Kit Fulfillment Center Serving Distributed Small-Series Assembly Centers in Hyperconnected Supply Chain Networks

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What is Kitting and What are the Benefits of Kitting?

- Bozer and McGinnis (1992) defined kitting as the practice of **preparing kits containing predefined quantities of parts that serve specific assembly efforts in the manufacturing plant**.

- Kitting **saves space** around the assembly line, as all parts will be stored away from the assembly line and only required parts will be fed to the assembly line in kits when needed.

- Kitting **improves assembly labor efficiency**, as organized kits saves time for assembly workers on finding the parts required for assembly.
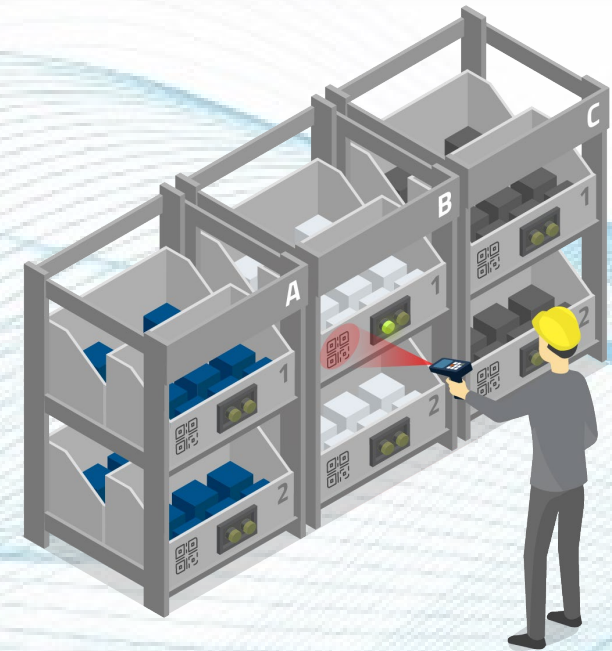
Kitting + Fulfillment + PI = π-Enabled Kit Fulfillment Center (KFC)

- **Kitting:** KFCs produce kits serving multiple short-series agile assembly centers (AACs).

- **Fulfillment:** The short-series nature of the AACs creates variable demand for KFCs. KFCs receive orders from AACs and fulfill those orders like fulfillment centers.

- **PI:** KFCs serve AACs in a π-enabled hyperconnected supply chain network. The kits produced by KFCs are multi-level kits contained π-containers.
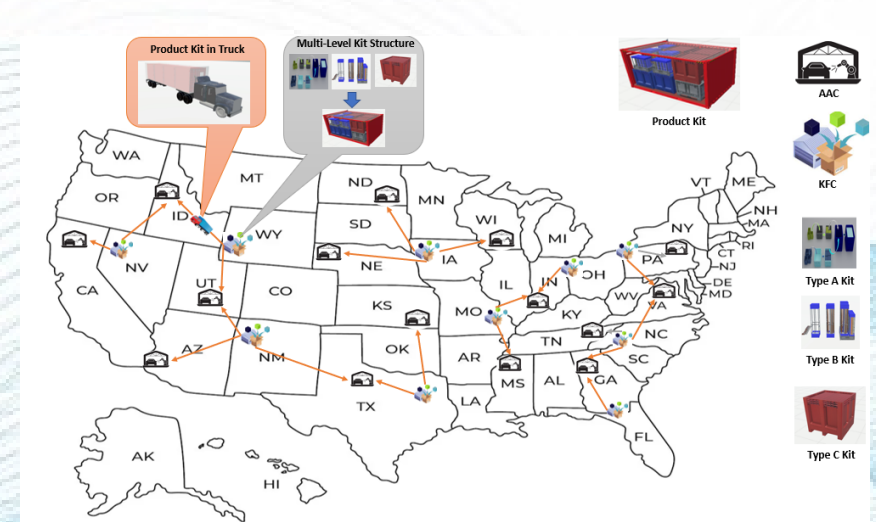
Multi-Level π-container Kits: Levels of Kits

- **Task Kit:** Kits that contain all the parts that are required by an assembly task in AAC.

- **Skill Kit:** Kits that contain all the task kits that are required in a specific takt time by a team of worker with a specific type of skill in a workstation.

- **Workstation Kit:** Kits that contain all the skill kits that are required in a specific takt time in a workstation.

- **Product Kit:** Kits that contain all the workstation kits that are for a product.
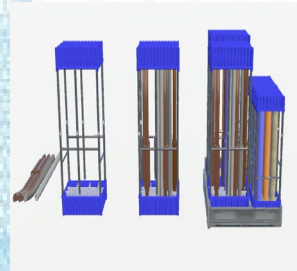
Multi-Level π-container Kits: Types of Kit Containers

Type A Kit Container

Kit containers that contain parts that fit in a modular packaging container and are not heavy.
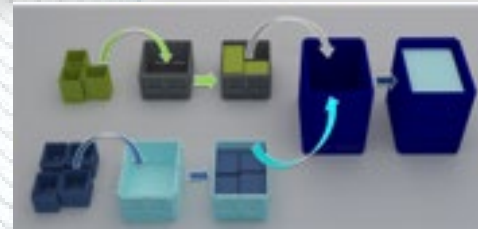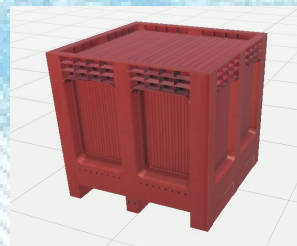
Type B Kit Container

Kit containers that contain parts that are elongated but are not heavy.

Type C Kit Container

Kit containers that contain parts that are large and heavy. Sometimes, it is the original packaging of the part.
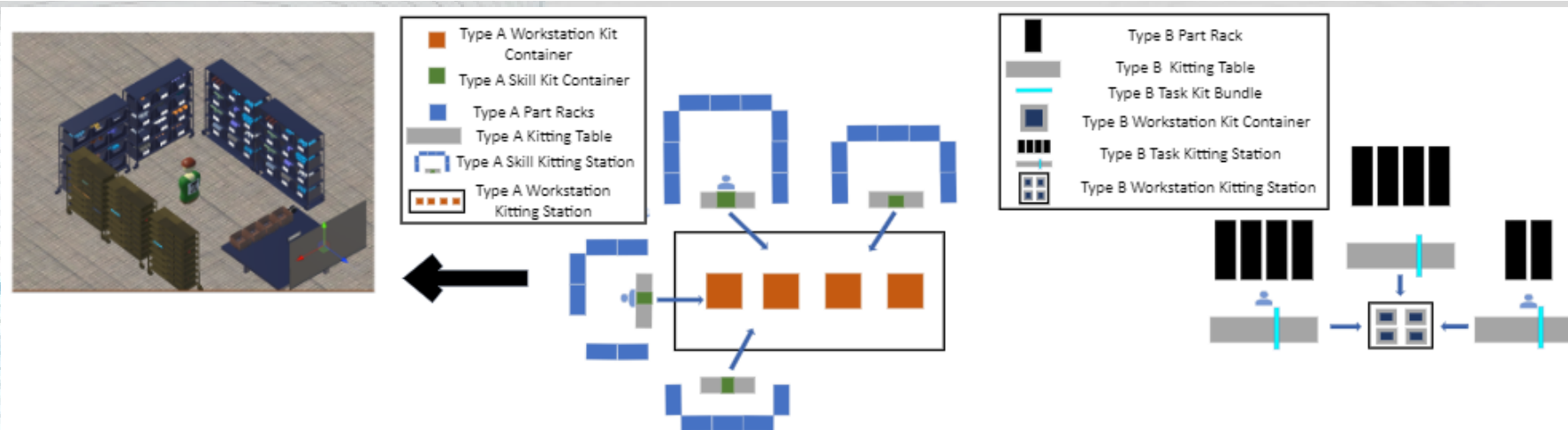
Product Kit Container

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Organization Model

Type A and Type B Kitting

- **Reconfigurability** is important for KFCs due to the variable demand from AACs. The **modular kitting cell design** enables quick and easy reconfiguration under changing demand.

- To **improve space efficiency**, the kitting process requires no intermediate inventory space between different levels of kit, lower-level kit containers are put directly into higher-level kit containers upon finish.

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Product Kitting

Type A Workstation Kit Staging

Type B Workstation Kit Staging

Type C Part Staging

Product Kit Container
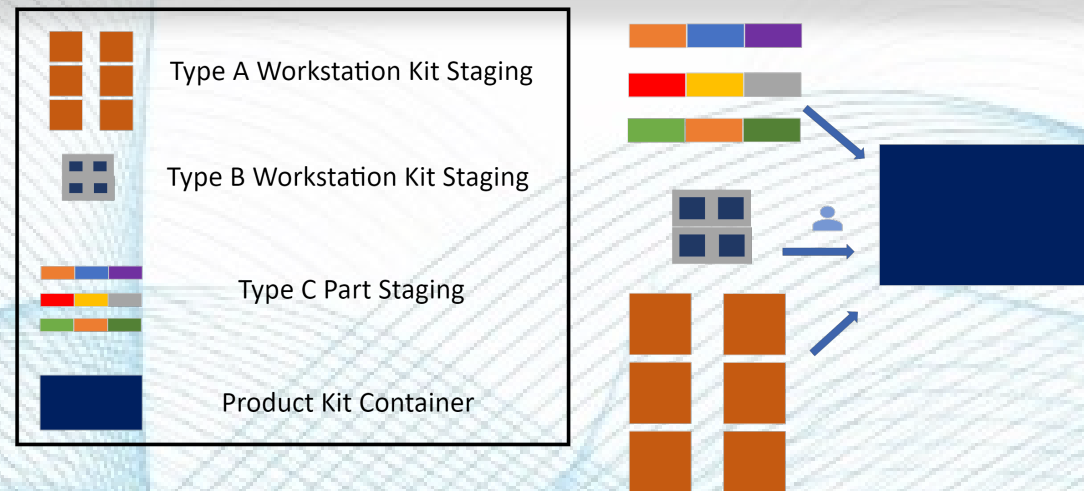
- To keep the **integrity** of the product kit, product kitting workers move type A, B, C workstation kit containers into the product kit container (modular transport container) in the order that complies with the designed arrangement inside the product kit container.

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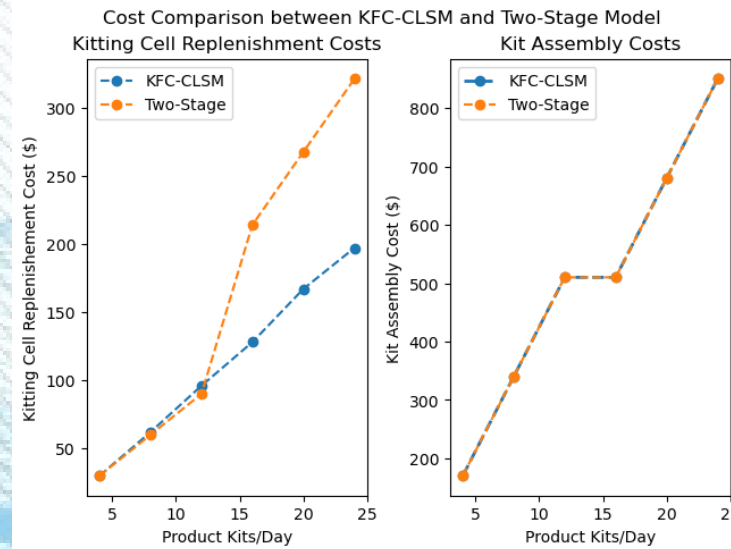# Configuration and Labor Scheduling Model KFC-CLSM
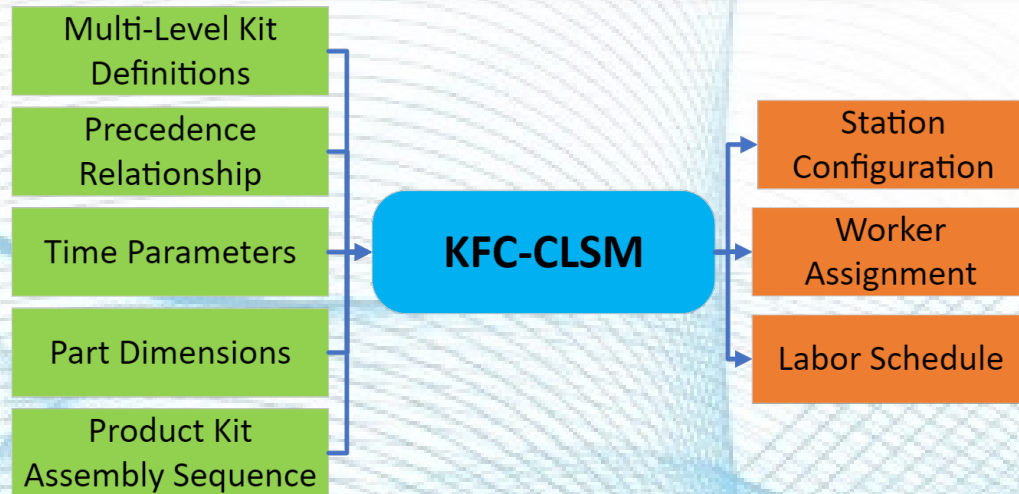
- For kitting, the part assignment to kitting cells (**station configuration**) poses constraints on kitting task assignment to stations (**labor schedule**). KFC-CLSM solves this problem by solving these two problems in one step.

- KFC-CLSM is a mixed integer linear optimization model that **configures kitting stations** and generates **worker assignment** and **kitting labor schedule** in one step, minimizing **kit assembly and kitting cell replenishment costs**.
- **Station Configuration**: whether a kitting station is closed or open, and what parts are assigned to each kitting station and their quantities.
- **Worker Assignment**: which worker is assigned to each kitting station.
- **Labor Schedule**: The working schedule of workers.

KFC-CLSM Experiment Results

- The performance of KFC-CLSM was compared with a two-stage model under different demand scenario on the synthetic automobile manufacturing multi-level kit definition provided by our industrial partner.
- The two-stage model solves for station configuration first, and then solves for worker assignment and labor schedule with the same formulation as KFC-CLSM. Since parts are unique between different skills, the two-stage model pre-defines kitting cells that are designated to skills and replicates those kitting cells to fulfill demand.

Cost Comparison between KFC-CLSM and Two-Stage Model

- The KFC-CLSM has much **lower kitting cell replenishment costs**, especially in higher demand scenarios. As expected, the **assembly costs were always the same** for the two models, since having all part types of each skill available in the designated kitting cells gives the two-stage model more flexibility in labor scheduling.
- For kitting, the part assignment to kitting cells (**station configuration**) poses constraints on kitting task assignment to stations (**labor schedule**). KFC-CLSM can achieve global optimality by solving station configuration and labor schedule in one step.

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Operating Model
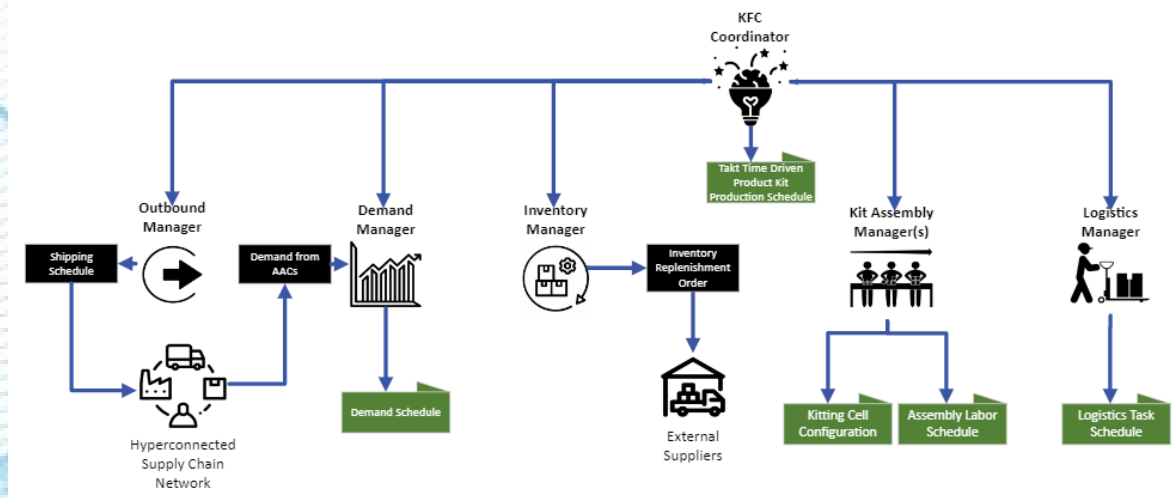
- The **demand manager** receives kit production orders from vicinity AACs in the supply chain network.
- The **KFC coordinator** then assigns kit production tasks to kit assembly centers and generates takt-time driven kit production schedules for each kit assembly center.
- The **kit assembly manager** of each kit assembly center generates kitting cell configurations and labor schedule, and assigns the assembly tasks to workers according to the schedule.
- The **logistics manager** generates logistics task schedule and assigns them to workers.
- The **outbound manager** schedules outbound trucks to make sure all product kits will arrive at their corresponding AACs on time.
- The **inventory manager** constantly monitors and manages the stock level and storage position of each part type in the inventory and sends inventory replenishment orders to external suppliers when necessary.

Kit Flow Logic in AACs
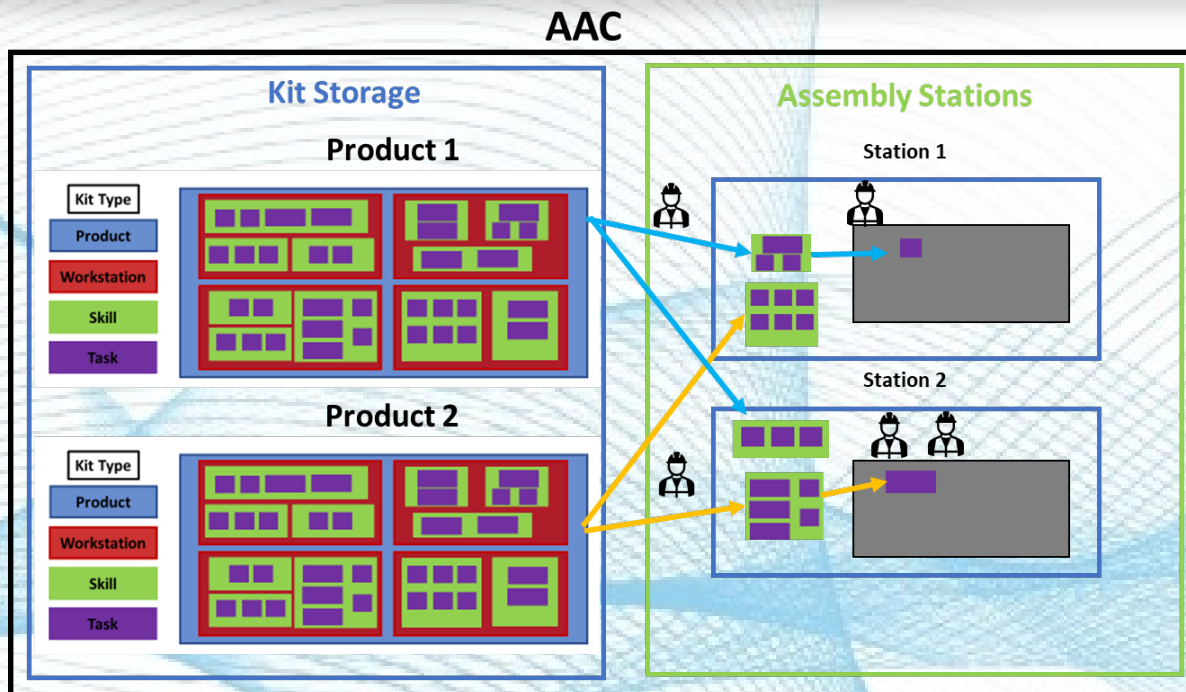
- When a **workstation kit** is required at a workstation, the logistics workers in AACs moves the workstation kits to corresponding workstation.

- Then, the assembly workers take the **skill kit** that are required by their skill type from the workstation kit.

- For each task, the assembly workers take the corresponding **task kit** from their skill kit.

- After consumption, the kit containers will be transported back to KFCs to be reused.

Thank you!
Questions?