**Supply Chain Analytics**

**Question 1: Production Planning Model (Skateboard Company)**

**Problem Statement:**

A company produces skateboards in the US and must plan monthly production for the upcoming year. It can produce up to 30,000 units per month under regular time, and up to 15,000 additional units under overtime (at higher cost). The cost of production is $32 per unit for regular time and $40 per unit for overtime. There is an initial inventory of 2,000 units, and holding cost is $5 per unit per month.

**Objective:**Minimize total cost (production + overtime + inventory holding) while satisfying monthly demand and adhering to capacity constraints.

**Result:**

* The minimum total cost to satisfy all monthly demands while meeting capacity constraints is: $11,247,000
* The optimal plan efficiently balances regular production, selective overtime, and inventory carryovers.

A screenshot of a computer

AI-generated content may be incorrect.

**Question 2. Kellogg Planning System (KPS) Case Analysis**

**Ans: 1.Main Supply Chain Issues and Scope**

The Kellogg Company, as the world’s largest cereal producer, faces significant supply chain challenges due to the complexity and scale of its operations. Key issues include:

* **Diverse Product Portfolio:**

Kellogg manages over 600 SKUs across approximately 80 core products, with multiple packaging formats for each. These SKUs are processed across more than 90 production lines and 180 packaging lines, increasing the complexity of scheduling and capacity allocation.

* **Multiple Production and Distribution Locations:**

Operations span five company-owned plants, about 15 co-packers, and seven distribution centers, working across approximately 27 unique sites. This geographically dispersed network requires careful coordination to balance production, packaging, shipping, and inventory across locations.

* **Capacity and Operational Constraints:**

The production facilities must respect processing and packaging capacities, which vary by plant and product. Additionally, production scheduling must account for constraints such as packaging compatibility, shipment freshness (especially for products like Variety Paks), and seasonal demand fluctuations.

* **Operational vs. Tactical Planning Needs:**
  + **Operational Level (Weekly):** Involves detailed production, inventory, packaging, and distribution planning over a 30-week rolling horizon, with near-term decisions fixed to account for material lead times. A typical weekly model handles a 30-week planning horizon and includes detailed production, packaging, inventory, and shipping decisions.
  + ***Tactical Level (Monthly):*** Involves longer-term decisions related to budgeting, capacity expansion, and network optimization (spanning 12–24 months), including handling shelf-life constraints via heuristics.

In summary, the scope of KPS spans both real-time operational scheduling and strategic tactical planning to address production, inventory, and distribution challenges in a highly dynamic market environment.

**2. Planning Approach and Tools**

Kellogg developed a customized optimization tool—the **Kellogg Planning System (KPS)**—to address these challenges. The planning approach consists of the following components:

* **Linear Programming Model:**

KPS is built on a large-scale linear programming (LP) framework that extends the classical production-inventory balance model:

**Inventoryₜ = Inventoryₜ₋₁ + Productionₜ − Demandₜ**

This equation is used across multiple time periods, SKUs, production lines, plants, and distribution centers. The system accounts for:

* Capacity limits at each facility
* Flow-balance across production, packaging, and shipment stages
* Safety stock targets to buffer against uncertainty

**Elastic Constraints and Penalties:**

To introduce flexibility, constraints such as capacity and inventory requirements are modeled as **elastic goals**, allowing the model to slightly violate them at a cost. This models the real-world need for **overtime**, **subcontracting**, or **inventory shortfalls**, providing a system-wide optimal response.

**Dual-Model Structure:**

* The operational model is solved weekly and fixes immediate decisions (e.g., week 1) to account for raw material and packaging procurement lead times.
* The tactical model avoids unrealistic long-term production-storage combinations by using a sliding 5-month window to enforce shelf-life limitations.

**Rolling Horizon and Solution Persistence:**

KPS operates on a **rolling horizon**, with new data integrated weekly. Production for week 1 is fixed by Sunday morning, while week 2 onward remains adjustable. Weekly runs take **20 minutes** on a 500 MHz Pentium III or **2–4 hours** on older DEC Alpha machines.

**Managerial Interface and Adjustments:**

Although KPS generates an optimal plan, production planners adjust it for practicality. For example, if the model suggests fractional production runs (e.g., one-third of a shift), managers may consolidate into **whole-shift schedules** to minimize setup costs and align with labor requirements.

**3. Limitations and Recommendations**

Despite its successes, KPS has several limitations that could be addressed in future enhancements:

* **Deterministic Framework:**  
  The current model is deterministic and does not explicitly account for uncertainty in demand, yields, or capacity. Instead, Kellogg uses safety stock rules to buffer against variability. A stochastic or robust optimization model could provide more realistic insights under uncertainty.
* **Absence of Raw Material Modeling:**  
  KPS does not incorporate raw material constraints, primarily due to data complexity and maintenance concerns. Incorporating raw material flows could further refine production planning.
* **Continuous Decision Variables:**  
  The LP model allows for fractional production values (e.g., one-third of a shift), whereas actual production processes require integer or discrete decisions. Transitioning to a mixed-integer programming (MIP) model could better represent real-world production scenarios such as setup times and minimum batch sizes.
* **Shelf-Life Handling:**  
  The tactical model uses a heuristic sliding time window to manage product shelf life. A more rigorous, age-differentiated inventory model would improve accuracy but at the expense of increased model complexity.
* **Integration with ERP Systems:**  
  While KPS is a standalone tool that complements Kellogg’s ERP system, deeper integration with real-time data and advanced forecasting systems could enhance decision-making and responsiveness to market changes.

**Recommendations for Improvement:**

* Develop a stochastic or robust optimization variant to explicitly handle uncertainty in key parameters.
* Enhance the model by incorporating integer constraints to better reflect production realities.
* Integrate raw material planning to capture the complete supply chain.
* Improve shelf-life modeling using time-indexed inventory variables.
* Consider closer integration with ERP systems for real-time planning adjustments.

**Conclusion**

KPS is a sophisticated and high-impact optimization tool that supports Kellogg’s operations and strategy across multiple levels. It has delivered **$4.5 million/year in operational savings** and **$35–40 million/year from tactical initiatives** like plant consolidation. Despite being deterministic and continuous in structure, its flexible constraint design and rolling horizon planning make it practical and effective. Future enhancements using stochastic modeling and MIP could take it even further.