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A Holistic Framework Towards the Digital Adoption of Flexible Facility Layout Design

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Abstract

Supply chain and flexible facility layout aspects play an important role in the project management, especially in the competitive Small\Medium Enterprises (SMEs). Due to continuous demand changing and challenging decision-making in the industrial environment and market, traditional Facility Layout (FL) design has uncertainty outputs, long-term mistake, and unreliable models. So, this paper introduces an adaptive solution framework aligning with this significant issue. This comprehensive framework discusses the design phases of flexible facility layout from digital transformation perspective. The framework consists of three design phases (Conceptual, Design Optimization, and Real-Time Design Phase). Identifying the enabling technologies for each design phase assists the designers, decision makers, and managers to respond immediately and take fast decision and right action on time. The past research work discussed the conceptual and optimization design phases. So, the real-time design phase is the novelty of this research that is aligned with Industry 4.0 movement, and it can be integrated with smart production and logistic systems. Thus, This framework shall enable the project management to follow the right path resolving the dynamic facility layout problem and minimizing the production cycle time (e.g., material handling time). The research sheds the light on the promising digital design of flexible facility layout, discusses the limitations and challenges, and it conclude with recommendations for future work.

Keywords: project management, enabling technologies, real-time design, holistic framework, flexible facility layout

1. Introduction

Design process passes through many critical phases and requires different enabling technologies to build optimal and reliable design models. Dynamic Facility Layout Problem (DFLP) is one of the crucial issues in the design and manufacturing stages, which requires carefully identifying the suitable technologies that enable the decision makers to adapt the continuous changing of demands, product design features, fluctuating quantities delivering the products (semi-product) on time to the costumers, clients, or suppliers. Flexible Facility Layout Design is the key element to overcome this dynamic FL problem, especially in the small-medium enterprises providing the production department variant facility layout patterns for different periods matching with the master production schedule and planning (Akash Tayal, Arun Solanki, and Simar Preet Singh, 2020). But the challenge in this era of Industry 4.0 is which enabling technologies are fitting with each design phase to produce robust facility layout design, and how digital transformation plays an important role to improve flexible facility layout design adding an updated design phase (Real-Time Design Phase) (Hunagund, I.B., Pillai, V.M. and Kempaiah, U.N., 2020).

This paper shows a holistic framework dividing the design process of flexible facility layout model into three phases: Conceptual design phase; Design optimization phase; and Real-Time Design phase. Each phase has particular design processes and its enabling technologies (Tailor-Made Technologies). The purpose of taking a step forward is not only to adopt the fast development of digital transformation, while it is necessary to fill the gap of estimated data inserted in the design simulation systems, which causes long-term mistakes and errors during the implementation of design models. The past authors (Shreyanshu Parhi, Kanchan Joshi, and Milind Akarte, 2021; Lingguo Bu, et al., 2021) worked on different frameworks for general purposes related to Smart Manufacturing System (SMS) and FL design, but they did not focus on flexible FL and not considered the real-time design (On-Line Design- In-Service) phase, which is the most important addition in this framework shown in Figure 1 due to the adaptability with most popular and recent technologies in the era of Industry 4.0. So, the past research works discussed the first two phases form design processes perspective (not enabling technologies).

Nowadays, Internet of Things (IoT), Radio Frequency Identification (RFID), Simulation, Cyber-Physical Systems, Digital Twin (DT) technologies are key factors that can transform the old and traditional systems and processes to be autonomous, digital, more useful and aligning with the smart factory levels (Alcácer, V., et al, 2021; Boton, C., 2021). Embedding and integrating these technologies do not mean eliminate the past technologies used in the era of Computer- Integrated Manufacturing (CIM), which still play a significant role in this era such as Computer- Aided Design (CAD), Artificial Intelligence (AI), Expert and Information Systems, algorithms, etc. Flexible Facility Layout Design implementation passes through three stages of digital transformation and three design phases simultaneously; the practitioners can use some technologies in first two phases (Off-line Design- Before Starting up the production services) and other technologies in the last two phases showing such a digital transformation perspective.

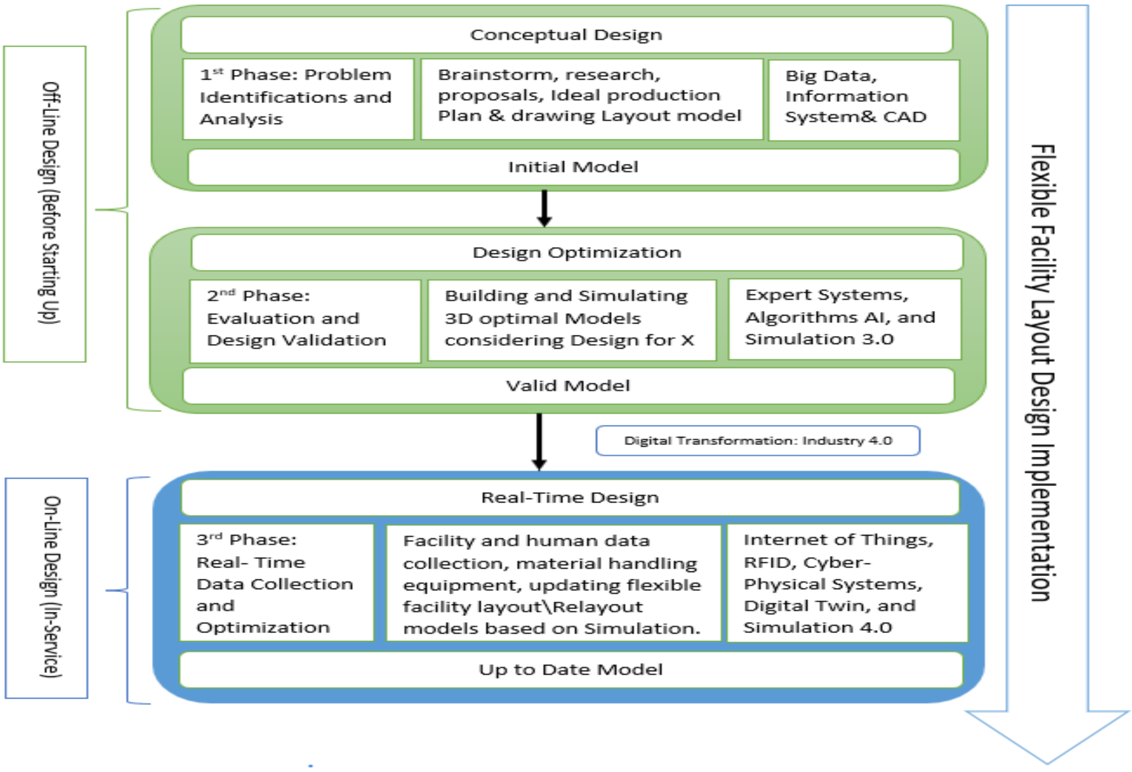

Figure 1: A Holistic Framework Towards the Digital Adoption of Flexible Facility Layout Design

2. Digital Transformation Towards Smart Flexible Facility Layout Design

In this rea of Industry 4.0 revolution, billions of digital devices have connected to Internet-based networks. This fast development has pushed Information and Communication Technologies (ICT) to become a vehicle of industrial and manufacturing systems, where the rapid, smart, and adaptive design, production, and delivery of a wide variety of demands and products are enabled by support from digital and virtual design, production, modeling, simulation, and presentation techniques (R. Y. Zhong, X. Xu, E. Klotz, and S. T. Newman, 2017). The need for digital transformation in Industry imposed due to the competitive market and game players (companies) require developing an increased capacity to plan and manage their operations efficiently. Therefore, they have to understand the level of current maturity concerning Industry 4.0 and what robust functions are identified to assist them reach higher levels such as higher design phase (Barbalho, S.C.M. and Dantas, R.F., 2021).

Flexible Facility Layout design as an important aspect of Logistics and production design will be influenced in two dimensions in regarding Industry 4.0: the physical dimension, with the use of collection facilities for movements, transportation and loading and unloading and even manufacturing processes belonging to the facilities (machines), and the digital dimension with the collection of processing data through using the internet of things (IoT)- Based sensors, data transmission to the cloud and optimizing the process itself utilizing these data (Hofmann and Rüsch, 2017). Indeed, Dynamic Facility Layout Problem, which caused by demand changing, product features modifications, etc. it will influence on the technological process and then material handling transporter (equipment, robot, human, etc.) route. This dynamic scenario increases the production cycle time and causes deficiency of the performance in the current facility layout. Thus, the practitioners try to overcome this continuous problem aligning with the digital transformation to produce smart and flexible facility layout models relying on the connected devices, equipment, machines, and facilities (Ghobakhloo, M. and Iranmanesh, M. 2021). The goal is not only the facility layout design itself, while getting up do date facility layout will enable the production management and decision makers to take an immediate decision and action regarding the material handling systems, process planning, change management, manufacturing processes, especially in the Small Medium Enterprises (SMEs) (Lee, J.J. and Meng, J., 2021).

The fast digital transformation in this era is not only belonging to the Industry 4.0 movement, while COVID19 pandemic accelerates the wheel of innovative methodologies to be adapted within the industrial systems in terms of safety and ergonomics (Taghipour, A., & Merimi, M., 2021). Although, this advancement, the old technologies used in first two phases are still useful such as CAD, Simulation, and Expert systems. While the update is to integrate and expand the communication aspects (e.g., IoT, Real- Time data collection) with the past technologies such as transforming the current edition of facility layout simulation into Facility Layout Simulation 4.0, or Engaging Facility Layout design in Digital Twin Systems (Anastasia Panori, et. al., 2021). On other hand, the recent technologies such as Big Data, IoT, etc. can be used in the first phase (Conceptual Design), thus, digital transformation in terms of smart flexible facility layout design is not only participating in adding a new phase, while it can add value to the first phases and facilitate the design processes (Djojodihardjo, H., 2018). Next section will explain deeply how these technologies shall play a significant role in producing real-time design models.

3. Real-Time Design Phase

The This design phase treats the real- time data as inputs to the intelligent systems instead of inserting historical data; the intelligent systems manipulate these data through the embedded algorithms and protocols in microseconds. The information obtained from the sensors installed/attached on shopfloor related to the machines, transportation equipment, human\worker, process time, etc. can be manipulated at once through digital and intelligent systems. For instance, the information of worker movement from machine to machine can be collected and manipulated using certain algorithms; Each algorithm has its inputs and outputs. Thus, when all inputs are available, the algorithm of the digital system can work immediately optimizing the proposed objective. So, it is necessary to monitor certain parameters that fill objective function (fitness function) and constraints. Identifying the required parameters help the designers to know which sensor is more suitable to be installed/attached on the shopfloor.

Data collection and monitoring is the key factors of this design phase; hence the real data assist the overall design system providing a reliable design and high confidence factor to the designers and managers. Data collection from the shopfloor relies on different technologies and sensors can be installed\attached on\within the shopfloor space as shown in figure 2.

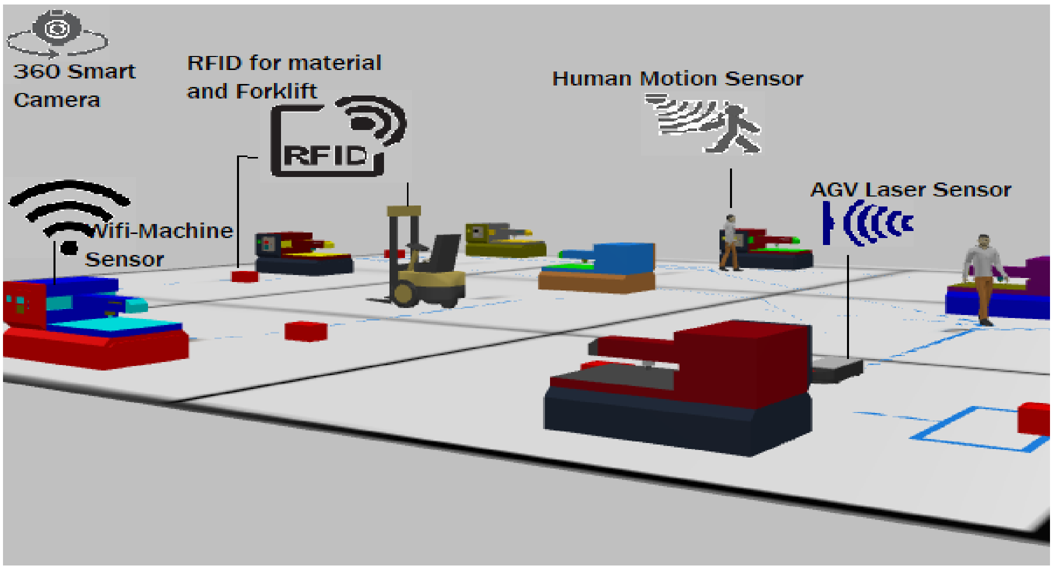

Figure 2: Virtual 3D View shows the possible installation\attachment of Shopfloor Sensors

Flexible facility layout design requires many different parameters such as the destination sequence of the process, the frequency of each two destinations, the time spun between them for the human and equipment, the whole cycle time, the facility intersections on the shopfloor, etc. Each kind of information could require a certain kind of the sensor considering the compatibility, the accuracy, the cost of the sensing system, installation cost, maintenance, etc.

After getting the real-time data, it is crucial to be manipulated using the algorithmic system to start evaluating the status of the current and the possible alternative facility layout models (comparison). At this moment, the decision makers must identify the tipping point parameters in terms of facility layout substitution (the life of each facility layout, Relayout cost, etc.). During the production time (In-Service), the intelligent systems (Advanced simulation software, Digital Twin Systems, or Cyber-Physical System) work to introduce suggested iterative design models. The optimal model can be selected based on decision parameters related to objective function and other managerial parameters.

Thus, this real-time design phase relies on three main design processes: real-time data collection, design evaluation (comparison with the exist one), and optimization and alternative design model selection. These design processes require using different enabling technologies and tools such Internet of things and tracking systems, wearable technology and its support sensors, simulation, cyber-physical system, and digital twin technology.

As we can notice in this online design phase, many new technologies are engaged related to information and communication technology in particular, but this does not mean that the technologies used in the past phases are no longer in service. The recent communication technologies shall enable the designers to produce smart and optimal flexible facility layout relying on real data. The next paragraphs will shed the light on the most popular technologies in this domain and capsulize the concepts of real-time design in a proposed architecture as a prior step of smart flexible facility layout design.

3.1. Data Collection Technologies

3.1.1 Wearable Devices and Supportive Technologies

Wearable devices are mainly applied to collect Human-Based Data; those devices are ergonomically designed to fit with comfort work; it does not disturb the human movement or decrease his efficiency in the industrial environment and workplace; Industrial wearables devices are oriented to four main purposes and functions: monitoring, supporting, training, and tracking. The short-range and mid-range connectivity solutions in industrial wearable applications include Radio Frequency Identification (RFID), ZigBee, Bluetooth, Bluetooth Low Energy (BLE), and Wireless Fidelity (Wi-Fi) (Svertoka, E., et al., 2021).

Plenty of real applications and practical cases exist in industrial companies; for example, Reactec company has designed a wearable device that measures the Hand-Arm Vibration (HAV) amount. This device is attached to the wrist and provides real-time monitoring and automated reporting of HAV exposure. This wearable device application is called HAVWEAR and is utilized by several construction companies to prevent HAV-related diseases such as the white finger syndrome, so this shall monitor the health conditions of the workers. Another important example, DAQRI, maker of intelligent AR helmet solutions, developed a proof of concept for KSP Steel company that enabled shopfloor workers to access control room-level data points on their headsets. The solution was developed by DAQRI, working closely with Kazakhstan Seamless Pipe KSP Steel's leadership team that oversees production to understand better the steel production process, operational challenges, and worker pain points. DAQRI focused on the Hot Rolling Mill line, a set of computerized machinery that can produce up to 110 tons of seamless pipe each hour. The DAQRI headset provided data visualization and control room-level data to the shopfloor workers, reducing trips that they would have to make to the control room. As a result, there were improved efficiency gains, which would ultimately result in improved uptime and reduced occurrences of unscheduled maintenance. (Kaul, A.; and Wheelock, C., 2016).

In terms of Flexible Facility Layout Design, the most essential data identifying the worker's position, movement directions, and time spent for each trip in a relatively limited area, referring mainly to indoor localization. It is important to notice that localization accuracy is still a big issue in such manufacturing as construction or logistics, especially in the indoor environment (Quuppa 2021, Cao, Z, 2018). Ur Rehman, O., et al., 2012, the first group considers the conversion of various parameters to the range. It comprises time-based measurements Arrival Time, Difference of Arrival time, angle-based measurements (Arrival angle, Departure Angle), power-based measurements (Received Signal Strength Indicator (RSSI), in connection with which path loss models are used).

3.1.2 Facility Sensing Technologies

The above paragraph briefly explained Human-based data technologies (Wearable technologies). As well known, the shopfloor contains other important data besides the human-data in the field of logistics and facility layout design, which require different technologies and approaches to be collected in a real-time manner. So, in this paragraph, we will explain the most popular technologies that are working nowadays.

RFID technology has become one of the most useful technologies that are applied in the industrial environment, especially that related and not limited to logistics, equipment tracking, material monitoring, process control, etc. One of the industrial reasons for using this technology is the low cost compared with the other smart technologies. RFID is one of the enabling technologies in this era of Industry 4.0 movement; it helps in transforming the mute machines to smart through embedding the RFID tags inside these machines; It can work with different industrial environments, so this technology could assist in achieving the framework in terms of data collection in real-time considering its limitations and challenges (D. Ambrosini, A. Pirondi, L. Vescovi, F. Arbucci and F. Gabba, 2021).

Smart Camera (smart CAM) is one of the developed technologies that collect accurate data from the industrial environments (Outdoor and Indoor) in real-time. Smart CAM can recognize the movement of the entities on the shopfloor, the direction and time of each facility between two destinations, the operation level (stop or in-process), etc. In short, Smart CAM can replace the human eyes at the workplace, but certainly, there are many limitations related to the environment, company policy, and information security (O'Rourke, K. 2009).

Wireless Sensor Network (WSN) is a promising and developed solution technology for monitoring physical objects and collecting the data from the shopfloor in real-time (C.C. Liao, C.K. Ting, 2017). WSNs enable machines, humans, and the environment to be integrated and monitored. Separated sensors formed WSNs for environmental monitoring or physical conditions, such as temperature, pressure, precision, sound, machine surveillance, facility management, monitoring, preventive maintenance, logistics, and transport, etc. Subsequently, their data bypass via the network to the main location cooperatively (Gherbi, C.; Zibouda, A.; Mohamed, B. A, 2019)

Wireless sensors have sensing capabilities, computation, and communication that can effectively overcome the problems exposed in the RFID and Bar code technologies by deploying many wireless sensor nodes on the shopfloor (V. Damjanovic-Behrendt and W. Behrendt, 2019). For example, placing a sensor device on a piece of equipment to monitor the condition of the environment around the car is a concept of Vehicle as a Mobile Sensor (VaaMS) or it can also be called the Vehicle as a Mobile Sensor Network (VaaMSN) can be a solution to this problem. However, in developing a VaaMSN system, it is necessary to consider cloud computing services to receive, process, and display data (S. Abdelhamid, H. S. Hassanein, and G. Takahara, 2014).

3.2. Communication and Real Time Optimization Technologies

Real-time data collection requires robust communication systems to transfer the data to the cloud or optimization software. As well known, communication technologies create a significant impact on the industry, especially in this era of Industry 4.0. Thus, engaging the communication technologies will activate the design systems and make it work together simultaneously. After inserting the real-data in the simulation software the design optimization process will start immediately. The edge approach in this field (Real-time design phase) is to design flexible facility layout models periodically in a real-time relaying on the above and the next illustrated technologies taking in account the challenges and limitations.

3.2.1 IoT and Cyber-Physical Systems

IoT creates a comprehensive network infrastructure to integrate physical assets and virtual systems by using the Internet. IoT devices use built-in sensors to collect and send data and take actions within a network, as explained previously. So, sensors and data collection form the first layer of IoT architecture (Vaidya, S., Ambad, P., Bhosle, S, 2018).

IoT network layer is the next level of IoT architecture, which relies on cloud computing platform (communication network, Internet, Internet of Things management center); the top layer of IoT architecture is the application-optimization layer (warehouse management, intelligent logistics, intelligent material handling systems, safety, etc.), which can manipulate the collected data, analysis, and perform the optimization process by problem-solution algorithms embedding in the advanced simulation software (optimization software) (Ning lei, 2022).

What is missing in the literature and industry fields, facility layout design and reconfiguration are not included in the top layers of IoT architectures or Digital Twin- Based design frameworks except very few research work with minor manners (Qiang Liu et al., 2021, Jiewu leng, 2019). At the Institute of Transport and Automation Technology at Leibniz University Hannover, the last author targeted the layout optimization for Cyber-Physical material flow Systems using a genetic algorithm; this is a serious attempt and an initial step in the field of digital facility layout design. Another research paper was presented at the Proceedings - 2018 1st IEEE International Conference on Artificial Intelligence for Industries in Florida. The authors discussed intelligent cyber-physical systems for industry 4.0 towards designing facility layouts with hard and soft constraints by evolutionary algorithms.

IoT and Cyber-Physical systems shall play a significant role to build and optimizing flexible facility layout design. So, the suggested framework unifies many concepts and establishes new guidelines in terms of Real-Time Design of flexible facility layout.

3.2.2 Digital Twin Technology and Simulation 4.0

Real-time locating systems (RTLS) as an aspect of digital twin technology are useful to support flexible facility layout design and real-time optimization. Digital twin system is capable of predicting the production and logistic status and provide valuable information for monitoring the performance of material handling equipment, worker, machines thanks to the real-time connections of the RTLS and adaptive iterative simulation models. Furthermore, RTLS can demonstrate how the concept of Simulation 4.0 supports the analysis of human resource effectiveness (HRE) in the production domain.

Tamas Ruppert, Janos Abonyi, 2020, The authors designed Simulation 4.0 framework to satisfy the following requirements: Update the model's parameters based on information extracted from the MES (manufacturing execution system), update the parameters of the model based on data extracted from the RTLS. And utilize the benefits of the object-oriented structure of the Siemens Plant Simulation software. Digital Twin- Driven Simulation is an advanced aspect of Industry 4.0 paradigm. It starts to be expanded on different industrial applications relying on inserting real-time data into the simulation system and sending feedback in microseconds to the central information management system (T. -a. Tran, 2021)

4. Autonomous Digital Twin System Architecture for Smart FL Design: A Suggested Approach

Digital Twin (DT) maturity can be classified into five levels (classes): the higher level is autonomous Digital Twin (Intelligent Digital Twin), which relies on heterogeneous data acquisitions and synchronizing cross-domain models considering real-life changes (physical world changes) without human intervention. Autonomous DT enables processes such as optimization of the process flow, automatic control code generation for newly added equipment in the context of plug and work, and predictive maintenance using stored operation data in the DT throughout the lifecycle (Yong-WoonKIM, 2020). As a long-period Facility Layout strategic plan, the Layout can be changed, the transportation and material handling equipment can be changed too; many statements in the shopfloor can be changed over time.

It is reasonable to consider the intelligent digital twin system architecture to enable the smart, flexible facility layout design in the future, aligning with the recent industrial developments and considering the full automation environment systems. The Intelligent Digital Twin can implement machine learning algorithms on available models and data to optimize the operation and continuously test what-if-scenarios (Behrang Ashtari Talkhestani, 2019). The most important layers in the digital twin architecture are information and functional layers, which are highly integrated and communicated with other layers (Gernot Steindl, 2020), as shown in Figure 3.

Information Layer—Within the Information Layer of the Digital Twin architecture, data is gathered and enriched with semantics and related with other context information. So, the data dimension of the DT becomes an information dimension at this stage (layer). The central element inside the Information Layer is a Shared Knowledge base, which stores contextual information about resources and processes. The Shared Knowledge base acts as a semantic integration layer for run-time data and engineering data by providing access to historical data (archives) and holding contextual information. The idea is to add a control code repository to the shared knowledge assigned to process new data detected from the physical world, which does not exist in the basic models. This method is called Anchor Point Method (B. Ashtari Talkhestani, N. Jazdi, W. Schlögl and M. Weyrich, 2018). To synchronize multiple application models of the Digital Twin, the Anchor Point Method can help when detecting occurring changes in the physical shopfloor and analyze the relations of the changed physical assets within it. In this approach, the current programmable logic controller code of the PLC-controlled system is considered the data source of the current state. This approach shall enable a subsequent adaptation of the changes in the interdisciplinary system topologies and control models and the partial adaptation of ECAD- and CAD models within the Digital Twin system to remain consistent. The method of Anchor Point has been presented in previous works of many authors (B. Ashtari Talkhestani, W. Schlögl and M. Weyrich, 2017). It is essential to know whether any changes to the physical components have occurred to adjust the digital models, highlighting the importance of the Anchor Point Method in detecting changes and synchronizing models (B. A. Talkhestani, N. Jazdi, W. Schloegl and M. Weyrich, 2018).

Functional Layer—The DT processes\services can be grouped by their functionality and build on each other (Zhang, Z., Zhu, Z., Zhang, J. et al,. 2021). Five groups are identified (proposed): Simulation processes, Monitoring Processes, Prediction processes, Control processes, and Reconfiguration Processes. Next to these functional processes, the Shopfloor (e.g., facility layout) Management component covers service registration, discovery, and obtaining status information about the certain process. The information about a process is part of the Shared Knowledge in the Information Layer.

Services/ Processes. An Autonomous Digital Twin of a physical thing must include all the functionalities performed by the asset in the real world on various tasks. These functionalities are stored in the autonomous Digital Twin as different processes. Examples of such processes are human movement and manual material handling, Automated Guided Vehicle (AGV), or Forklift, which can move, load, drop or unload, etc. (Vermesan O. et al. 2021). These functionalities can be utilized by other Intelligent Digital Twins for various purposes. For example, an Intelligent Digital Twin's processes can be used within a what-if simulation condition in communication with different DTs to make the most proper decision for reconfiguring a system based on new needs and available resources. Or the Intelligent Digital Twin of the process can manage the shopfloor tasks of the real asset by searching and finding suitable processes of production systems. However, an essential point with the Intelligent Digital Twin is that these services can be continuously expanded as real assets change.

Simulation Processes are the core Processes, as they are part of the Virtual Entity of the DT concept. Typically, there is one model of the physical entity in a DT, but a set of executable models is specific for the intended purpose and evolve. Different models for various domains, like the equipment movement, loading\unloading, picking, human behavior, manufacturing\assembly processes, etc., can be hosted and used inside the Simulation DT's Processes Jonas Friederich, et al., 2022).

Monitoring processes are elementary Processes to acquire data from the physical entity and observe its current state. An example could be a fault detection process, which can be implemented based on simple statistical models and indicate abnormal operating conditions of a shopfloor. Monitoring processes in combination with Simulation processes is to gain more insight into the current state of the Physical Entity (Tiep Nguyen, et al., 2022).

Prediction processes are important for the DT to make decisions based on future events. Such processes can be used, for instance, for predictive maintenance or the prediction of equipment flow. Also, external variables, like adding new equipment or changing the equipment, can be predicted. Additionally, external prediction processes can be integrated. For example, control processes can use the prediction results to realize an optimized control or generate recommendations for the operating staff (Dimitris Mourtzis, et al., 2021).

Automatic Control Processes influence the operation of the shopfloor via recommendations over Anchor point as an assistant system. Automatic Control Processes with automated self-access can bypass the Smart Data Process in the Information Layer to change the state of the physical entity without additional delay. Usually, the Control Process uses monitoring and prediction services to achieve optimized operation (E. Jharko, 2021).

Reconfiguration Processes. Reconfiguration means a rather static change of the fundamental properties of the Physical Entity by the DT itself. This has a significant influence on the context information inside the Shared Knowledge. For example, reconfiguration can be initialized through events or changed objectives inside the business logic, which resides inside the business layer (Jiewu Leng, et al., 2020).

The proposed framework is not the only configuration or architecture in this design aspect, the practitioners can follow other roadmaps and focus on different design entities, goals, and organization desires. The concern facility layout problem itself can guide the designers to identify the goals and propose the most convenient framework of digital design. We think that the possibility for applying and engaging this kind of design framework will be popular next decade according to the recent advent and progression in different technologies, especially in ICT and advanced simulation software.

The designer shall face plenty of limitations and challenges related to this approach itself (internal) and others related to the industrial companies, government rules, stakeholders, workers, contractors, etc., but the vision in the industrial field is heading to digitize most of the aspects starting from the design implantation and not limited to production and shipment.

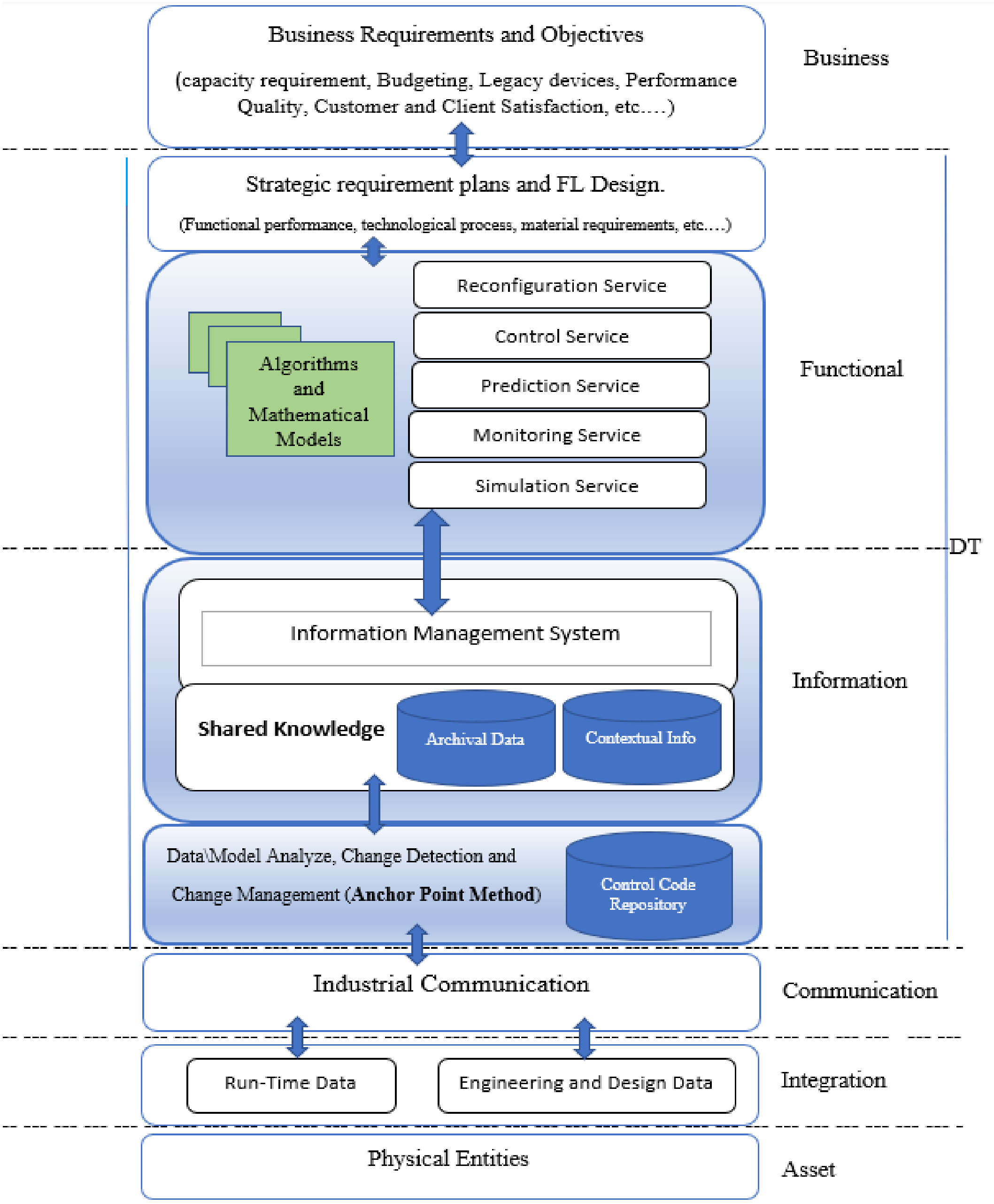

Figure 3: Autonomous Digital Twin System Architecture for a Smart Facility Layout Design

5. Ongoing Case Study and Discussion

Applying the suggested framweork is going on through digitizing the assets, real-time data collection of the human and the machine on the shopfloor using RFID technology- Based IoT, and Simulation Software based on optimization algorithms. The case study relying on collecting the data from mechanical workshop and manufacturing department. The purpose is to automate the process of real-time data insertion from the shopfloor into the simulation software in real-time. After getting all the required data, the simulation software starts running to produce optimal models (Real-time optimal model). Right now, we transformed the traditional Method-Time Measurement (MTM) into MTM4.0 (Fantoni G., at al., 2021), and traditional Spaghetti Chart (SC) into SC4.0 as enabling tools to transform the tradtional FL simulation into (FL Simulation 4.0). but it is necessary to mention a plenty of limitations and challenges for this long journey.

The limitations and challenges related to real-time design phase can be divided into main five parts: human issues, hardware fail and maintenance (e.g., manufacturing machine, AGV), poor communication, information security and system integration, and organization culture.

Human issues can be divided into two main areas: legal considerations, and human motion prediction. One of the challenges of implementing digital monitoring "human 4.0" is the compliance with the GDPR. The consent and awareness of each worker is necessary to create legal environments that are ethically delegated by agreement rules and GDPR compliant (Calvetti, D, et al., 2020). Another important issue related to the human is motion and behavior prediction, which are difficult to be systemize in the simulation programs due to the unconstrained human action on the shopfloor, so it is highly recommended to train the workers following the instructions and process plan accurately and supported with lean tools (Vatsal, V., 2021).

Machine fail and maintenance influence on the efficiency of the digital twin system. Hence, the unpredictable breakdown of the machine will impact the whole production processes and provide low amount of real-data for the concern machine, which requires urgent maintenance to return in the service as soon as possible. This uncontrollable intervention shall affect on the real-time design process. The practitioners work on preventive maintenance with Decision Support System (DSS) to reduce eliminate this kind of intervention (Anis Assad Neto, et al., 2021).

Poor communication is another hard technological problem that has the development of connectivity solutions and propagation models in underground work sites (Jiayang Zhang, et al., 2022). The problem of the existing solutions like Wi-Fi, Zigbee, Bluetooth, cellular technologies lies in short communication distance and high delay. Simultaneously, the need to develop a reliable technology for this field is undeniable and creates a direction for further research. As mentioned before, localization accuracy is still a big issue, especially in the indoor environment (Shahmoradi, Javad, et al., 2020).

Information security and system integration (Diego Mendez Mena, Ioannis Papapanagiotou, Baijian Yang, 2018) mentioned that information security and privacy has emerged as a significant challenge for each layer of the Internet of Things architecture (perception, network, and application), enabling technologies and protocols (e. g., Wireless Sensing Network, RFID, Bluetooth, Zigbee) have many limitations and security challenges such as attacks on authenticity, attacks on confidentiality, attacks on availability, privacy concerns, optional or weak encryption, Non-secure default settings , weak PIN usage, Insecure unit keys, etc. Another challenge is information integration with other\main information systems (e.g., Enterprise Resource Planning Software). Hence, It is obviously understood that successful integrated enterprise solutions rely on the validity of aggregated enterprise information, which are collected from different sensors and systems; it is absolutely complicated in some environment (R. G. Qiu, 2007).

Organization Culture and readiness (responsiveness), the culture and privacy of the organization workers that prefer not sharing their personal information with the employer, (M. Kritzler et al., 2015) in state that this problem could be eliminated by a clear explanation of the purposes of the implementation of wearable technology in the enterprise, Some workers cannot quickly learn how to use the wearable device and do not want to spend additional time on it, considering the traditional way of the work process as the most convenient and the only possible. Some organization managers do not prefer changing the current technologies, it is hard to convince them the recent technologies aligning with digital transformation can enhance the overall performance of the organization systems (S. A. Bahlooq, M. A. Omar and T. Mezher, 2020, Singh, R.K., Kumar, P. and Chand, M. 2021).

6. Conclusion

The above limitation and challenges are research trends; they shall be controllable, especially the facility layout design\redesign is not instantaneous decision because it usually depends on weekly production data basis or daily production data basis in the small enterprises, while the direct influences shall affect on other production management aspects such as process plan, productivity, safety, etc. so, the impact of these drawbacks shall not affect strongly on the facility layout design like the other aspect that requires an immediate actions.

The proposed framework seems promising and able to algin with this Industry 4.0 movement, especially when the practioners can overcome the challenges mentioned above. Our future work will focus on the real-data collection and automatic insertion into the simulation software transforming to Simulation 4.0

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