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Plant design and control in food service industry. A multi-disciplinary decision-support system

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A B S T R A C T

Every day, thousands of pupils, students, employees, and hospital patients eat food outside their homes that is cooked far from the place of consumption. The food service industry is responsible for supplying this food to schools, hospitals, nurseries, as well as to company canteens. The design, control, and management of food service operations is challenging given the complexity of such multiple facility production networks and entails multidisciplinary perspectives and competences. Both production and logistics operations play crucial roles and significantly affect the service performance as long as food products are prepared within a facility, and as long as they are distributed to multiple consumption sites. Hence, there are many planning decisions (e.g. the definition of the production facility location, the allocation of task to resources and the scheduling of production jobs), that are handled at different stages by different actors, who often decide based on their own practical experience and barely adopt integrated decision-support systems.

A review of the literature shows that there is no integrated approach to support the design of food service production facilities, known as centralized kitchens (CEKIs). To facilitate such integration and assist food service managers to adopt quantitative and data-driven design approaches, this study proposes an original computer-based multidisciplinary decision-support tool for the design and configuration of a CEKI. The proposed tool aids decisions taken by multiple actors simultaneously through a set of interfaces driven by quantitative data that follow the logistical flow of materials throughout the CEKI (1), assesses performance indicators in a multidisciplinary dashboard (2), and implements what-if, multiple scenario analyses based on simulations (3). Graphical interfaces are designed to facilitate communication between the decision makers and the integration of data-driven analyses. The design of a new CEKI is used as a testbed for the decision-support tool. The real-world example highlights the interdependencies between issues and decisions and showcases how computer applications facilitate decision-making and improve communication between managers.

1. Introduction and background

Every day, thousands of pupils, students, employees, and hospital patients, eat food outside their homes that is cooked far from the place of consumption. The food service industry is responsible for supplying warm, safe, and tasty food to schools, hospitals, and nurseries, as well as to company canteens; this industry has been gaining increasing importance in the last decade. One third of private European companies outsource their food services to food service providers [1]. In Italy, up to 41.8% of meals are consumed outside homes [2], and 15% of these are served by the contract catering sector [3]. In Europe, the turnover of the food service industry is approximately 24 billion Euros [1]. The economic, social, and educational importance of food services is hence not negligible.

The design, control, and management of food service operations is challenging given the complexity of such multiple-facility production networks and entails multidisciplinary perspectives and competences. Many decisions are expected to be managed in the food service industry. The long-term strategic design of a catering service entails the determination of the processing technology, the allocation of cooking resources, their localization on the plant layout, and the selection of the recipes and related working cycles. Tactical issues deal with the selection of suppliers and configuration of the menu. Short-term operational decisions aim at the continuous improvement in the performance of the food production process, and involve daily sequencing of processing

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lots, scheduling of recipes on resources, vehicle loading management, and vehicle routing for the delivery phase.

Both production and logistics operations play a crucial role and significantly affect the service performance as long as the food products are prepared within a facility and last-mile distributed to multiple consumption sites. However, most of the issues are concerned with, or are caused by the inadequate design of the production facilities or the lack of proper management of food processing operations. It is not difficult to fathom how the design of a production facility affects its processing capability, resource allocation and utilization, safety, quality, and the cost of supplied products. Nowadays, food consumers enhance their expectation on food quality, taste, ingredients and their origin (e.g., organic vs. GMOs, low-fat, local). While this is beneficial for consumers, it results in an increased complexity in production and logistical tasks in food service that ultimately leads to hundreds of working cycles (i.e., recipes) and thousands of working tasks.

To address such complexity, production facilities need to be flexible and efficient. Maximizing the throughput (i.e., meals per hour), minimizing food cost, and reducing the consumption of energy—in agreement with safety standards and rules—are some of the divergent goals of these production systems. A food service company may operate according to two alternative service models [4]. Cook-serve service (1) occurs when the production is decentralized, located inside the point of consumption, and is managed by a contract catering company. Within decentralized kitchens the meals and recipes realized per day are few, and the type of decisions, typically of operational nature, alike. Conversely, deferred service (2) is when a facility, namely a centralized kitchen (CEKI), owned by a company produces meals for many points of consumption. Fig. 1 shows the complexity involved by representing the entities within a CEKI that are primarily involved and provides a graphical glossary of the terms and background notations used in this study.

Despite the typical food processing system built by automated lines, the increase in the production mix justifies the configuration of a CEKI as a job shop, whereby a homogenous set of *resources/working stations* are assigned to different departments. Each resource (e.g., oven) is located on a *control point* (CP) on the plant layout and is responsible to perform a specific production task (e.g., baking, grilling, and boiling). The material flow of ingredients and work in progress (WIP) throughout the *production process* is guaranteed by manually handling tasks performed by operators.

A middle-size CEKI is able to prepare, pack, and deliver more than 10.000 meals per day by working in a short-spanned time batch (e.g., from 5.00 A.M. to 11.30 A.M. for the lunch service); it can provide food service within a short-range, usually at distances that are under 30 km. The type of service is also characterized by the temperature at which the meals are distributed at. Three alternative temperature profiles are possible:

- Cook-warm: the product is cooked and maintained warm (above 65 °C) until it is consumed
- Cook-and-chill: the product is cooked, blasted, and delivered to the customer who rewarm it before service [5]
- Cook-chill-and-rewarm: this is when cook-and-chill products are rewarmed at the CEKI and delivered according to the cook-warm profile

Among these profiles, cook-warm is the most critical for safety issues because the product's temperature must be maintained above the danger zone (4–65 °C) at which bacteria propagate exponentially [6]. The cook-warm meals should be conserved at conditions that are outside the danger temperature range to comply with safety rules and standards from the time they are produced until their consumption, and should be necessarily subjected to continuous and expensive hazard analyses and critical control points (HACCPs), as well as monitoring and control of the processing tasks.

The design of a CEKI implementing these three production temperature profiles simultaneously is another degree of complexity that needs to be handled.

Furthermore, to enhance the flexibility of this complex production-mix, most of the processing tasks are performed manually by operators. Semi-automatic resources/working stations (e.g., peeling and cutting tools) are adopted for some activities, but most are similar to those carried out in a domestic kitchen. Material handling is usually manual to avoid generating bottlenecks and new HACCPs. Therefore, congestions, availability of handling vehicles and tools (e.g., cars and rolls), WIP accumulation, and delays are the most crucial in-site issues from a logistics perspective.

As illustrated in Fig. 1, a CEKI is made of multiple departments specialized in processing different ingredients or WIPs, e.g., vegetables and meat, raw-food, and cooking and packing departments.

For each recipe/working cycle, the material flows throughout the departments are convergent as typically occurs in other assembling systems, e.g., for electronic devices and automobiles. Ingredients are cut within the preparation departments, then

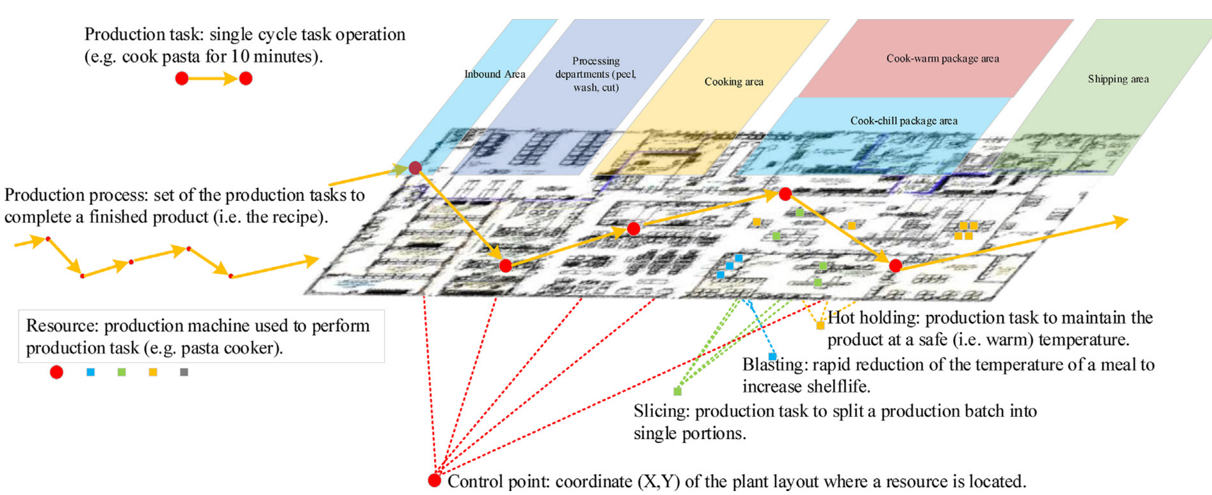

Fig. 1. Graphical glossary and main CEKI's entities.