CUSTOMER CASE STUDY

Layer picking in intralogistic: securing the integration of a technological breakthrough with WorlLab™

ABSTRACT

CUSTOMER CONTEXT & BUSINESS PROBLEM: The customer needed a preliminary design solution to conduct exploratory analyses of an automated warehouses featuring a groundbreaking technology, so they can take the best high-level architectural design decisions before moving to more detailed and costly analyses with more specialized tools.

SOLUTION IMPLEMENTATION: Development of a formal model featuring a few high-level parameters with Σ™, our system specification language. Data-driven derivation of parametric distributions representing external input / output logistic flows of a warehouse. Integration of the digital twin that significantly reduces the time required to modify and redeploy the digital twin in case of new inputs / changes in model parameters from project stakeholders.

RESULTS AND TAKEWAYS:

- A systemic digital twin of the system of interest, able to handle:
  - Interactive simulations: to showcase the content of the model to stakeholders – facilitating trust building and adoption and to study the context (or cause) of a known inefficiency / bottleneck.
  - Stochastic simulations: To explore the performances of various operating conditions and warehouse design variations, while integrating all meaningful causes of randomness. Prevent huge investment mistakes, anticipate surge load, help to staff the teams accordingly.
- Business and data analyses, bringing high added value to the customer, on top of the digital twin.

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CUSTOMER OVERVIEW & CONTEXT

The customer is a leading turnkey intralogistics systems provider, specializing in designing and implementing advanced automated warehouse solutions for clients in various industries.

They faced a challenge with a new project to develop automated warehouses capable of supplying points of sale in dense urban zones. These warehouses needed to be compact and fast to cope with high demand and limited physical space. Traditional piece or case picking methods using Automated Storage and Retrieval Systems (ASRS) and fast Autonomous Mobile Robots (AMR) were not sufficient because requiring a large implementation footprint.

They opted for a new kind of system that could work with slower (but stronger) mobile robots, able to process entire layers of a pallet at once.

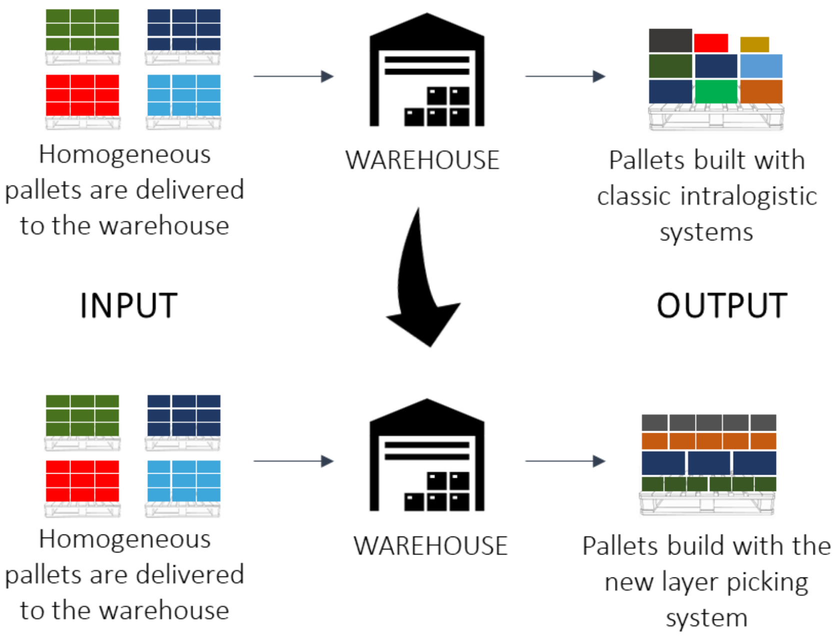

Figure 1: The new technology introduces a change in the input/output paradigm.

An automated warehouse with this new layer picking technology is an incredibly complex system, and relying on engineering judgment alone is not an option anymore because of the novelty factor. Designing automated warehouses featuring this kind of system constitutes a challenge for engineers, as they had hard time to grasp the consequences of local decisions on the rest of the system and understand the effect of fluctuating operating conditions on its overall performances.

BUSINESS PROBLEM

In order to conduct research and development activities of new “turn-key” solutions integrating this kind of system and facilitate answers during tender processes, the customer needed a tool they can use in preliminary design, able to conduct thorough design space exploration at a macroscopic level.

They wished to be able to take the best high-level architectural design decisions, based on a “few” critical design levers, while avoiding wasting time performing detailed and costly analyses on warehouses configurations that were not viable.

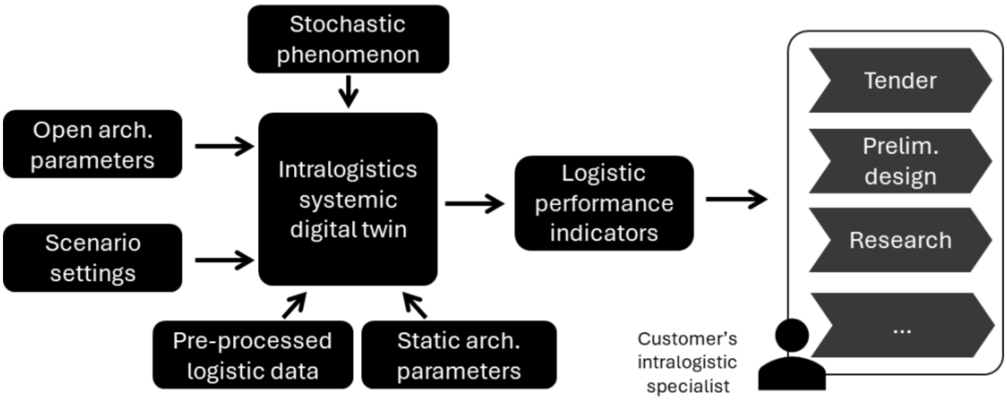

Figure 2 : Value chain of the Systemic Digital Twin

In this business context, two key use cases that were of particular importance to them.

Use case 1 – <u>Analysis of the impact of load and delivery profiles variation</u>:

- For a given warehouse architecture, what would be the impact of a higher-than-usual load – of various amplitude - on warehouse activities?
- Warehouse supplies can be sometimes very regular, or delivery trucks can arrive by batch. What is the impact of delivery fragmentation on warehouse activities?

Use case 2 – <u>Optimization of logistic assets fleets and process variation:</u>
For a predictive and fixed intensity of warehouse activities, to maximize the utilization rate of costly assets and minimize buffer inflation.

- What is the optimum size for the various fleets of assets?
- What is the best automation-to-human ratio for the logistic activities in the warehouse?

SOLUTION IMPLEMENTATION

The implementation of a systemic digital twin with WorldLab™ invariably starts with a business analysis of the system of interest. In this case, the flow of palletized goods within the warehouse has been traced from an entry point to an exit point. Every step involved in the processing of pallets has been thoroughly characterized by our analyst team – including its input and output, the resources it requires to function properly and the impact of a missing resource, the activities performed to turn inputs into outputs and the key parameters that can be handled by engineers as part of the preliminary design analysis of a warehouse.

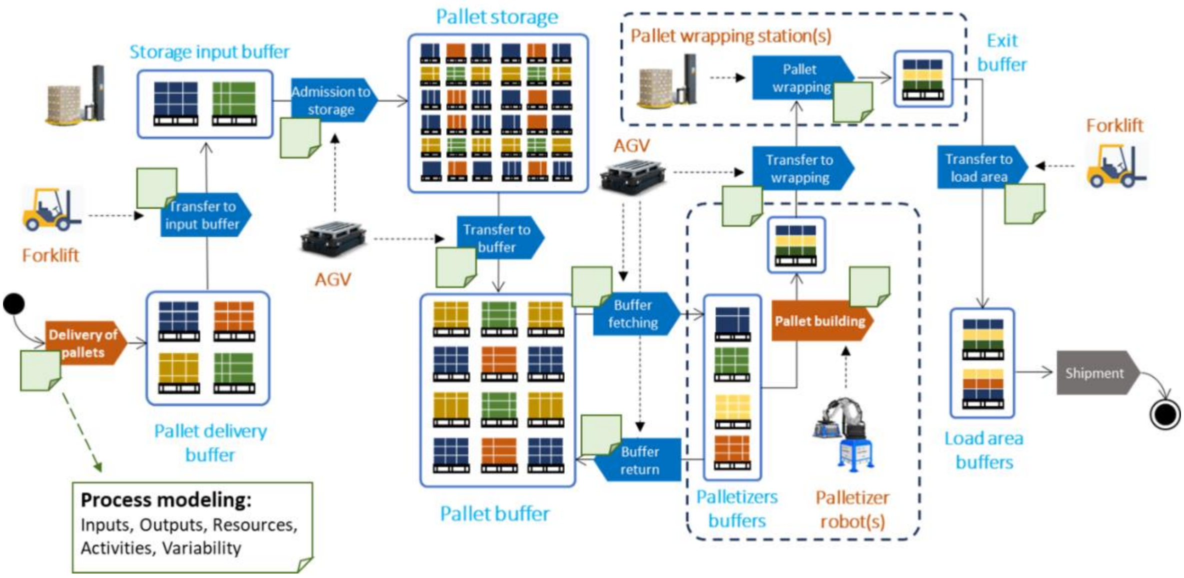

Figure 3 : Overview of the business analysis conducted prior to formal process modeling

Thanks to its dedicated primitives, Σ™ allows to build a formal model aligned with the business analysis of the system of interest.

```
system Automated_Warehouse

    // Model parameters
    parameter WeeklyPalletQty weeklyPalletQty (unit = "pallets/week")= P2700 ;
    parameter ArrivalProfil arrivalProfil (
        unit = "MIXED, MORECLUSTERED, MOREUNIFORM")= MOREUNIFORM ;

    // Model key variables
    int dayOfSimulation (init = -1);
    initialisationState initialisation (init = STANDBY) ;
    State clockState (init = STANDBY) ;
    int clockHour (init = 6);
    int clockMin (init = 0);
    DayPeriod dayPeriod (init = OFFHOURS);

    // Model subsystems structure
    system TrucksDeliveryArea ... end
    system DeliveryArea ... end
    system StorageInputArea ... end
    system MainStorageArea ... end
    system BufferingArea ... end
    system PalletizersArea ... end
    system WrappingArea ... end
    system LoadArea ... end
    system Shareressources ... end

end
```

Figure 4 : Σ™ code allowing to declare the systemic structure of the warehouse, as well as the highest level parameters and variables

Once the model is compiled with WorldLab™, users run simulations over one day of operation: the automated warehouse is exposed to externally driven logistic flows: deliveries and customers' demand. These I/O flows are of variable intensity from one simulation scenario to another, and throughout the simulated day.

The data used as "operational scenarios" for simulations have been derived from "real life" warehouse data. Data analyses were performed on large sets of data from a warehouse handling similar kinds of wares, covering several months of operations. It allowed us to build a statistical model of the pallets' delivery and ordering processes.

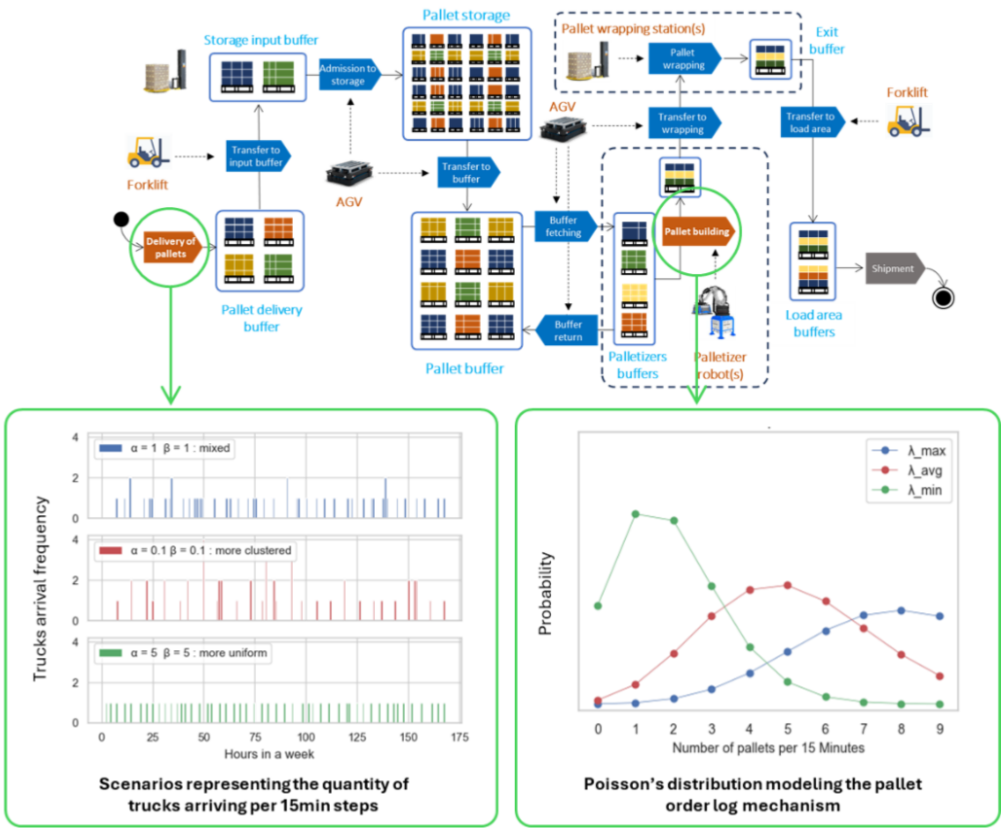

Figure 5 : Mathematical distributions to quantify the input / output flows of the wares

These data models are generated by an external data pipeline, which can be configured at the beginning of a simulation to extrapolate a very large variety of hypotheses regarding the operational conditions of the warehouse. The data model generates files prior to a simulation, and the simulator load the data at runtime.

The key use cases of the digital twin require the assessment of high-level indicators, which must take into account the uncertainties featured by a large variety of phenomena involved in the functioning of the automated warehouse.

This is made possible thanks to the stochastic simulation capabilities of WorldLab – but requires that a day's worth of operations must be simulable in a very short amount of time:

- The main pitfall would have been to pick a too-detailed level of abstraction which would make simulation costly to execute.
- However, being too "high level" would have led to missing important issues.

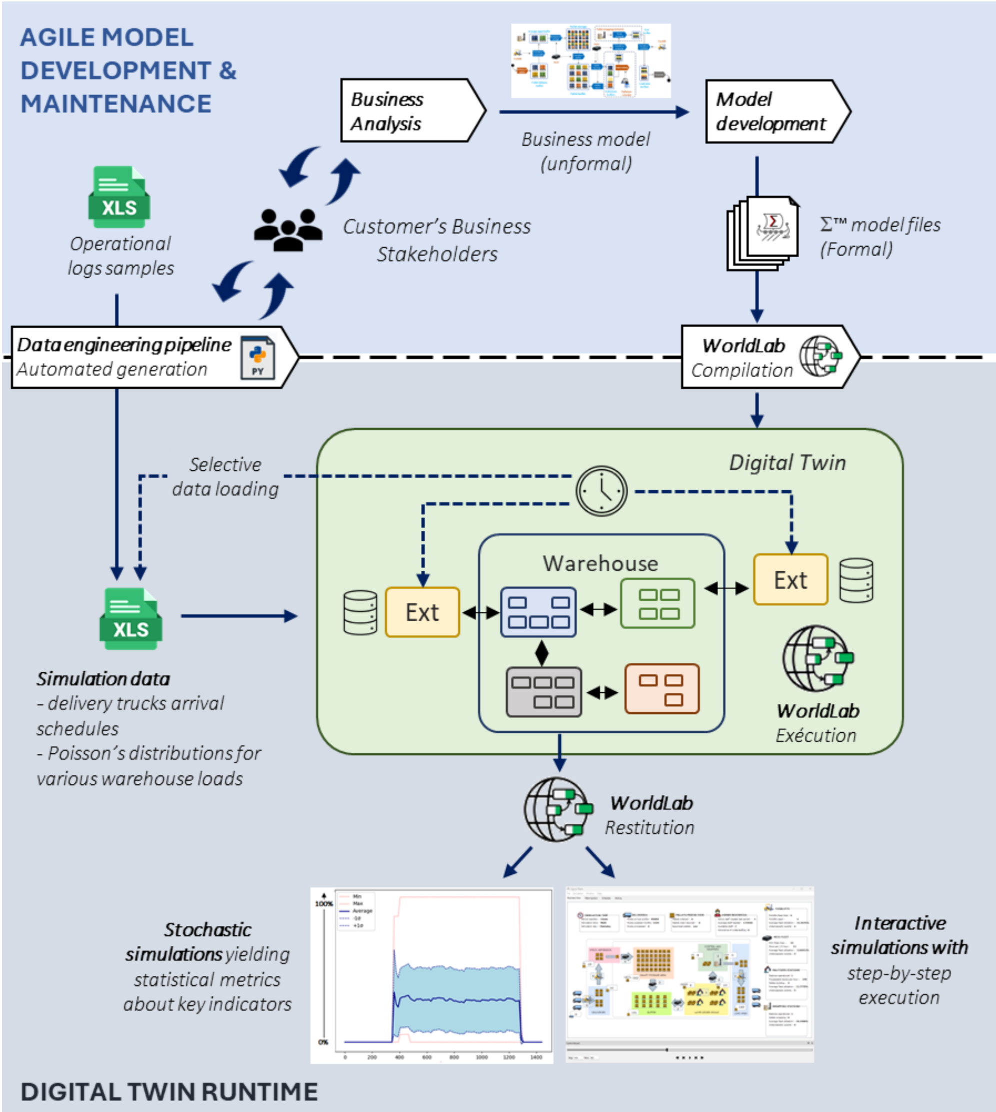

Figure 6 : Model development and runtime logic illustrated

WorldLab is an excellent tool to manage this kind of concern, as it allows to abstract away details that are irrelevant, while giving the opportunity to its users to "zoom in" on things that are important to solve the business problem, and to integrate various abstraction level seamlessly.

A time abstraction has been added on top of the structural abstraction through a capacitary approach. We simulate logistic activities "atomically", with a fixed time step; At each time step, each fleet of assets / resources has a limited number of operations they can perform, for instance: the palletizers can process X layers and the AMRs have a limited numbers of "capability points" which they spend on scheduled logistic operations. The capacities of each fleet are driven by their performance, allowing the user to conduct trade-offs between various solutions – Capacity can also be impacted by random phenomena. For instance : fetching a pallet from the ARSR can take more time – hence consuming more capability points – if it is stored deep into the storage area.

RESULTS AND TAKEWAYS

Business analysis: The business analysis of the industrial system of interest is a mandatory step to ensure an efficient implementation of the formal Σ™ model. It is also a valuable project output, as it gave the stakeholders a well-documented, unified "bird's eye" view of the system of interest and its operational environment.

Data analysis: Data analyses were performed on large sets of data from a warehouse handling similar kinds of wares, covering several months of operations. It allowed us to build a statistical model of the pallets' delivery and ordering processes - which are driving the course of the simulations. This mathematical model can be tweaked and scaled up or down to explore a large array of operational scenarios.

Interactive simulation capabilities: WorldLab™ provides a module called WorldLab™ Player, which leverages the Σ™ model and the outputs from the data analysis to offer the capability to control the flow of simulation step-by-step and to access model variables & metrics using an explorer. It is also equipped with a simple yet powerful interface description language, allowing to project in real time variables & metrics onto tailor-made interfaces.

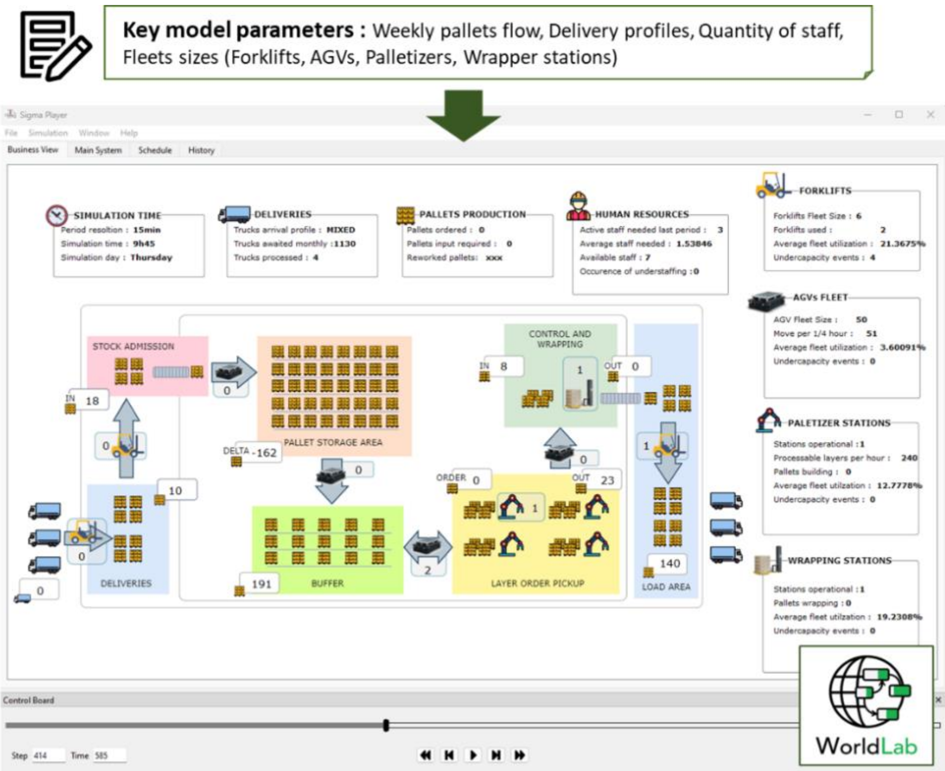

Figure 7 : WorldLab Player allows to run simulations step-by-step, with support of custom interfaces

The interactive simulations were particularly useful to validate and debug the model. It was also very valuable to showcase the content of the model to stakeholders, which facilitated its adoption. It was also used extensively when users wanted to study the context (or cause) of a known inefficiency / bottleneck.

Answers to the business problem: Running a series of experiments leveraging the stochastic simulation capabilities of WorldLab allowed users to assess the risks related to several feared events - such as the inability to dispatch an order due to the apparition of a bottleneck or the shortage of a particular kind of resource.

The “baseline” configuration is a “medium” sized warehouse that is properly designed to work with good performances in a standard operation context.

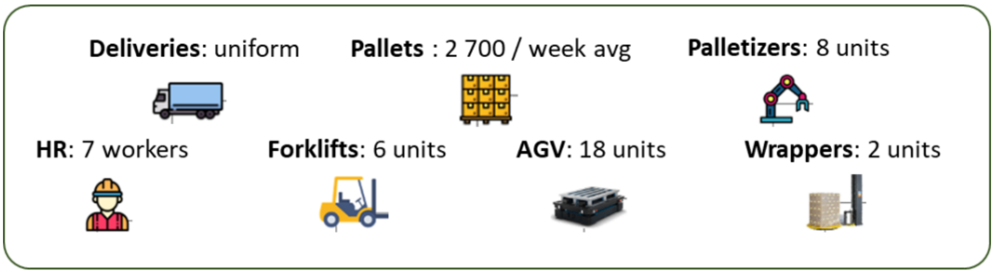

Figure 8 : Key model parameters for the "baselined" warehouse, with a nominal operation scenario

On the plots below: the thick blue line is the average over 10 000 runs of the same simulation, the light blue area represents the maximum of likeliness and the red dashed curves represent the min / max values witnessed. All key resource business indicators are good and peak capacity is rarely reached: For instance, below is the evolution of the load rate for human resources (around 40% average), and for AGVs (60 % average).

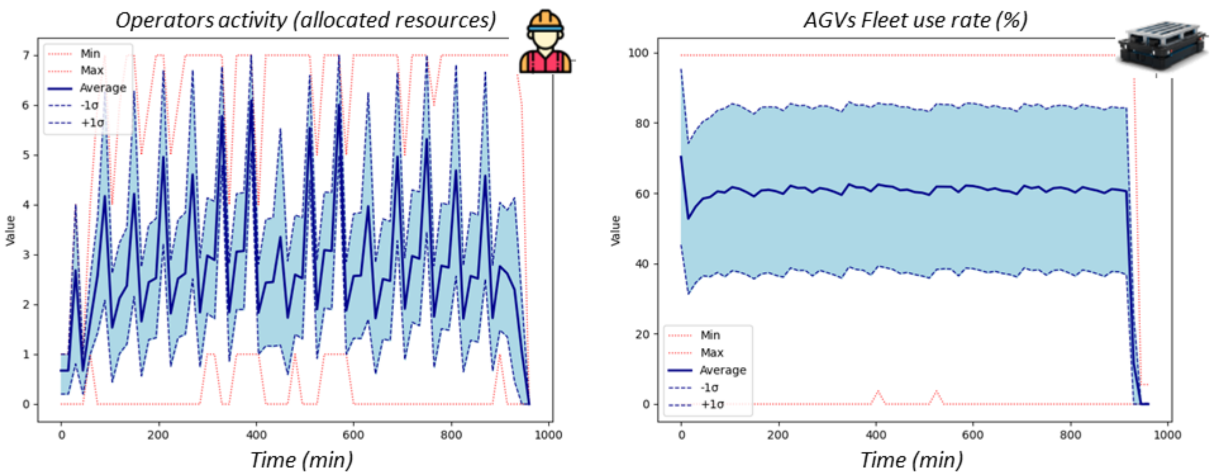

Figure 9 : Utilization charts for operators and AGVs, two critical resources in the warehouse (10 000 runs)

Also, there is no persistent accumulation phenomena that occur in key buffers zones: below an illustration with the pallet’s delivery area, and the palletizers orders backlog.

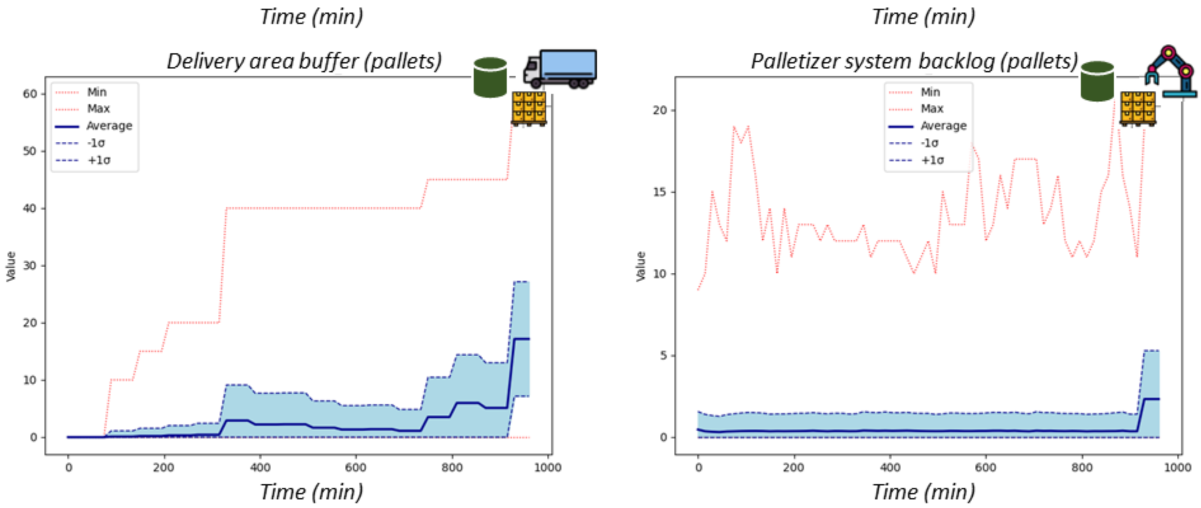

Figure 10 : Evolution of key buffers with a nominal operation scenario (10 000 runs)

To simulate the event of a sharp rise of warehouse activity, of +50 % averaged over a week corresponding to a period of sales – for instance. The model can be easily reconfigured with the following parameters.

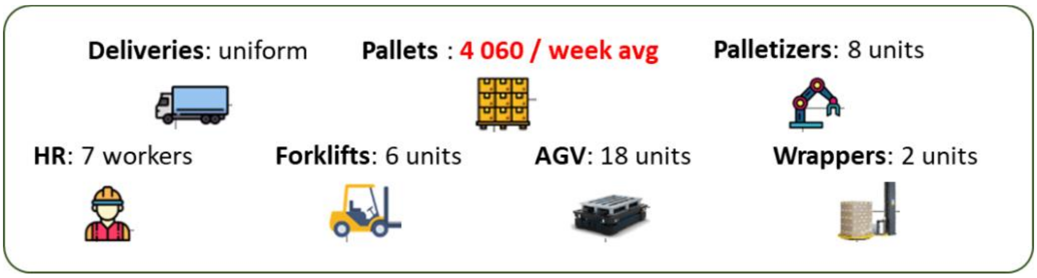

Figure 11 : New set of key parameters to simulate a "surge" in activities.

The simulations now show that the palletizers – based on the baselined size of the fleet and allocated performance - run at full capacity throughout the day in most of the scenarios. AGVs are quite solicitated too (mean + std dev of utilization rate ~95 %)

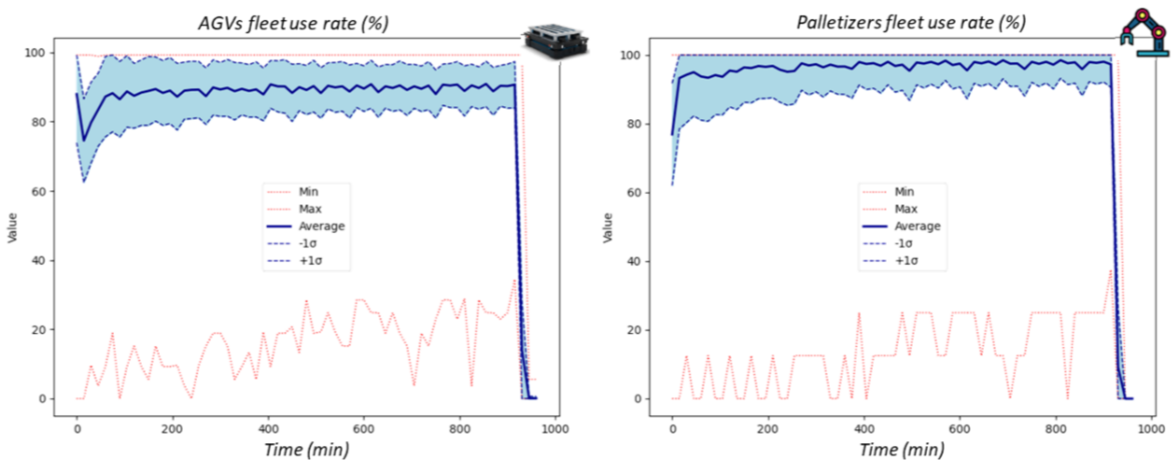

Figure 12 : Utilization rates throughout the day for AGVs and palletizers stations with an activity surge (10 000 runs)

This causes the apparition of a significant build-up of orders in the backlog at the end of the day, as illustrated on the next figure. Conducting several experiments based on the key design levers of the warehouse, we can takeaway that - to be effective in surge scenarios – the operator of the warehouse would need 2 extra palletizer stations (about 200k€ each) and 6 extra AGVs (about 100k€ each). However, this 1M€ of extra equipment would be idled most of the rest of the time. We are able to quantify the number of orders that cannot be processed by the "baselined" warehouse during a surge day:

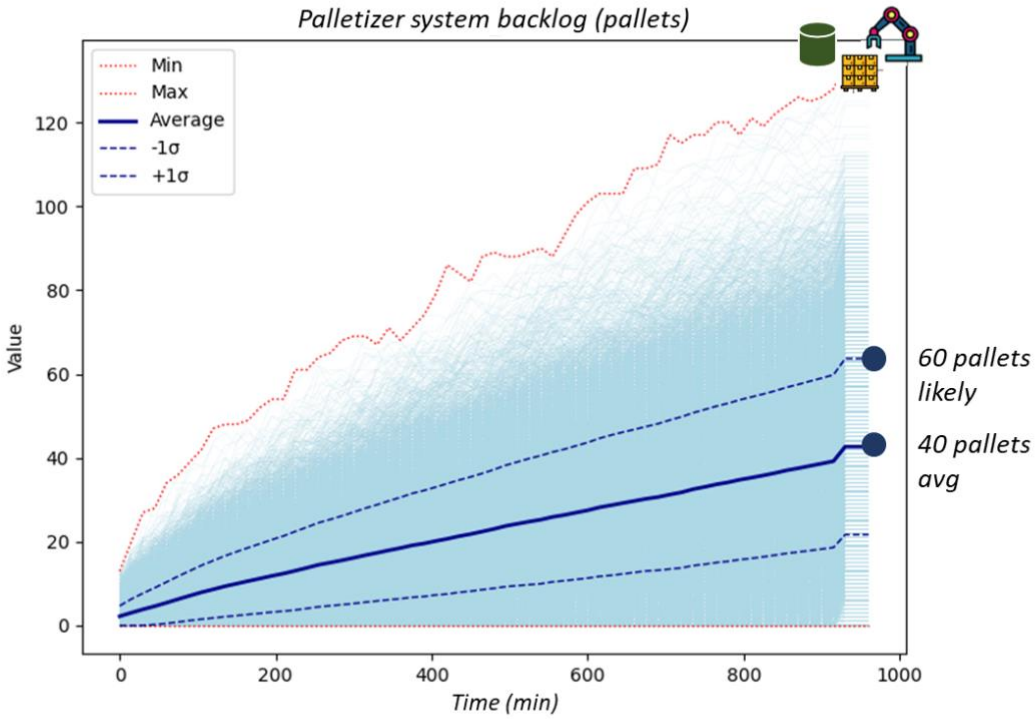

Figure 13 : Evolution of pallets orders backlog through the day, plotting each of the 10 000 simulation runs

Estimation shows there would be a need to build ~120 pallets a day, which is a worst case – most scenarios do not reach 90 pallets.
As these events are rare and predictable, hiring the right quantity of temporary human resources is a much better solution than acquiring new machines.

(1) The digital twin allows to avoid making large investment mistakes and determine the performance degradation due to surge loads.
(2) As logistic operators are sometimes a rare kind of resources, the digital twin also allow the user the determine quite precisely the number of extra operators they have to hire and anticipate the risk severity and likelihood of being short-staffed in case all positions cannot be filled.
(3) The digital twin provides direction to designers as to which extend human operators and automated systems will have to collaborate in order to absorb the order backlogs of the most severe