Journal of Construction Engineering, Management & Innovation
2024 7(2):112-126
DOI 10.31462/jcemi.2024.02112126

RESEARCH ARTICLE

Next-Gen warehousing: Integrating automation and control in CAD for efficient industrial rack system design using parametric modeling

Fatih Yesevi Okur[1,2]

[1] Karadeniz Technical University, Department of Civil Engineering, Trabzon, Türkiye
[2] Earthquake and Structural Health Monitoring Research Center, Karadeniz Technical University, Trabzon, Türkiye

Article History

Received 30 November 2023
Accepted 03 May 2024

Keywords

Parametric design
Warehouse racking systems
Construction industry
Design methodologies
Warehouse racking optimization
Structural integration

Abstract

In the dynamic landscape of the construction industry, the demand for efficient and precise project design methodologies has become paramount. Traditional approaches often struggle to cope with the complexities of contemporary projects, leading to delays, errors, and inefficiencies. This paper explores the evolution of parametric design methodologies, specifically focusing on the revolutionary TemesistCAD software developed to automate and optimize the modeling processes for warehouse and rack systems. Parametric design, characterized by dynamic adaptability through interconnected parameters, is showcased as a paradigm shift from labor-intensive conventional methods. The paper details the methodology of parametric design and its application in diverse industrial contexts, including Back-to-Back Racking, Mezzanine Racking, Radio Pallet Shuttle, Drive-In Racking, and Rack Clad Building Systems. It introduces the innovative TemesistCAD software, rooted in parametric principles, designed to streamline project workflows, reduce errors, and enhance precision in warehouse system designs. The software's application in various industrial scenarios is illustrated, emphasizing its versatility and effectiveness. When compared to other software in the warehouse and racking systems design field, TemesistCAD distinguish with its excellence in project design, manufacturing drawing preparation, and automated material takeoff generation. Its emphasis on parametric modeling not only addresses intricate design needs but also enhances accuracy in cost estimation and materials planning, ultimately optimizing workflow efficiency and minimizing project completion time.

1. Introduction

In the continuum of human civilization, the construction industry has undergone a remarkable evolution, adapting to the burgeoning demands of an expanding global population and diverse needs. The intrinsic link between societal growth and construction needs has propelled the industry into an era where traditional project design methodologies struggle to cope with the escalating demand for buildings of various scales and complexities. As the pace of construction accelerates worldwide, propelled by urbanization and industrialization, engineering marvels continue to shape the landscape. The construction sector finds itself in a dynamic and competitive landscape,

Correspondence Fatih Yesevi Okur yesevi@ktu.edu.tr

eISSN 2630-5771

where project companies strive to achieve optimal results in the shortest time and at the lowest cost. The size and intricacy of projects significantly impact completion times, workforce requirements, costs, and the precision of outcomes. Human errors, especially in tender calculations, have far-reaching consequences, leading to missed opportunities and financial losses. Against this backdrop, the construction industry seeks innovative approaches and technologies to streamline the design, modeling, and calculation processes. Conventional modeling programs widely used in architecture and engineering follow a generic approach, lacking templates or predefined modeling structures. This deficiency is particularly pronounced in complex projects, prolonging the projection process.

Navigating the challenges of architectural design from concept to construction, and subsequently preparing a static project aligned with the architectural vision, poses numerous obstacles. Traditional modeling methods become increasingly convoluted, especially in the static projection process of complex designs. Recognizing this complexity, the development of computer-aided parametric modeling tools emerged to address the need for designing intricate geometries efficiently. Among this sophisticated organization, it is crucial to successfully navigate the procedure, develop a methodical sequence, and accurately enumerate the variables while establishing their interconnections [1]. The need for environments that facilitate the creation of sophisticated geometries was recognized, and efforts were made to address this by developing computer-aided parametric modeling tools [2]. The parametric system's capacity to define and modify the model's geometry is attributed to the interdependence of its parameters, as stated by Senagala [3].

Parametric design, characterized by dynamically linked parameters defining and altering the model's geometry, offers a versatile solution [4, 5]. This approach facilitates easy modifications and the exploration of numerous design alternatives by manipulating parameter values [6]. The adoption of parametric design methods and software by architects and engineers globally underscores the need for more advanced tools in the industry [7, 8].

In recent years, the exponential growth of e-commerce has spurred an urgent need for warehouse solutions that can keep pace with the increased volume and rapid turnover of products. Concurrently, the adoption of various software in the sector has been instrumental in achieving these goals. Industry-specific CAD programs, for instance, have been integrated into the planning and execution phases to facilitate more precise designs, enhance space utilization, and streamline inventory management. Such software enables designers and warehouse managers to simulate and implement effective racking arrangements, taking into account load capacities, material handling, and safety standards. Additionally, Warehouse Management Systems (WMS) and Enterprise Resource Planning (ERP) software are now commonly intertwined with CAD programs, allowing for real-time tracking of inventory and resources, further contributing to the operational efficiency of warehouse facilities. There are many types of carrier systems in warehouse racking systems, mainly back-to-back, mezzanine, radio pallet shuttle, drive-in, rack clad building system. These are systems that can be installed according to the needs of the customer, such as terrain conditions and roboticization. Various software for warehouse and racking systems have been developed in the industry [9-13]. These software tools now extend beyond mere structural design; they are pivotal in creating concept designs for storage and shelving systems, executing animations and simulations, and incorporating technological advancements in warehouse and racking system management. Through these software applications, stakeholders can visualize the conceptual layout in three dimensions, animating the workflow to predict and optimize operational efficiency. They enable the testing of different scenarios through simulations to ensure that the racking systems not only maximize space and accessibility but also comply with safety regulations. These simulations are integral in assessing the feasibility and effectiveness of

warehouse operations before the physical implementation of the systems.

Despite these advancements, the industry still grapples with gaps in the seamless transition from design to execution, particularly in the creation of detailed projects, manufacturing files, and precise quantity calculations necessary for the establishment of warehouse and racking systems. The current tools often require manual intervention to translate designs into actionable blueprints and accurate material assessments, a process prone to human error, which can lead to inefficiencies and increased costs. The lack of fully integrated systems that can automatically generate all necessary documentation and metrics for the assembly and management of warehouse systems underscores the need for further innovation in this field. Thus, study aims to bridge the gap by introducing a CAD program designed to automatically model based on parametric principles. Developed as part of an R&D project initiated at the request of Temesist Warehouse and Rack Systems, a leading company in storage solutions, this CAD program stands poised to revolutionize the design process for industrial structures. Tailored to automate the modeling, drawing creation, and quantity calculations for warehouse and racking systems, this program offers efficiency and accuracy. The anticipation is that this CAD program, initially designed for warehouse and racking systems, can be customized for diverse industrial structures, expediting project design processes and mitigating potential human-induced errors.

2. Methodology

In the contemporary landscape of design, the prevalent modeling methods often involve the manual editing of designs followed by reflecting these changes onto the modeling screen. However, this conventional approach presents a substantial drawback: any alteration to the designed concept necessitates the arduous task of deletion and subsequent remodeling. This becomes particularly time-consuming, especially when dealing with intricate and expansive structures. In stark contrast, the advent of parametric modeling has revolutionized this paradigm, offering an innovative solution that eliminates the need for wholesale remodeling. The key advantage of the parametric modeling method lies in its dynamic adaptability. Unlike traditional methods, where modifications trigger a cascade of remodeling tasks, parametric modeling allows instantaneous adjustments without the need to reconstruct the entire model. This time-saving feature proves particularly invaluable when dealing with the intricacies of large and complex structures.

Parametric modeling tools are broadly categorized into text and visual algorithm editors, each serving as a gateway to harnessing the power of parametric design (Fig. 1). Notable examples of text-based algorithm editors include Rhinoscript (McNeel), Generative Components (Bentley), and Mayascript (Autodesk). On the other hand, visual algorithm editors such as Grasshopper (McNeel) and Dynamo (Autodesk) provide a more user-friendly interface [14], eliminating the need for coding knowledge and thereby facilitating wider adoption in the design community [14, 15].

The parametric design process begins with the identification of key variable parameters crucial to the design vision. These parameters are the driving forces behind the flexibility and adaptability inherent in parametric design. Establishing relationships between these parameters is a critical next step, creating a dynamic and interconnected system where changes to one parameter have a cascading effect on the entire model. This dynamic relationship ensures that any modification, no matter how small, triggers an instantaneous and comprehensive update across the entire design. This characteristic lies at the core of the holistic functionality of parametric design.

In essence, parametric design represents a paradigm shift from traditional modeling methods, which tend to be labor-intensive and time-consuming, to a more agile and responsive approach. By embracing variable parameters and their dynamic relationships, designers can navigate the complexities of design evolution with unprecedented efficiency and precision.

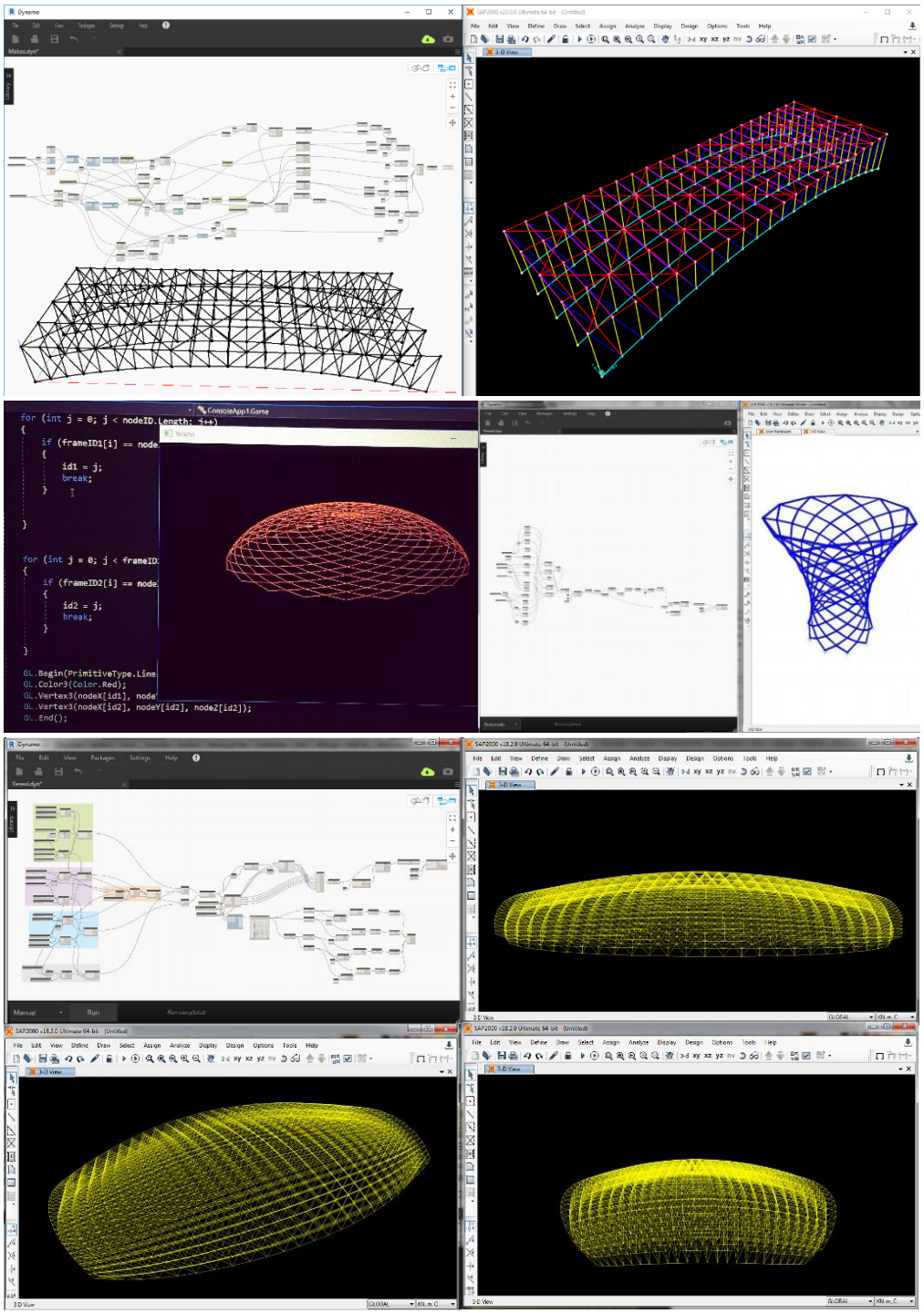


Fig. 1. Written and visual algorithm editors in parametric modeling

The visual representation of this process, as illustrated in Fig. 1, emphasizes the accessibility and user-friendly nature of contemporary parametric design tools. These tools empower designers to explore, iterate, and refine their ideas rapidly, fostering a more iterative and collaborative design process. The interconnected web of parameters not only accelerates the design phase

but also facilitates a more nuanced and sophisticated exploration of design possibilities. Overall, parametric design stands as a transformative methodology, revolutionizing the way designers conceive, refine, and realize their creative visions.

3. Warehouse Racking Systems

This section provides an overview of various racking systems including the Back-to-Back Racking System, Mezzanine Racking System, Radio Pallet Shuttle System, Drive-In Racking System, and Rack Clad Building System.

3.1. Back-to-back racking system

In the context of warehouse or storage systems, "back-to-back" typically refers to a configuration where two rows of racks are positioned with their backs against each other. This design is often used to maximize the use of available space in a warehouse or storage facility. Utilizing a back-to-back racking system in warehouse design offers notable advantages. The arrangement of racks in close proximity enhances space efficiency, particularly beneficial in warehouses where space is a premium commodity. This configuration allows for a higher storage density, enabling businesses with substantial inventories to store more goods in a given area. However, it's essential to consider the impact on accessibility, as forklifts or other material handling equipment may need to navigate through narrow aisles between the back-to-back rows. Careful layout planning is crucial to ensure efficient material handling. Back-to-back configurations often pair seamlessly with selective racking systems, providing direct access to every pallet position and facilitating the retrieval of specific items without the need to move others. Moreover, some setups incorporate pallet flow systems in conjunction with back-to-back arrangements. These systems, employing rollers or wheels, facilitate the smooth flow of pallets from the loading side to the unloading side, typically utilizing gravity. This integration enhances the efficiency of inventory rotation and order picking processes within the warehouse. General images of the back-to-back racking system are given in Fig. 2.

3.2. Mezzanine racking system

A mezzanine racking system refers to a type of storage system that incorporates a raised platform or mezzanine level within a warehouse or storage facility. This system is designed to optimize vertical space utilization, effectively doubling the storage capacity of the area without the need for a larger footprint. The mezzanine level is essentially an intermediate floor positioned between the main floor and ceiling.

A mezzanine racking system serves as a strategic solution for businesses seeking to optimize their storage capacity without expanding their physical footprint. The primary objective is to capitalize on vertical space above the main floor, enabling the storage of additional goods. These systems boast a high degree of customization, accommodating various storage configurations like shelving, pallet racking, or a combination of both to meet specific business needs. Modularity is a key feature, facilitating easy assembly, disassembly, and reconfiguration, providing adaptability as storage requirements evolve. Accessibility is ensured through the inclusion of staircases, ladders, or freight elevators, crucial for efficient material handling and picking processes. The potential for multi-level storage enhances the scalability of these systems, with each level dedicated to specific goods or operational needs. Mezzanines seamlessly integrate with diverse racking systems, such as selective racking, pallet racking, or shelving, allowing for versatile storage options. Beyond storage, mezzanines find utility in office spaces, workstations, or other operational uses, exemplifying their dual functionality and ability to maximize both storage and workspace within a single facility. Compliance with local building codes and regulations, encompassing factors like load capacity, safety features, and fire codes, is imperative in the implementation of mezzanine racking systems to ensure the safety and structural integrity of the storage infrastructure.


(a)


(b)


(c)

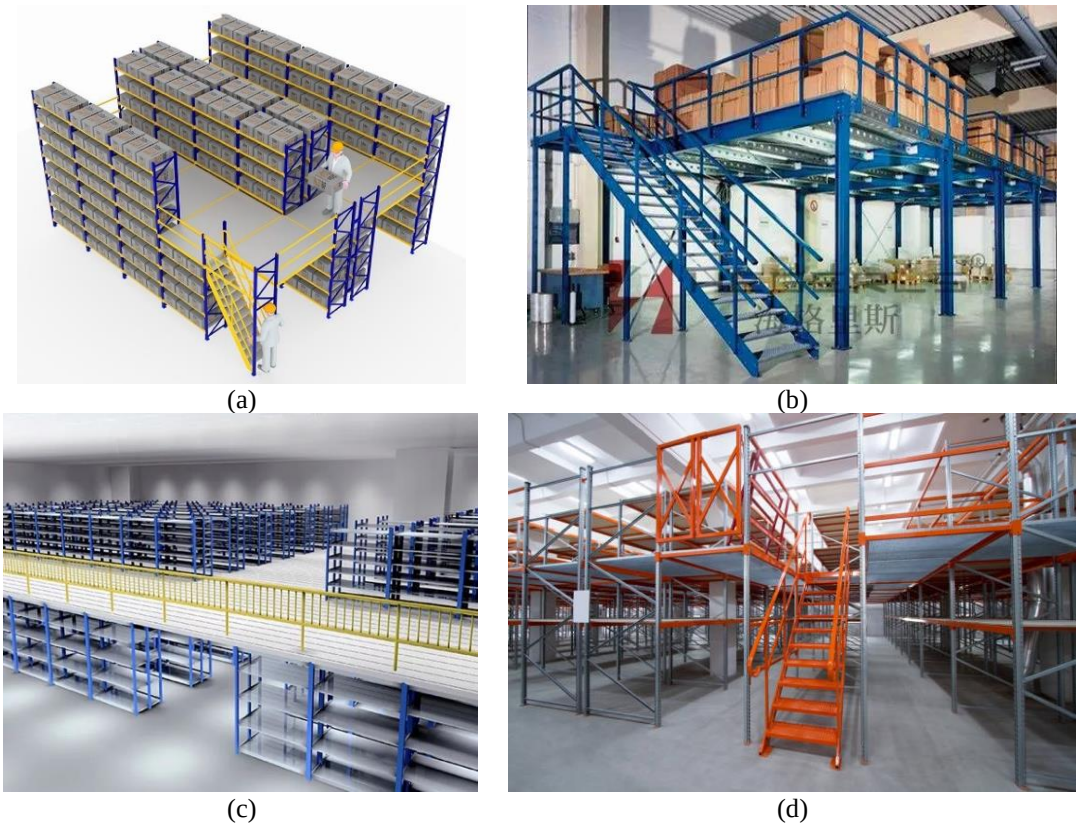

(d)

Fig. 2. General images of the back-to-back racking system [16-20]

Mezzanine racking systems are commonly used in various industries, including manufacturing, distribution, and retail, where efficient use of space is essential. Businesses often invest in these systems to adapt to changing storage requirements and to optimize their overall operational efficiency. General images of the mezzanine racking system are given in Fig. 3.

3.3. Radio pallet shuttle system

Radio Pallet Shuttle System is a type of automated storage and retrieval system commonly used in warehouses and distribution centers for handling and storing palletized goods. It's a sophisticated system designed to optimize storage space and enhance the efficiency of material handling operations. The Radio Pallet Shuttle System is a sophisticated warehouse automation solution centered around a shuttle vehicle, also known as a pallet shuttle or radio shuttle. This motorized device is radio-controlled, facilitating independent movement within specific channels or lanes of the storage racks. Equipped with guide rails, these lanes ensure precise shuttle movement. Loading and unloading are streamlined processes, with the shuttle autonomously transporting pallets from the entrance of a lane to available storage locations and vice versa. The "Radio" aspect involves wireless communication between the shuttle and a central control system, enabling efficient coordination. Remote operation capabilities empower operators or warehouse personnel to direct the shuttle remotely, enhancing flexibility in managing inventory. Notably, the system excels in achieving high-density storage, allowing shuttles to navigate racks efficiently and store multiple pallets deep within each lane. By automating pallet movement and eliminating the need for aisles, the Radio Pallet Shuttle maximizes warehouse space utilization.



(a) (b)

(c) (d)

Fig. 3. General images of the mezzanine racking system [21-23]

Designed for time efficiency, the system handles pallet movements swiftly and accurately, proving particularly advantageous in environments with high volumes of palletized goods and a demand for rapid inventory turnover. It's worth noting that specific implementations of Radio Pallet Shuttle Systems may vary among manufacturers, and technological advancements in warehouse automation continue to evolve. For the most up-to-date and detailed information, it's advisable to consult with suppliers or manufacturers specializing in automated storage and retrieval systems. General images of the radio pallet shuttle system are given in Fig. 4.

3.4. Drive-in racking system

A Drive-In Racking System is a type of high-density pallet storage system used in warehouses and distribution centers. It is designed to maximize storage capacity by allowing forklifts to drive directly into the racks for the storage and retrieval of pallets. This system is particularly useful for storing large quantities of homogeneous products with low stock rotation. Structural Design: Drive-In racks are typically designed with a series of lanes that can accommodate the width of a forklift. The racks have strong horizontal and vertical beams to support the weight of multiple pallets.

A Drive-In Racking System operates on the Last-In, First-Out (LIFO) storage principle, where the last pallet placed in a lane is the first one to be retrieved. This feature is suitable for products that don't require strict chronological order, making it ideal for applications where stock rotation is not a critical factor. The system's continuous racking structure allows forklifts to drive directly into the storage lanes, eliminating aisles and increasing storage density by minimizing wasted space. Support rails or guide rails on either side of each storage lane facilitate proper forklift alignment during pallet placement and retrieval.

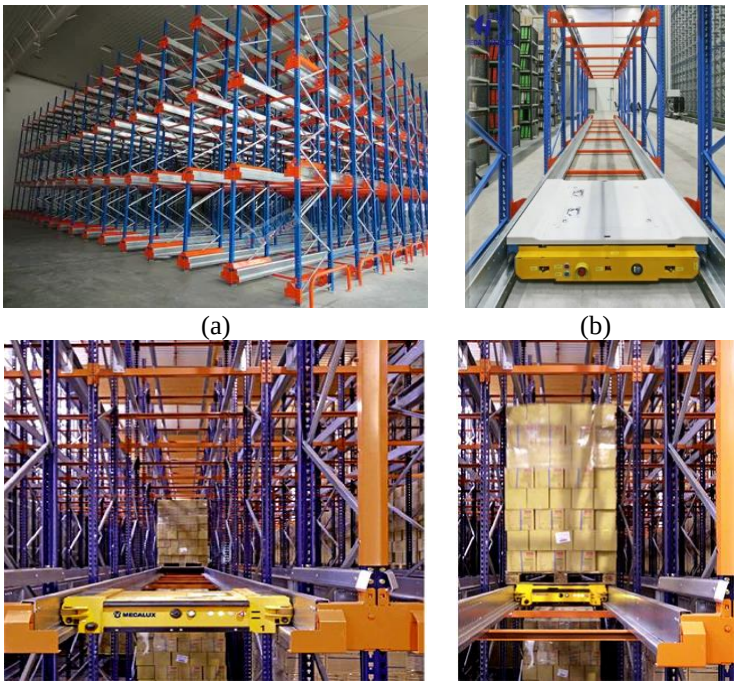


Fig. 4. General images of the radio pallet shuttle system [24-26]

Drive-In racks are particularly effective for storing large quantities of the same product, filling entire lanes with identical pallets. However, this efficiency comes with reduced selectivity, as accessing a specific pallet within a dense configuration may require moving multiple pallets. Known for their space efficiency, Drive-In Racking Systems accommodate more pallet positions within the available warehouse space by eliminating the need for aisles. Forklift maneuvering is a critical aspect of the system, requiring careful operation to prevent damage to the racks and ensure safe and efficient material handling operations. It's important to note that while Drive-In Racking Systems offer advantages in terms of storage density, they may not be suitable for all types of products or storage requirements. Factors such as inventory turnover, product characteristics, and accessibility requirements should be considered when deciding on the most appropriate racking system for a specific application. General images of the Drive-In Racking System are given in Fig. 5.

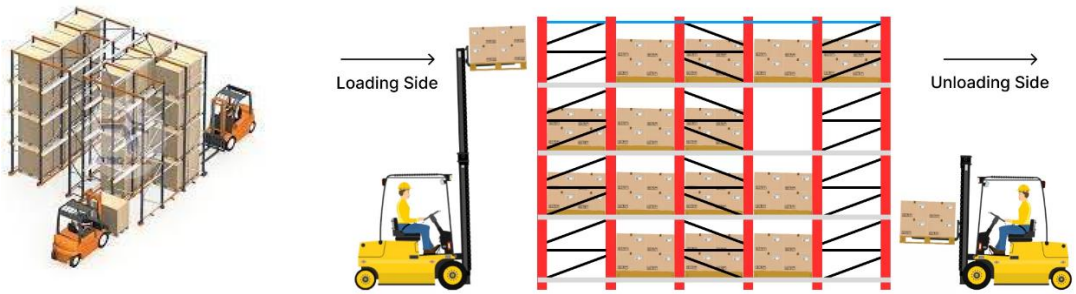


Fig. 5. General images of the drive-in racking system [27, 28]

3.5. Rack clad building system

A Rack Clad Building System is an integrated storage solution that combines traditional warehouse storage racks with the structural elements of the building itself. In this system, the storage racks serve as both the structural support for the building and the framework for storing goods. This approach optimizes space utilization, as it eliminates the need for separate columns and other structural components within the storage area.

A Rack Clad Building System represents an innovative approach to storage and construction, seamlessly integrating storage racks into the structural framework of the building. Unlike traditional structures where storage racks are added within the building, here they become intrinsic to the building's frame, contributing to both storage functionality and structural stability. This integration maximizes available space, eliminating the need for additional columns or support structures and leading to increased storage capacity. The storage racks serve a dual purpose by not only supporting goods but also enhancing the overall stability and load-bearing capacity of the structure. This integrated design often proves cost-effective, particularly in scenarios where both storage space and building structure are essential, resulting in potential savings in construction and land use. The system is particularly adept at high-density storage applications, such as those requiring pallet racking, allowing for the full utilization of vertical storage space without interference from internal columns. Customization is a key feature, enabling businesses to tailor the configuration of storage racks, their height, and layout to meet specific operational requirements. Moreover, the integrated design makes Rack Clad Buildings well-suited for automated systems like conveyor systems or automated guided vehicles (AGVs), enhancing the efficiency of material handling processes. Design considerations, including load-bearing capacity, seismic requirements, and adherence to local building codes, are paramount. Engineers and architects play a crucial role in ensuring that the integrated system meets rigorous safety and regulatory standards, making Rack Clad Buildings a versatile and efficient solution for businesses with diverse storage and structural needs.

Rack Clad Building Systems are commonly employed in industries where efficient storage and retrieval of goods are essential, such as logistics, manufacturing, and distribution. As with any storage system, careful planning and consideration of specific operational needs are crucial for the successful implementation of a Rack Clad Building. General images of the rack clad building system are given in Fig. 6.

4. Exploring Diverse Approaches in CAD Software Development: Beyond Parametric Modeling

Temesist Warehouse and Racking Systems [30], established in 1980, has established itself as a global player in the design and production of storage, warehouse, and rack systems for diverse brands across various sectors worldwide. Over the years, the company has undertaken numerous projects, showcasing its expertise in delivering high-quality storage solutions. In an industry marked by fierce competition, the ability to achieve swift and precise results is paramount for securing and executing projects successfully. Recognizing the challenges posed by the intricate nature of storage and warehouse systems, Temesist Warehouse and Racking Systems sought to streamline their project workflow, aiming to reduce modeling complexities and minimize errors in cost estimation. The conventional methods employed in the industry often led to delays in modeling processes, and errors in calculations during cost estimation could result in project losses due to inaccuracies, either exceeding or falling short of the actual cost.

To address these challenges and enhance efficiency, TemesistCAD software was developed. This software, rooted in the parametric modeling technique, offers an automated solution for modeling the structures of warehouse and rack systems.

(a)

(b)

Fig. 6. General images of the rack clad building system [29]

It goes beyond conventional methods by not only creating detailed 3D models but also generating drawings, calculating approximate costs, and compiling comprehensive tender files. This integrated approach ensures a seamless and error-free transition from the conceptualization to the implementation phase of a project.

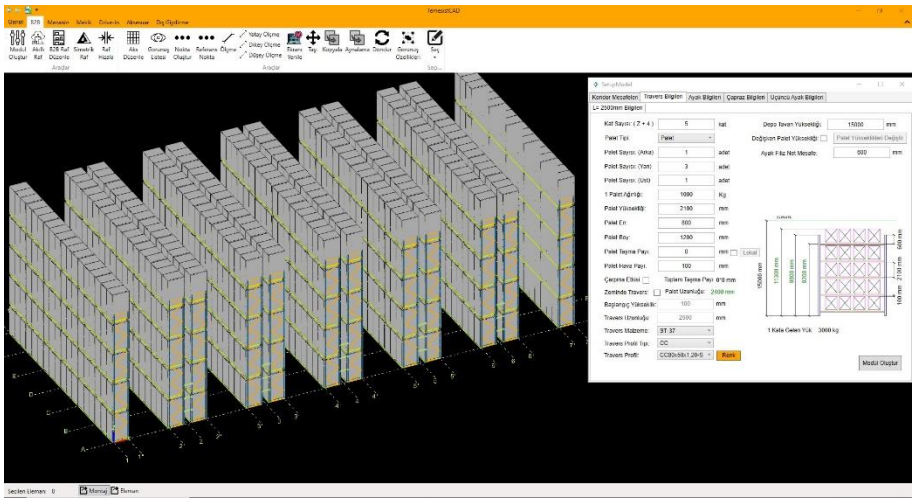
TemesistCAD software has become a cornerstone in diverse industrial applications, showcasing its versatility and effectiveness across various storage and logistics systems. In the realm of warehouse optimization, the software is instrumental in designing Back-to-Back Racking Systems, enabling efficient space utilization by strategically placing racks in close proximity. Mezzanine Racking Systems, which involve multi-level storage platforms, benefit from TemesistCAD's capabilities for creating customized and space-efficient configurations. The software extends its utility to Radio Pallet Shuttle Systems, enhancing the automation of pallet storage and retrieval through radio-controlled shuttles. Drive-In Racking Systems, known for their high-density storage, leverage TemesistCAD for optimal layout design and structural considerations. Rack Clad Building Systems, integrating storage racks into the building's structure, benefit from the software's prowess in combining storage functionality with architectural elements. TemesistCAD's broad application in these industrial systems underscores its adaptability and effectiveness in addressing the complex spatial and logistical challenges associated with modern storage solutions. In the project design of warehouse and racking systems, and in the acquisition of manufacturing parts and material quantity take-off, TemesistCAD emerges as a critical resource.

The TemesistCAD software boasts a user-friendly visual interface, facilitating 3D modeling through the parametric technique. Each rack type is categorized under specific tabs on the modeling screen, enabling automatic modeling by inputting relevant dimensions in the designated boxes. The program's interface, as illustrated in Fig. 7, showcases its adaptability to different warehouse and rack configurations, demonstrating the

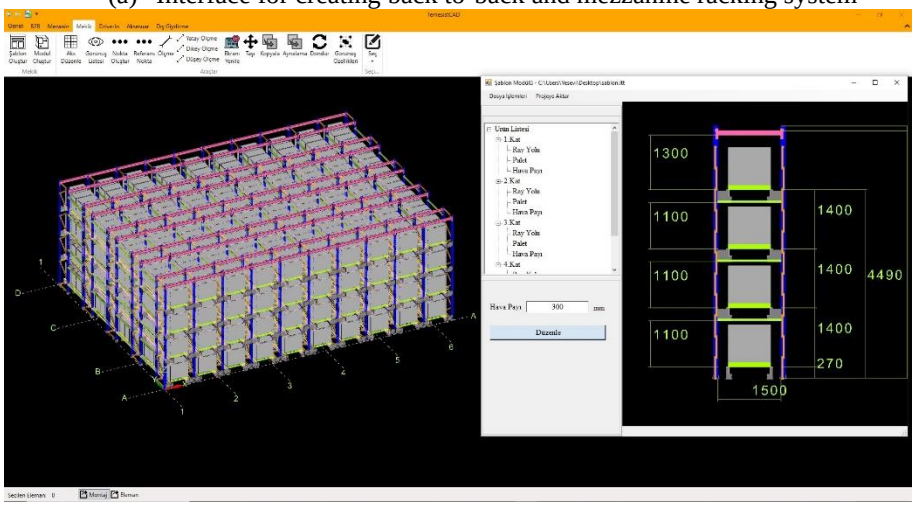
versatility and customization capabilities of the software.

In Fig. 8, the visuals of the warehouse and rack systems project created parametrically in the TemesistCAD software are given.

TemesistCAD software offers a highly efficient solution for managing multiple projects within a short timeframe. Through parametric modeling, the program enables the rapid creation of column, racking, and roof systems. It also facilitates the generation of external cladding and various building accessories. The software provides the capability to obtain project drawing files, allowing for streamlined documentation. Notably, the program ensures the accuracy of cost estimations, enabling precise calculations. Additionally, it supports the creation of comprehensive tender dossiers for the respective structures. This results in a reduction of project development time, minimizes conflicts in assembly elements on-site, and offers flexibility for instant revisions in models and outputs in response to project changes. Overall, the program significantly enhances efficiency and precision in the planning, design, and execution phases of multiple projects.

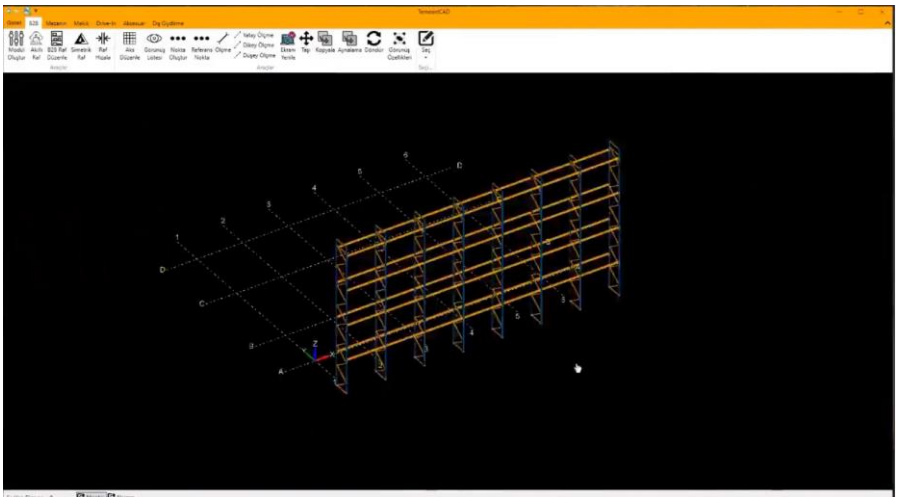


(a) Interface for creating back to-back and mezzanine racking system

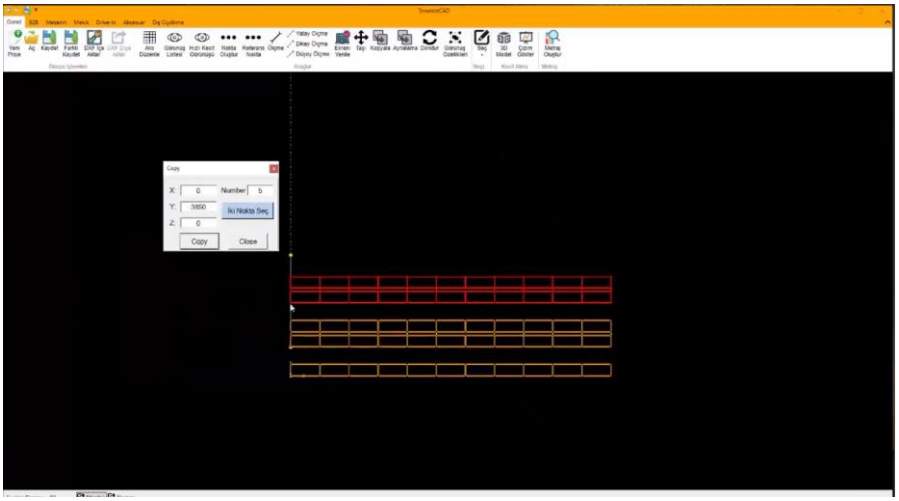


(b) Interface for creating radio pallet shuttle and drive-in racking system

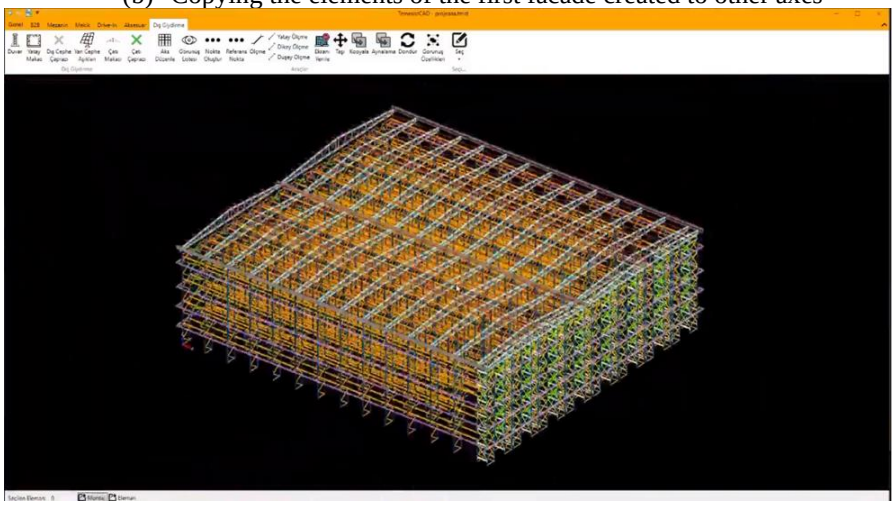
Fig. 7. Program interface prepared according to different warehouse and rack types



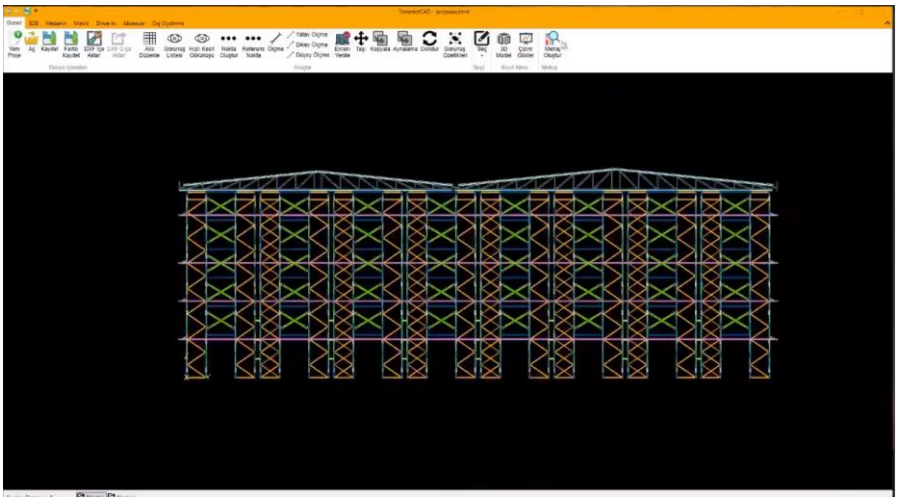
(a) Establishment of the axis system of the project and determination of the column and rack system of the first facade



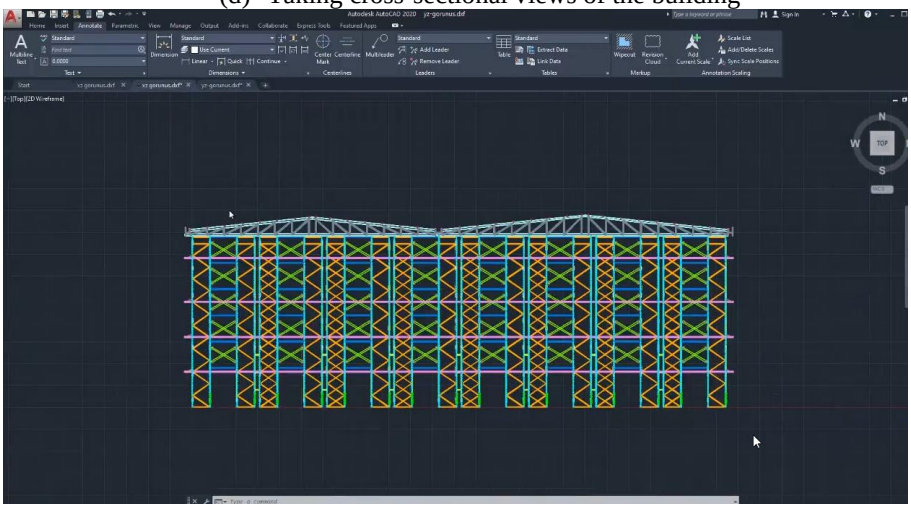
(b) Copying the elements of the first facade created to other axes



(c) Completion of the three-dimensional model of the project



(d) Taking cross-sectional views of the building



(e) Transferring drawings to AutoCAD program

Fig. 8. Images of a project prepared in the developed TemesistCAD software

5. Conclusion

This paper present TemesistCAD software that revolutionized project design workflow in Warehouse racking systems. Rooted in parametric modeling, this innovative tool accelerates the modeling process, reduces errors in cost estimation, and ensures precise execution of diverse warehouse and rack system projects worldwide. The software's versatility, showcased in applications like Back-to-Back Racking and Drive-In Racking, demonstrates the adaptability of parametric modeling to optimize space and enhance storage efficiency. With a user-friendly interface and automatic modeling capabilities, TemesistCAD stands as a beacon of efficiency, mitigating complexities in the industry and paving the way for a new era in storage solutions.

In comparing TemesistCAD with other software in the domain of warehouse and racking systems design, it is evident that TemesistCAD stands out in several critical areas. Its proficiency in project design, preparation of manufacturing drawings, and automatic creation of material takeoffs highlights its superiority and efficiency. The software's emphasis on parametric modeling provides a robust framework for addressing complex design requirements, streamlining the design process, and ensuring accuracy in cost estimation and materials

planning. This distinction not only enhances the workflow but also significantly reduces the potential for error and the time required for project completion.

In conclusion, the evolution from conventional manual editing methods to contemporary parametric modeling represents a paradigm shift in design practices. The paramount advantage lies in the dynamic adaptability of parametric modeling, enabling instantaneous adjustments without the need for wholesale remodeling. This proves especially valuable for large and intricate structures, where traditional methods would be time-consuming. The categorization of parametric modeling tools into text and visual algorithm editors provides a spectrum of options, catering to diverse user preferences and coding expertise. The process involves identifying variable parameters, establishing relationships, and creating a dynamic system that ensures comprehensive updates with each modification. Parametric design, exemplifies efficiency and precision in navigating the complexities of design evolution, marking a significant advancement in the contemporary landscape of design methodologies.

Future studies inspired by the advancements in TemesistCAD and parametric modeling could focus on several key areas. Firstly, integrating artificial intelligence to automate and optimize the design process, potentially making real-time adjustments based on changing needs. Secondly, incorporating sustainability metrics into parametric models could pioneer environmentally conscious designs in warehouse systems. Additionally, leveraging virtual and augmented reality could offer immersive design experiences, enhancing decision-making and accuracy. Lastly, comparative analysis across different parametric modeling tools could highlight areas for software improvement, driving further innovation in this field. These focused research paths promise to refine and expand the capabilities of parametric modeling, pushing the boundaries of efficiency and adaptability in warehouse design.

Declaration

Funding

This research received no external funding.

Author Contributions

F. Y. Okur: Conceptualization, Methodology, Formal analysis, Investigation, Writing - Original Draft, Writing - Review & Editing.

Acknowledgments

Not applicable.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Ethics Committee Permission

Not applicable.

Conflict of Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

[1] Yıldız Y, Yavuz AÖ (2019) A model proposal for the contribution of parametric design software to the design-production collaboration process: Revit-dynamo example. In: 3rd ISAS International Symposium on Innovative Approaches in Scientific Studies 367-371. Press, Turkey (Turkish).

[2] Wu M, Ma Z (2012) The realization of nonlinear architectural on the parametric model. Physics Procedia 25:1470-1475.

[3] Senegala M (2002) Time-like architectures - the emergence of post-spatial parametric Worlds. In: 20th ECAADE Conference 254-261. Warsaw, Poland.

[4] Harding J, Joyce S, Shepherd P, Williams C (2012) Thinking topologically at early stage parametric design. Advances in Architectural Geometry.

[5] Turrin M, Von Buelow P, Stouffs R (2011) Design Explorations of Performance Driven Geometry in Architectural Design Using Parametric Modeling and Genetic Algorithms. Advanced Engineering Informatics 25(4): 656-675.

[6] Dino IG (2012) Creative Design Exploration by Parametric Generative Systems in Architecture. METU Journal of The Faculty of Architecture 1: 207–224.

[7] Hernandez CR (2006) Thinking parametric design: introducing parametric Gaudi. Design Studies 27: 309-324.

[8] Ma Z (2012) The Realization of nonlinear architectural on the parametric model. Physics Procedia 25: 1470-1475.

[9] Anylogic Simulation Software https://www.anylogic.com/

[10] FlexSim Software, Autodesk https://www.flexsim.com

[11] SimCad Pro, Warehouse Simulation Software https://www.createasoft.com

[12] CLASS Warehouse Layout and Simulation Software https://www.simplan.de

[13] Easy Mecalux Warehouse Management System Software https://www.mecalux.com

[14] Çinici SY, Akipek FÖ, Yazar T (2008) Computational design, parametric modelling and architectural education, Arkitekt 518:16-23.

[15] Stouffs R, Janssen P, Roudavski S, Tunçer B (2013) A method for comparing designers' behavior in two environments: parametric and geometric modeling. Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA 2013) 479: 488.

[16] URL-1, https://ergstorage.eu/wp-content/uploads/2011/01/ergstoragepalletbacktoback13.jpg. Accessed 30 Nov 2023.

[17] URL-2, https://interlakemecalux.cdnwm.com/blog/img/push-back-racking-system-applied-sacks-warehouse.1.0.jpg. Accessed 30 Nov 2023.

[18] URL-3, https://apexwarehousesystems.com/wp-content/uploads/2016/02/push-back-web.jpg. Accessed 30 Nov 2023.

[19] URL-4, https://portalimages.blob.core.windows.net/products/images/dit0ss2m_backtoback.jpg. Accessed 30 Nov 2023.

[20] URL-5, https://image.made-in-china.com/2f0j00TRFGuNiKOrpH/Warehouse-Heavy-Duty-Shelving-Supported-Mezzanine-Racking-System.jpg. Accessed 30 Nov 2023.

[21] URL-6, https://iororwxhkimqln5p.leadongcdn.com/cloud/mrBqjKkoRlpSpjipkiop/Mezzanine-Racking.jpg. Accessed 30 Nov 2023.

[22] URL-7, https://iororwxhkimqln5p.leadongcdn.com/cloud/mrBqjKkoRlpSpjipkiop/Mezzanine-Racking.jpg. Accessed 30 Nov 2023.

[23] URL-8, https://media.istockphoto.com/id/681834498/tr/foto%C4%9Fraf/high-rise-racks-with-ladder-mezzanine-shelves.jpg?s=612x612&w=0&k=20&c=syYN63QC0uDRHbTPyvw1NPWFfoinUGs7FzI_Z6UeS4g=. Accessed 30 Nov 2023.

[24] URL-9, https://m.warehousingracks.com/photo/pt13634190-high_density_storage_racks_radio_shuttle_racking_adjustable_baseplate_type_50_meters_per_min.jpg. Accessed 30 Nov 2023.

[25] URL-10, https://www.materialstoragesystem.com/images/products/radio-shuttle-storage-systems1.jpg. Accessed 30 Nov 2023.

[26] URL-11, https://eurorack.vn/vnt_upload/news/03_2020/drive-in-racking-system_4.jpg. Accessed 30 Nov 2023.

[27] URL-12, https://v8d2f4g2.rocketcdn.me/wp-content/uploads/2022/05/Drive-Through-Rack-Example.png. Accessed 30 Nov 2023.

[28] URL-13, https://www.temesist.com/wp-content/uploads/2022/09/dis-giydirme-raf-sistemi.jpg. Accessed 30 Nov 2023.

[29] URL-14, https://mecaluxcom.cdnwm.com/standard-rack/rack-supported-buildings/newimg0.1.1.jpg?imwidth=1024&imdensity=1. Accessed 30 Nov 2023.

[30] Temesist Industrial Warehouse Engineering (1980) (https://temesist.com/).