly, should be a key objective to site layout design.

Currently, there is a noticeable reduction in available on-site storage space in residential construction projects, which has led to the need for either off-site storage centers or methods to optimize on-site space utilization. In this context, some studies have proposed methods for storage area planning and dimensioning (Li et al., 2019; Sanad et al., 2008; Tommelein, 1994). Tommelein (1994) focuses on optimizing material handling through visual planning of the site layout and real-time control of material locations. However, the emphasis is more on handling logistics than on space dimensioning and optimization itself. Sanad et al. (2008), in turn, presents an optimization algorithm for space planning and specifics the parameters required for spatial representation of the construction site. More recently, Li et al. (2019) advanced this field by integrating BIM and image-based technologies to recognize unoccupied areas on-site in real time. Nevertheless, these previous studies do not provide a method for designing storage areas explicitly aligned with a project's takt requirements. Yet, Reck and Fireman (2023) presents a logistic framework to enable takt planning, this framework was composed by four drivers: equipment sizing; layout; material management; routes and routines. Although the study effectively demonstrates the practical role of logistics in supporting takt planning, it lacks an explicit description of the storage area design process. Therefore, this study aims to improve the framework proposed by Reck and Fireman (2023), creating inside the layout driver a method for designing macro and micro layouts for material storage and temporary installations.

UNDERLYING CRITERIA FOR THE DESIGN OF STORAGE AREAS

According to the literature, storage can be approached through various strategies, as shown in Table 1. These characteristics are based on factors such as the nature of materials, their frequency of use, storage location, and logistical demands. Therefore, the choice of storage design criteria must encompass multiple factors and also account for the potential side effects that each strategy may entail (Fireman et al., 2022), as there is no one-size-fits-all solution for any type of construction projects. For instance, in projects without space constraints for on-site storage, bulk storage may be considered ideal for smaller components with frequent demand, which need to be stored in centrally located, easily accessible areas (Riley & Sanvido, 1997). However, this storage strategy may require more movement and transportation compared to pre-kitted materials, potentially increasing inefficiencies in material handling.

Table 1: characteristics of storage types

Storage Type	Description	References
Bulk Storage	Smaller components stored centrally for quick access.	(Riley & Sanvido, 1997)
Distributed Storage	Large materials delivered directly to points of use to minimize movement.	(Riley & Sanvido, 1997), (Heinonen & Seppänen, 2016)
Remote Storage	Materials stored off-site, transported as needed to support activities.	(Riley & Sanvido, 1997), (Heinonen & Seppänen, 2016), (Tetik et al., 2021)
Proximity Storage	Critical materials positioned close to work areas to optimize productivity.	(Riley & Sanvido, 1997), (Seppänen & Görsch, 2022)
Modular or Kit Storage	Materials organized into kits, eliminating the need for individual item inventories.	(Heinonen & Seppänen, 2016), (Tetik et al., 2021)
Centralized Storage	High-value materials stored in secure locations, transported as required.	(Riley & Sanvido, 1997), (Tetik et al., 2021)

The takt planning literature highlights key factors that influence the design and sizing of material flows to reduce transportation waste, as shown in Table 2. These include material type, demand patterns, storage organization, flow coordination, and waste logistics. Together, they support an efficient material flow aligned with takt planning goals.

A common theme among takt planning studies involving logistics is the premise that using small sets of materials enables a continuous flow of materials, reduces transportation waste, and facilitates an improved layout (Lehtovaara et al., 2019; Tetik et al., 2021; Riekki et al., 2023). This aligns with the practical approach of reducing batch sizes to shorten production lead time, as discussed by Koskela (2000). In this paper, we argue that the same premise can support both macro- and micro-level site dimensioning — not to implement zero-inventory continuous flow, but to clearly define stock levels with buffers sized for demand fluctuations, improving alignment with takt planning.

A limitation of these studies is that, while they serve as a starting point, they do not specify the steps for determining storage area dimensions. However, the work of Sanad et al. (2008) can be considered a valuable starting point, as it presents an optimization model based on genetic algorithms to design construction site layouts using a two-dimensional grid. The grid model is set by user-defined area cells. Then, the number of cells occupied by a facility is the fraction between the facility area (m²) by the area of each cell (m²). This method allows for the accurate representation of both temporary and permanent facilities in the layout. The method also specifies the type of facility, distinguishing between fixed and non-fixed installations, and incorporates proximity weights assigned manually based on the frequency and importance of interactions between different areas. This model proves to be flexible in defining and analyzing scenarios and will serve as the foundation for this study.

Table 2: aspects for designing logistics layout

Aspect	Description
Nature and type of materials involved	Small materials stored in on-site “supermarkets” (Riekki et al., 2023). Large materials delivered directly to points of use at takt time (Riekki et al., 2023).
Material demand by wagons or activities	Spaces must align with the takt schedule, predicting demands for activities and work packages (Tetik et al., 2021). Material quantities must be accurately calculated for each work package (Riekki et al., 2023).
Maintenance and Organization	Areas should have sufficient space for receiving, organizing, and quickly distributing materials and kits (Tetik et al., 2021). 5S principles should be applied for organization and retrieval (Seppänen & Görsch, 2022).
Visualization and Coordination of material flows	Visual tools should be used to monitor availability and identify bottlenecks (Lehtovaara et al., 2019).
Synchronization of waste logistics routines	Storage design must include space for waste collection and synchronized routes for removal (Heinonen & Seppänen, 2016).

RESEARCH METHOD

The research is positioned as Design Science Research (DSR), aimed at developing an innovative method to dimension storage areas using a two-dimensional and three-dimensional grid to meet the takt of construction projects. This approach solves practical problems encountered in real-world scenarios while contributing to theoretical advancements (Lukka, 2003). The proposed artifact in this study is a method for designing the layout to support takt time planning and will be integrated to the framework presented by Reck and Fireman (2023).

The research was conducted during a case study of a residential project with two towers, each containing 17 floors and 8 apartments per floor, totaling 264 units. The construction company is a medium sized company in Brazil that at the time had 15 constructions sites at the same time. The construction company began its journey in lean construction three years ago and now demonstrates mature Last Planner System (LPS) practices while adopting takt planning in its projects. The authors of this paper acted during the case study as a consultant with the responsibility of implementing materials management strategies aligned with the takt planning. The study occurred over two non-consecutive weeks, and involved key stakeholders, including project engineers, site managers, warehouse supervisors, and the project sponsor.

Figure 1 shows the research design across the DSR phases. The process begins by analysing the company’s logistics challenges, especially in material sizing and management. Then, available site areas are mapped to identify possible storage locations. Based on this, required storage areas are defined to meet takt production needs. Layout simulations are performed to test and optimize configurations. The artifact was developed in two cycles: the first focused on macro layout (site and surroundings), and the second on micro layout (small material storage). Finally, the study evaluates its theoretical and practical contributions by assessing the number of layout scenarios for usability and comparing planned versus actual on-site implementation to measure utility.

The definition of the takt time is an input information for the method proposed in this paper. The case study presents layout simulations for 12 takt times, the scenario of greatest interest to the company and the worst case for material demand. This was based on stock level calculations, which considered an average of 4 takt times from on-site request to order placement, and a delivery lead time ranging from 1 to 8 takt times. Therefore, material takt demand was simulated according to the strategies defined by the construction company.

Evidence sources included participant observation, consultancy reports, result indicators, and data from kit-based kanban implementations in two other sites.

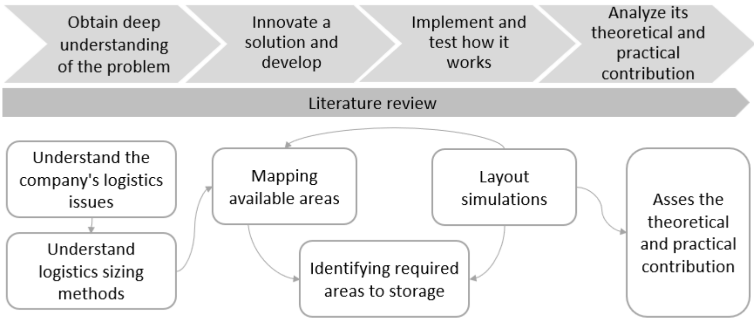


Figure 1: research design

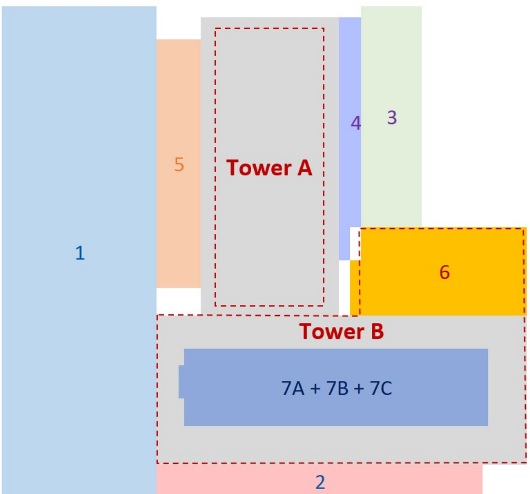
CASE STUDY

MACRO LAYOUT

In the macro layout, large materials are stored in a distributed manner and according to the execution sequence.

Mapping available areas

The first step of the method involves identify and quantify the available areas on-site (Figure 2). Zones 1 and 2 are outside the construction site and require lease agreements with neighboring properties. Zone 3 must be handed over to the municipality as a compensatory measure. Zones 4 and 5 are internal and available from the start but needed for infrastructure at the project's end. Zone 6 is open-air and usable only after two slabs are completed. Zones 7A, 7B, and 7C are underground levels, available after slab completion, but with height restrictions. This gathering followed the method proposed by Sanad et al. (2008), in which the nine different areas were quantified using a two-dimensional grid (cell). The cell used in this study for the macro layout corresponds to the area of a pallet, measuring 1.2 m². As a result, a total of 6,639 cells are available for storage and temporary installations on-site, on 9 areas available.



(a) available areas layout

	High (m)	Area (m2)	Number of Cells
1	Free	2.968,00	2493
2	Free	421,26	354
3	Free	539,00	440
4	Free	197,56	164
5	Free	432,00	360
6	Free	600,00	500
7A	2,92	931,09	776
7B	3,15	931,09	776
7C	3,15	931,09	776
	Total	7.951,08	6.639

(b) available areas description/caption

Figure 2: available areas on-site

Identifying required area to storage

The takt planning adopted in the case study defined the takt area as 8 apartments, with a takt time of one week. To support this, the company evaluated four storage strategies based on the number of takt cycles covered: (i) 12, (ii) 8, (iii) 4, and (iv) 1 takt time. Based on this analysis, the next step was to define the necessary storage and support areas, considering both the takt time and the chosen strategy to ensure efficient material flow. To determining the required storage and support areas, the material volume per takt wagon was analysed using a two-dimensional grid. Figure 3 presents these volumes for each takt wagon under the four storage strategies.

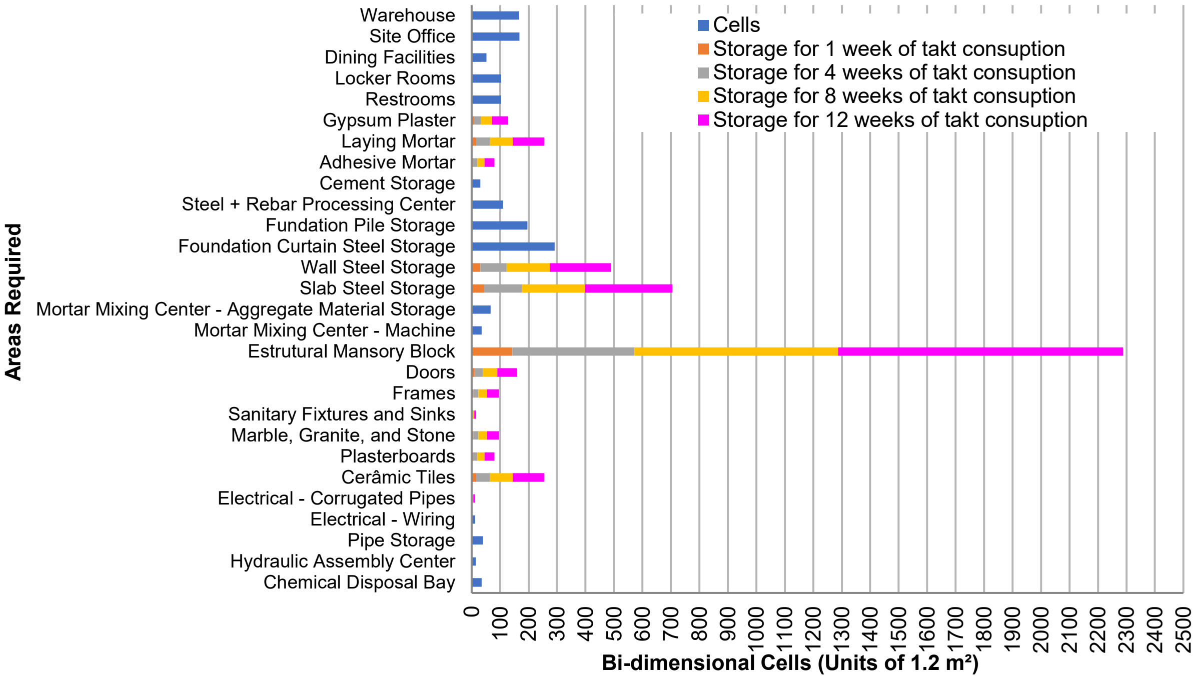
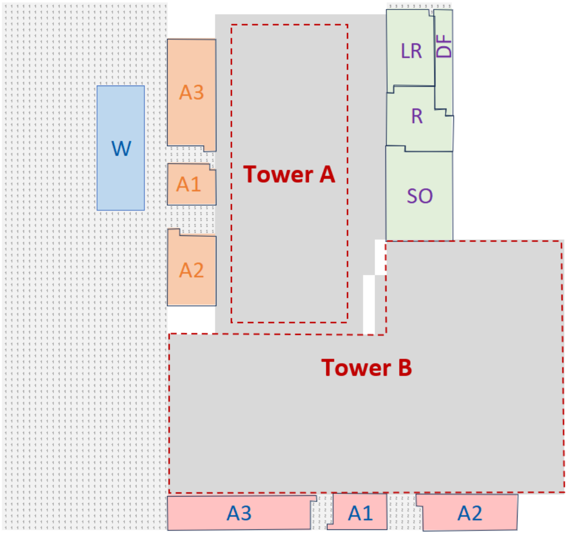


Figure 3: areas required for temporary installations

Figure 3 also presents the demand for areas supporting execution. For the warehouse, two tents measuring 10 x 10 meters were considered, based on data provided by the construction company. The areas allocated for cement storage, rebar processing, plaster mixing, wiring, electrical tubing, chemical bays, and pre-assembly of hydraulic installations were sized using references from the similar projects. The storage of structural masonry blocks accounts for 38% of the total required area. This high demand is due to the material's bulkiness, the need for on-site stockpiling to ensure a continuous supply for sequential construction activities. Finally, the areas for engineering offices, dining facilities, locker rooms, and restrooms were dimensioned in compliance with Brazilian NR-18 regulations, accounting for a workforce peak of 160 to 170 workers on-site.

Simulating Layout

The third step of the method involves simulating the available areas based on the required areas determined by the takt demand. Figure 4 presents the analysis of the occupancy of available areas during the foundation stage. The required areas during this period include the warehouse, site office, dining facilities, locker rooms, restrooms, and steel storage and rebar processing centers. These were distributed among the available areas, simulating 50% of the steel stock in Area 2, closer to Tower 2, and Area 5, closer to Tower 1. The occupancy rate, calculated as the ratio of required to available areas, showed higher values in Area 2 (85%), Area 3 (97%), and Area 5 (83%), while Area 1 had a low occupancy rate (7%). A total of four simulations were conducted, all based on a 12-takt time scenario. These simulations encompassed the foundation phase (Figure 4), the reinforced concrete structure phase of Tower B, the structural masonry phase, and the façade and interior finishing phases of both towers.



(a) simulation layout

Foundation stage		Available areas 1	2	3	5		
required areas	Warehouse	167				W	
	Site Office			168		SO	
	Dining Facilities			52		DF	
	Locker Rooms			104		LR	
	Restrooms			104		R	
	Steel + Rebar Processing Center		55		55	A1	A1
	Fundation Pile Storage		98		98	A2	A2
	Foundation Curtain Steel Storage		146		146	A3	A3
(a)	Total required cells	167	299	429	299		
(b)	Total available areas	2493	354	440	360		
	Occupancy rate (a / b)	7%	85%	97%	83%		

(b) occupancy rate

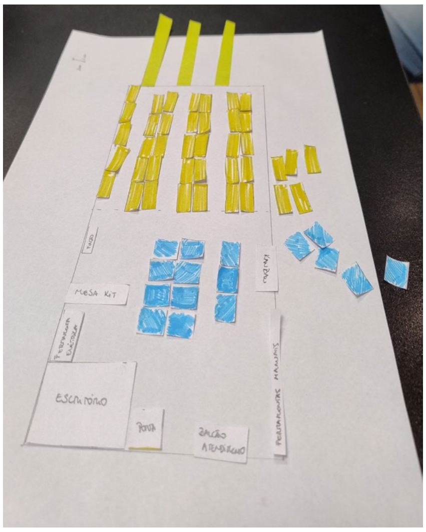
Figure 4: allocation of required cells vs. available cells in the construction site

MICRO LAYOUT

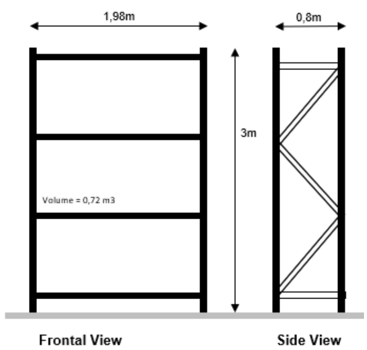
In the micro layout, small materials were stored in a centralized installation at the warehouse. This warehouse was allocated to Area 1, outside the construction site and near tower A.

Mapping available areas

However, it is necessary to define the available areas for the supermarket structure within the warehouse — i.e., the space where small materials are arranged on shelves before the kitting process. The first step was to identify the location where the mini pallet racks would be placed within the warehouse (Figure 5a). Subsequently, it was necessary to adapt the method proposed by Sanad et al. (2008) to a three-dimensional grid (Figure 5b). The three-dimensional grid represents the volume of a single shelf within a mini pallet rack, which is 0.72 m³. The storage system consists of 35 shelves with four levels, resulting in 140 storage cells (Figure 5c).



(a) simulation of the requires areas



(b) spatial dimension of shelves in the mini pallet rack

Column (180 cm) — Lines (80 cm)

P11 - N4	P12 - N4	P13 - N4	P14 - N4	P15 - N4
P11 - N3	P12 - N3	P13 - N3	P14 - N3	P15 - N3
P11 - N2	P12 - N2	P13 - N2	P14 - N2	P15 - N2
P11 - N1	P12 - N1	P13 - N1	P14 - N1	P15 - N1
P21 - N4	P22 - N4	P23 - N4	P24 - N4	P25 - N4
P21 - N3	P22 - N3	P23 - N3	P24 - N3	P25 - N3
P21 - N2	P22 - N2	P23 - N2	P24 - N2	P25 - N2
P21 - N1	P22 - N1	P23 - N1	P24 - N1	P25 - N1
P31 - N4	P32 - N4	P33 - N4	P34 - N4	P35 - N4
P31 - N3	P32 - N3	P33 - N3	P34 - N3	P35 - N3
P31 - N2	P32 - N2	P33 - N2	P34 - N2	P35 - N2
P31 - N1	P32 - N1	P33 - N1	P34 - N1	P35 - N1
P41 - N4	P42 - N4	P43 - N4	P44 - N4	P45 - N4
P41 - N3	P42 - N3	P43 - N3	P44 - N3	P45 - N3
P41 - N2	P42 - N2	P43 - N2	P44 - N2	P45 - N2
P41 - N1	P42 - N1	P43 - N1	P44 - N1	P45 - N1
P51 - N4	P52 - N4	P53 - N4	P54 - N4	P55 - N4
P51 - N3	P52 - N3	P53 - N3	P54 - N3	P55 - N3
P51 - N2	P52 - N2	P53 - N2	P54 - N2	P55 - N2
P51 - N1	P52 - N1	P53 - N1	P54 - N1	P55 - N1
P61 - N4	P62 - N4	P63 - N4	P64 - N4	P65 - N4
P61 - N3	P62 - N3	P63 - N3	P64 - N3	P65 - N3
P61 - N2	P62 - N2	P63 - N2	P64 - N2	P65 - N2
P61 - N1	P62 - N1	P63 - N1	P64 - N1	P65 - N1
P71 - N4	P72 - N4	P73 - N4	P74 - N4	P75 - N4
P71 - N3	P72 - N3	P73 - N3	P74 - N3	P75 - N3
P71 - N2	P72 - N2	P73 - N2	P74 - N2	P75 - N2
P71 - N1	P72 - N1	P73 - N1	P74 - N1	P75 - N1

(c) available cells on shelves

Figure 5: available three-dimensional shelves for material supermarket

Identifying required area to storage

The second step was measuring the required volumes off the materials. This data was derived from secondary sources, specifically through the quantification of kits from two similar projects by the same construction company. Warehouse supervisors from these two projects measured the typical size of each material included in the kits on-site, and this information was used to populate the simulation spreadsheet. Figure 6 illustrates the number of cells required to store materials for one takt time, totaling 6.11 cells. The construction company only considered the storage strategy of 12 takt times for supermarket material. This material storage strategy was aligned with the lead time of the supply management system in place.

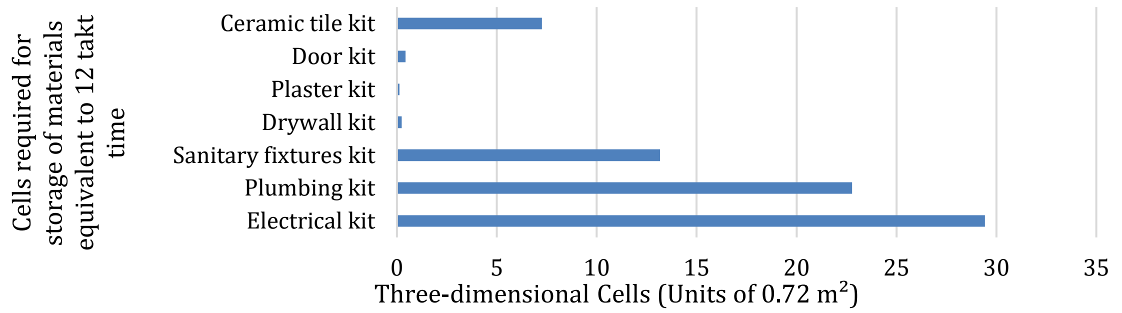


Figure 6: three-dimensional cells necessary

Simulating Layout

The third step of the method in the micro layout involves simulating the allocation of required cells within the available ones, as shown in Figure 7. A total of 78 cells are needed to accommodate 12 weeks of takt consumption. These cells were distributed by kit type as closely as possible, resulting in the final layout illustrated in Figure 7a, with a final occupancy rate of 55.7%. A total of four simulations were conducted, all based on the use of all dimensioned material kits on-site. The simulations varied according to the takt time: 12 takt times (Figure 7), 8 takt times, 4 takt times, and 1 takt time.

Column (180 cm)

Lines (80 cm)

P11 - N4	ELEK	P12 - N4	ELEK	P13 - N4	ELEK	P14 - N4	ELEK	P15 - N4	ELEK
P11 - N3	ELEK	P12 - N3	ELEK	P13 - N3	ELEK	P14 - N3	ELEK	P15 - N3	ELEK
P11 - N2	ELEK	P12 - N2	ELEK	P13 - N2	ELEK	P14 - N2	ELEK	P15 - N2	ELEK
P11 - N1	ELEK	P12 - N1	ELEK	P13 - N1	ELEK	P14 - N1	ELEK	P15 - N1	ELEK
P21 - N4		P22 - N4		P23 - N4		P24 - N4	ELEK	P25 - N4	ELEK
P21 - N3	PLUK	P22 - N3		P23 - N3		P24 - N3	ELEK	P25 - N3	ELEK
P21 - N2	PLUK	P22 - N2		P23 - N2	ELEK	P24 - N2	ELEK	P25 - N2	ELEK
P21 - N1	PLUK	P22 - N1		P23 - N1	ELEK	P24 - N1	ELEK	P25 - N1	ELEK
P31 - N4	PLUK	P32 - N4	PLUK	P33 - N4	PLUK	P34 - N4	PLUK	P35 - N4	PLUK
P31 - N3	PLUK	P32 - N3	PLUK	P33 - N3	PLUK	P34 - N3	PLUK	P35 - N3	PLUK
P31 - N2	PLUK	P32 - N2	PLUK	P33 - N2	PLUK	P34 - N2	PLUK	P35 - N2	PLUK
P31 - N1	PLUK	P32 - N1	PLUK	P33 - N1	PLUK	P34 - N1	PLUK	P35 - N1	PLUK
P41 - N4	SANK	P42 - N4	SANK	P43 - N4	SANK	P44 - N4		P45 - N4	
P41 - N3	SANK	P42 - N3	SANK	P43 - N3	SANK	P44 - N3		P45 - N3	
P41 - N2	SANK	P42 - N2	SANK	P43 - N2	SANK	P44 - N2	SANK	P45 - N2	
P41 - N1	SANK	P42 - N1	SANK	P43 - N1	SANK	P44 - N1	SANK	P45 - N1	DRYK
P51 - N4	CERK	P52 - N4	CERK	P53 - N4		P54 - N4		P55 - N4	
P51 - N3	CERK	P52 - N3	CERK	P53 - N3		P54 - N3		P55 - N3	
P51 - N2	CERK	P52 - N2	CERK	P53 - N2		P54 - N2		P55 - N2	
P51 - N1	CERK	P52 - N1	CERK	P53 - N1	DOOK	P54 - N1	PLAK	P55 - N1	
P61 - N4		P62 - N4		P63 - N4		P64 - N4		P65 - N4	
P61 - N3		P62 - N3		P63 - N3		P64 - N3		P65 - N3	
P61 - N2		P62 - N2		P63 - N2		P64 - N2		P65 - N2	
P61 - N1		P62 - N1		P63 - N1		P64 - N1		P65 - N1	
P71 - N4		P72 - N4		P73 - N4		P74 - N4		P75 - N4	
P71 - N3		P72 - N3		P73 - N3		P74 - N3		P75 - N3	
P71 - N2		P72 - N2		P73 - N2		P74 - N2		P75 - N2	
P71 - N1		P72 - N1		P73 - N1		P74 - N1		P75 - N1	

(a) simulation layout

	Kit types	Cells required for 12 takt times
ELEK	Electrical kit	30
PLUK	Plumbing kit	23
SANK	Sanitary fixtures kit	14
DRYK	Drywall kit	1
PLAK	Plaster kit	1
DOOK	Door kit	1
CERK	Ceramic tile kit	8
(a)	Total required cells	78
(b)	Total available cells	140
	Occupancy rate (a / b)	55,7%

(b) occupancy rate

Figure 7: allocation of required cells vs. available cells in the warehouse supermarket

PROPOSED METHOD

This paper presents an approach by introducing the concept of logistical representation based on two-dimensional and three-dimensional cells for planning layouts and material storage. Figure 8 outline the sequential steps, input, output and necessary resources in a IDEF representation.

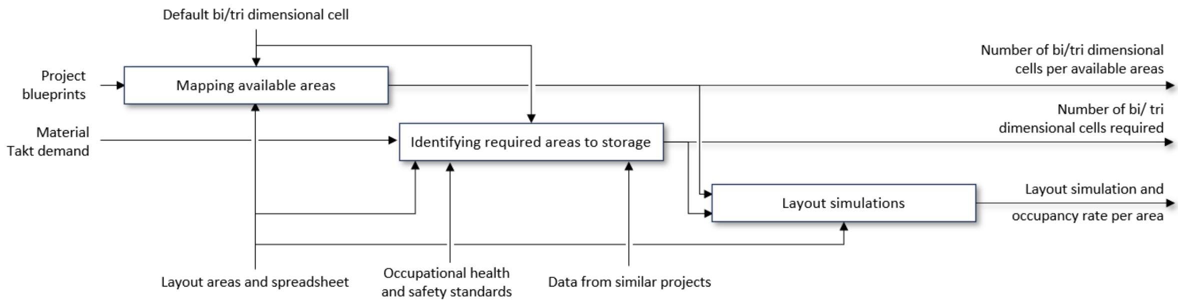


Figure 8: proposed method

The takt demand serves as a critical input, guiding the entire process by defining the required pace and volume of materials necessary for uninterrupted workflows. The sequential steps are described below:

a) **Mapping Available Areas**: The process starts by mapping on-site storage spaces using project blueprints and applying bi- or tri-dimensional cells. Required resources include layout drawings and a spreadsheet to formalize the grid. This step defines the number of cells per area, establishing the baseline for analysis.
b) **Identifying Required Areas for Storage**: Takt demand determines material volume per cycle, guiding storage needs. Layouts and spreadsheets support this step, along with safety standards and data from similar projects. The result is an estimate of required bi/tri-dimensional cells.
c) **Layout Simulations**: Based on available and required cells, simulations allocate storage efficiently. They assess layout performance and occupancy rates, ensuring alignment with takt-based workflows.

Thus, Figure 9 illustrates the correlation between the method proposed in this article and the framework by Reck and Fireman (2023), in which layout design practices, including macro and micro layouts, are integrated into the layout driver.

Figure 9: macro and micro layout practices at Reck and Fireman (2023) logistic framework

ARTIFACT ASSESSMENT AND DISCUSSION

With the application of the method, it was possible to simulate four scenarios for the macro layout and four scenarios for the micro layout, each level of simulation modifying different parameters. In the macro layout, which involved a larger volume of stored materials, the construction company aimed to understand the maximum site occupancy across different project phases. In contrast, the micro layout focused on simulating different stock levels based on the lead times of various suppliers. Therefore, the method proves usefully in simulating both inventory levels and material flow throughout different stages of the project, always aligned with the strategy defined by the planning team.

Figure 10 illustrates the current stage of the project regarding the macro layout. Foundation work is underway on both towers. According to the original plan, the following arrangements were in place: (i) Zone 3 is allocated for the site office, dining facilities, locker rooms, and restrooms; (ii) Zone 5 is used for storing steel and blocks; (iii) Zone 2 also stores steel; (iv) Zones 4, 6, 7A, 7B, and 7C remain unoccupied; and (v) Zone 1 is designated with the warehouse. However, deviations from the plan include the storage of steel and blocks in Zone 1. Within the warehouse, the mini pallet racks have been assembled and are currently in use. These observations demonstrate that the proposed method is effectively useful for dimensioning both macro and micro layouts, even when implementation deviates slightly from the initial plan.

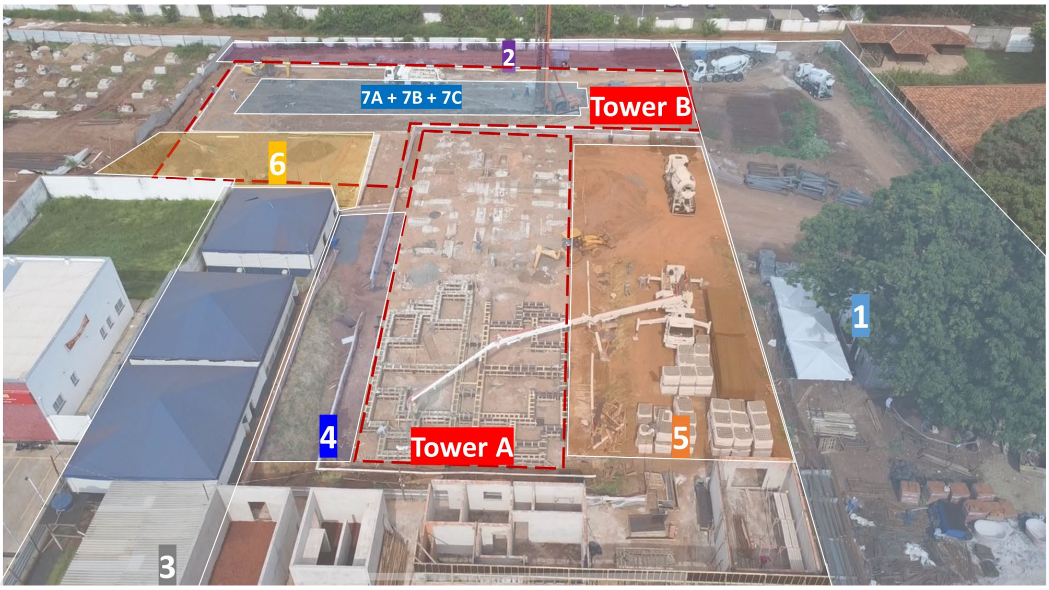


Figure 10: macro layout utility assessment

The proposed method optimizes storage areas by incorporating takt planning demand, aligning on-site storage with the production rhythm and improving coordination with the external supply chain. The cell-based clustering approach enables structured and space-efficient planning. By reducing storage batch sizes, inventory levels can be synchronized with production needs and better controlled through purchase triggers based on actual consumption — reflected in the reduction of active storage cells on-site. Although batch size reduction and supply synchronization were not fully explored in this case study, these strategies can be effectively managed using the structured grid of cells, which also enhances confidence in stock level dimensioning.

Similar to Sanad et al. (2008), the method proposed in this paper also uses a fixed grid to represent the construction site (available areas) and maps the required installations based on needed space and occupancy rates. Sanad et al. (2008) further introduces constraints related to the positioning of each area, as well as the routes and distances between them. These latter parameters were not explored in this case study. However, together, they provide a foundation for new methodologies that combine detailed spatial representation with logistical optimization. Integrating this approach with optimization algorithms could further improve the predictability and efficiency of on-site logistics. This optimization can also be aligned with digital tools such as BIM, allowing for greater accuracy in spatial planning and site layout parameters.

The limitation of this study lies in its reliance on data from similar projects, such as kitting material quantification. This dependence may limit the direct applicability of the method in scenarios where historical data is unavailable or difficult to access. Although the approach is adaptable, the requirement for detailed information about materials and site layout can pose a challenge. However, this reliance on historical data highlights the potential for the construction industry to enhance its approach to material management systems. Improvements in data precision and the maintenance of reliable records should be key objectives.

CONCLUSIONS

This paper presents a method for designing macro and micro storage layouts in residential construction, aligned with Takt Planning principles. Building on the conceptual layout grid developed by Sanad et al. (2008), it incorporates material sets to reduce transportation waste and optimize layout design. The application of the case study showed the method's usefully in simulating both inventory levels and material flow throughout different stages of the project and useful for dimensioning both macro and micro layouts. This study advances knowledge by addressing the lack of structured methods for storage design. While often counterintuitive within the scope of Lean philosophy and Takt Planning, it is crucial in this environment to limit storage areas on-site without disrupting the material flow to the workstations, which constitutes the practical contribution of this study. Future research may explore its integration with genetic algorithms for optimization and with BIM tools to improve spatial visualization and detect operational conflicts.

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