Analysing reusable and disposable containers costs in food catering supply chain networks using optimization

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Abstract: Nowadays, strategies to minimize environmental impacts throughout food supply chains (FSC) are hotspots for academics and practitioners. A relevant portion of such impact results from food primary and secondary packaging. Food Catering Supply Chain (FCSC), made of multi-stage logistic networks, represents a challenging scenario for minimizing packaging disposal. Indeed, the booming widespread of reusable plastic containers (RPCs) in the FSC suggests the adoption of such containers to foster reuse and prevent material waste with respect to disposables. This paper explores the application of RPCs in the context of FCSC by proposing a MILP model that aids supplier and package choices considering the reusable package-pooler and the catering system networks. This model minimizes operational and logistic costs whilst optimizing the packaged product's flows. A case study provides the model's validation and offers insights for future research investigations. Results show that increasing the numbers of supply chain actors and the size of the logistic network make the adoption of RPCs economically convenient.

Keywords: Reusable Plastic Container, Food catering industry, MILP, Disposable containers, Food cost

I. INTRODUCTION AND STATE-OF-THE-ART

Anthropogenic needs, as human nutrition are among the main cause of climate change [1], [2]. Indeed, the food industry and food supply chain represent a hotspot, calling for scholars and practitioners to propose an urgent solution [3]. The food supply chain comprises processes from production to parceling distribution of packed products. Operations like harvest, consolidation, sizing, peeling, packing, and final distribution are drivers of economic, environmental, and social analysis [4]. Several studies underline logistics processes as an important driver of pollution and GHGs emissions throughout the supply chain [5], [6]. Food Catering Supply Chain (FCSC), made of multi-stage logistic networks, represents a challenging scenario for minimizing the distances traveled by food. In FCSC, warehouses (known as cross-docker) receive packaged food from the vendors and compose orders for the final customers. In such operations, warehouses might change the package hierarchy to satisfy customers' demands, thus generating package waste. Due to its pivotal role, the cross-docker is crucial for this kind of supply chain. Although the literature proposes mathematical models to optimize the supply chain, not all the costs incurred by the cross-docker are considered.

[7] estimate the energy savings potential that can be achieved using inflatable dock shelters versus simple curtain dock shelters for loading/unloading activities in logistics warehouses without considering the logistics optimization. [8] propose an innovative resolution of the vehicle routing problem but do not account for package purchasing and disposal costs. [9] formulated a mixed-integer programming model for perishable product cross-docking scheduling but missed to investigate the transportation and disposal cost for empty packages. [10] focus on integrating vehicle scheduling and routing with time windows in food cross-docking supply chains, but they do not implement the orders' consolidation.[11] propose a simulation model to analyze a multi-compartment distribution system with customer demands for shorter lead times constraints. Albeit the innovative insight and results shown, they do not incorporate package hierarchy decisions.

This paper models the FCSC and investigates how the choice of the secondary and tertiary packages in food-ordering affect the overall costs and the network topology. To assess the convenience of reusable or disposable packaging choices, a sensitivity analysis is proposed. The following section introduces and discusses the model and the generalized network. Section 3 presents the case study. In Section 4 we interpret the results, whilst in Section 5 conclusions are proposed.

II. METHODS AND MATERIALS

This section presents a mixed-integer linear programming (MILP) optimization model to handle packaged fruits and vegetables ordering from the perspective of the cross-. The objective is to suggest a secondary package for each supplier (2), to plan the handling and picking operations and manage flows of RPC and packaged food between the supply chain's actors while minimizing the overall logistic costs. The objective function minimizes the overall costs accounting for the transportation cost to deliver packaged food from the logistic provider to the customer and from the supplier to the provider, the management cost to supply the empty RPC from the poolers' facility to the food supplier, the packaging disposal costs, and the handling cost due to the logistics provider inbound operations.

A. *Network modeling and system boundaries*

The modeled catering supply chain for fruit items encompasses four main actors: the package pooler's, the suppliers, the order-picking warehouses (known as cross-dockers), and the catering customers. Supplier nodes receive and consolidate food products from the wholesalers and growers' consortia. Food products are washed, selected, packaged, and sent to intermediate warehouses. Warehouses or cross-dockers receive packaged food from suppliers and draw up orders for customers. Customers are private or public entities (e.g., schools, hospitals, and catering services) that cannot be supplied directly from large distribution centers because of the average size of the order. Each order is indeed made of a few containers of fruits, or even some fruits within one crate, and needs to be prepared at the cross-docker and to couple with the cooked meals at the centralized kitchen. The customers' orders d_{cipt} set the choice of package hierarchy (i.e., secondary and tertiary package type and size). The cross-docker may move the product from the supplier's package into the customer's package to satisfy the customers' requests. The initial single-use package must be then disposed of from where is emptied. RPC poolers' facilities manage the RPCs supply chain, managing the inventory of cleaned containers when and where needed.

The introduction of RPCs in the catering supply chain compels new partnerships among the supply chain's actors and adds the pooler to such a system. In such a context, suppliers, distribution centers, and customers can evaluate RPCs instead of disposable containers, resulting in the generation of new flows of RPCs, as shown in Fig 1. The pooler facilities ship the empty containers to the suppliers. Suppliers fill the RPC with perishable products, consolidate orders, and send full containers or full-pallet orders to the warehouses. The presented catering supply chain network is shown in Fig.1.

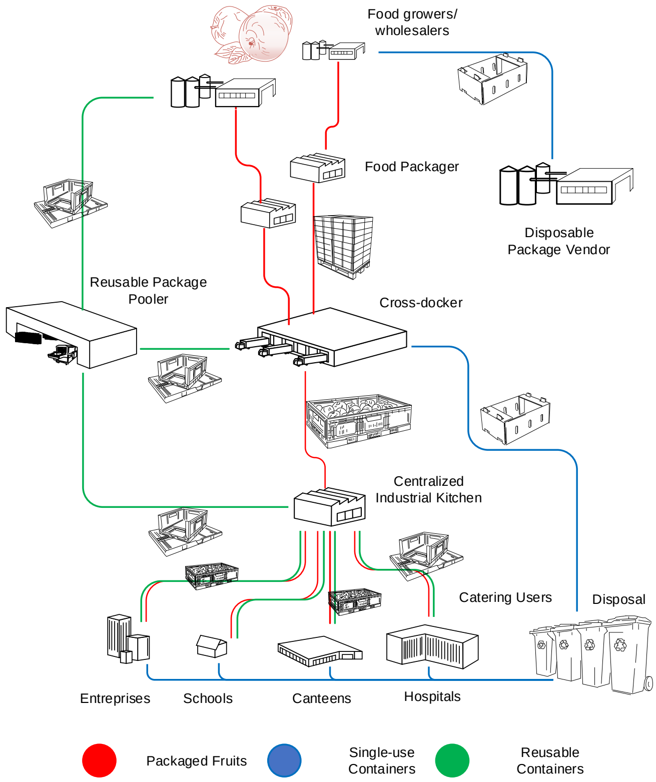

Fig. 1. Fruit and vegetables Catering SC network.

B. *Mathematical formulation*

In this network, the warehouse also behaves as a pooler facility, holding container inventory, replenishing the supplier's inventory, and collecting empty containers from the customers. The model assesses the convenience of the RPC system in logistic costs and waste reduction. We considered a set R of RPCs pooler facilities (including warehouses), a set V of supplier facilities, a set C of customers, and a subset $W \subseteq R$ of warehouses implementing the new management system.

Sets:

$v \in V$:	Set of suppliers
$i \in M$:	Set of perishable products
$c \in C$:	Set of customers
$r \in R$:	Set of RPC nodes/package makers
$w \in W$:	Set of warehouses
$p, p^{in}, p^{out} \in Pkg^{II}$:	Set of secondary packages
$t \in Pkg^{III}$:	Set of tertiary packages

Cost analysis comprises the cost of the logistic operations to satisfy the customer's requests and manage the distribution network of RPC. Costs can be organized into four groups: (1) packages cost, (2) disposal cost, (3) transportation cost from suppliers to warehouses and from warehouses to customers, and (4) handling cost.

To account for the cost of packages, the model considered the secondary package quantity times the unit cost of the package, whilst for the tertiary package, only the transportation costs are taken into account. Other transportation costs are related to supplier-warehouse, warehouse-customer, customer-pooler’s facility, and pooler’s facility-supplier paths. The cost of internal handling is estimated in terms of the labor hourly cost at the warehouse. The person-hour is the time necessary to record the incoming goods and manage their handling between inbound and outbound. The time required to move the products within the warehouse includes the handling made by the operators through the receiving dock, the storage cells (i.e., the reserve area), and the picking area. The regional waste tax and the weight of disposed of packages account for the package disposal cost.

New flows of empty packages are defined in the modeled network. Suppliers receive empty RPCs from pooler facilities whilst customers send them the empty RPCs. Since warehouses are considered an RPC pooler, they also send empty containers to suppliers. Such flow is modeled with the cost parameter paid for one pallet of empty RPCs. Transferring costs are paid whenever RPCs are unavailable at the supplier and the warehouse changes the package configuration, generating an extra handling cost. Two types of flows for the empty containers are generated. The former determines the disposal of non-returnable containers, whilst the second is for the consigned RCPs returned from the catering customers. The model quantifies the flows of disposal and delivery of empty containers and minimizes the overall cost.

Parameters:

lc	Labor cost at warehouse w[€/h]
wc	Waste cost for warehouse w [€/kg]
vp	Hand pallet truck average speed [m/s]
ht	Registration time for products i [h/kg]
$cPkg_{rp}^{II}$	Max number of package p storable in node r
Ep_{vw}	Transportation cost for one pallet from suppliers v to warehouse w [€/pallet]
ps_v	Number of secondary package types at supplier v
di_{wi}	Distance from in bays and storage area for product i at the warehouse w [m]
kp_p	Number of containers of type p for one pallet [container/pallet]
Ec_p	Cost for type p package [€/container]
wg_p	Weight of empty secondary package p [kg/container]
$tcPkg_t$	Transportation cost for one pallet of empty CPR container [€/km]
o_{vi}	Capacity of product i for supplier v [kg]
kgc_{ip}	Max weight of product i in secondary package p [kg/container]
cp_{vp}	Setup cost to use package p for the supplier v [€]
Ecl_{wct}	Transportation cost for tertiary package t to costumer c [€/Pkg^{III}]
$distrv_{rv}$	Distance between r node and supplier v [km]
$distrc_{rc}$	Distance between r node and customer c [km]
$nPkg_{rp}$	Capacity of package p in node r
$nPkg_{pt}$	Capacity of tertiary package t to contain secondary package p
$ncPkg_{pt}$	Number of close reusable container p contained in tertiary package t
$ht_{ip^{in}p^{out}}$	Time to transfer product i from package p^{in} to p^{out}[h/kg]
d_{cipt}	Demand of product i by customer c in package p on tertiary package t
$percocc_{pt}$	Utilization factor of secondary package p in tertiary package t

We distinguish two types of decision variables. The first ones are binary and provide information on which packages are chosen, while the second ones represent the good flows.

Variables:

y_{vp}	1 if supplier v uses package p; 0 otherwise.
yc_{rc}	1 if the empty containers flow from customer c to node r is possible; 0 otherwise.
x_{vwip}	Flow of product i in package p supplied by v *to* warehouse w
$z_{wip^{in}p^{out}}$	Flow of product i received in warehouse w in package p^{in} and transferred in p^{out}
$nPkgvw_{vwip}$	Flow of product i in package p moved by supplier v to warehouse w
$nPkgtr_{wip^{in}p^{out}}$	Number of containers of product i transferred from package p^{in} to p^{out} at warehouse w
pl_{vwiv}	Pallet of product i in package p delivered by supplier v to warehouse w
nUL_{wcpt}	Flow of secondary package p in tertiary package t form warehouse w to customer c
nF_{rvp}	Number of package p delivered from node r to supplier v
$nPkg_{ct}^{III}$	Number of tertiary packages t delivered from warehouse w to customer c

The model is built on a single cost-driven objective function (OF) (1), defined as follows:

$$
\begin{aligned}
&\min \sum_{p\in Pkg^{II}} \sum_{v\in V} y_{vp} \cdot cp_{vp} + \\
&\sum_{v\in V}\sum_{r\in R}\sum_{p\in Pkg^{II}}\sum_{t\in Pkg^{III}} nF_{rvp} \cdot \frac{1}{ncPkg_{pt}} \cdot ctPkg_t \cdot distrv_{rv} + \\
&\sum_{r\in R}\sum_{t\in Pkg^{III}}\sum_{p\in Pkg^{II}}\sum_{c\in C}\sum_{i\in M} \frac{d_{cipt}}{kgc_{ip}} \cdot \frac{1}{ncPkg_{pt}} \cdot ctPkg_t \cdot distrc_{rc} \cdot yc_{rc} \\
&+ \\
&\sum_{i\in M}\sum_{v\in V}\sum_{p\in Pkg^{II}}\sum_{w\in W} pl_{vwip} \cdot Ep_{vw} +
\end{aligned}
\tag{1}
$$

$$\sum_{p\in Pgk^{II}}\sum_{i\in M}\sum_{w\in W}\left(\sum_{v\in V} nPkgvw_{vwip}+\sum_{p^{in}\in Pkg^{II}} nPkgtr_{wip^{in}p}\right)\cdot Ec_p +$$

$$\sum_{i\in M}\sum_{p^{in},p^{out}\in Pkg^{II}}\sum_{w\in W} z_{wip^{in}p^{out}}\cdot ht_{ip^{in}p^{out}}\cdot lc +$$

$$\sum_{i\in M}\sum_{v\in V}\sum_{p\in Pkg^{II}}\sum_{w\in W} pl_{vwip}\cdot\left(\frac{di_{wi}}{vp}+ht\right)\cdot lc +$$

$$\sum_{c\in C}\sum_{w\in W}\sum_{t\in Pkg^{III}_{ct}} nPkg^{III}_{ct}\cdot Ecl_{wct} +$$

$$\sum_{p\in Pkg^{II}}\sum_{i\in M}\sum_{w\in W}\left(\sum_{p^{in}\in Pkg^{II}} nPkgtr_{wip^{in}p}\cdot\sum_{v\in V} nPkgvw_{vwip}\right)\cdot wg_p \cdot wc$$

Each term in equation (1) evaluates a specific cost item.

The term $\sum_{p\in Pkg^{II}}\sum_{v\in V} y_{vp}\cdot cp_{vp}$ considers the setup cost due to the package line format changeover for the supplier. The second and third addenda of the OF account for the transportation cost. The former assesses the cost of empty RPCs transportation from *r* to *v*, whilst the latter considers RPCs transportation cost from *r* to *c*.

For measuring transportation cost from a generic supplier *v* to warehouse *w*, we used a mean-cost for a unit load of product *i* in secondary package *p* gathered from the enterprise information database. This cost is measured with the term $\sum_{i\in M}\sum_{v\in V}\sum_{p\in Pkg^{II}}\sum_{w\in W} pl_{vwip}\cdot Ep_{vw}$, whilst $\sum_{c\in C}\sum_{w\in W}\sum_{t\in Pkg^{III}_{ct}} nPkg^{III}_{ct}\cdot Ecl_{wct}$ represents the transportation cost of unit loads from a warehouse to customers. The cost of package purchase is formulated by the term $\sum_{p\in Pgk^{II}}\sum_{i\in M}\sum_{w\in W}\left(\sum_{v\in V} nPkgvw_{vwip}+\sum_{p^{in}\in Pkg^{II}} nPkgtr_{wip^{in}p}\right)\cdot Ec_p$, whilst handling cost is evaluated through the following terms $\sum_{i\in M}\sum_{p^{in},p^{out}\in Pkg^{II}}\sum_{w\in W} z_{wip^{in}p^{out}}\cdot ht_{ip^{in}p^{out}}\cdot lc+\sum_{i\in M}\sum_{v\in V}\sum_{p\in Pkg^{II}}\sum_{w\in W} pl_{vwip}\cdot\left(\frac{di_{wi}}{vp}+ht\right)\cdot lc$. This calculation accounts for product transferring from the original package p^{in} to the customer-imposed one p^{out}, the registration, and internal handling. The last part of the objective function assesses the disposal cost.

The set of constraints can be clustered into two different groups. Constraints (2)-(8) refers to flows throughout the supply chain, whilst constraints (9)-(13) link the variables to each other. These clusters of constraints are formulated as follows:

Constraints:

$$\sum_{v\in V} nF_{rvp}\le nPkg_{rp}\ \forall r\in R, p\in Pkg^{II} \tag{2}$$

$$\sum_{w\in W} x_{vwip}\le o_{iv}\cdot y_{vp}\ \forall i\in M, v\in V, p\in Pkg^{II} \tag{3}$$

$$\sum_{p^{out}\in Pkg^{II}} z_{wipp^{out}}\le\sum_{v\in V} x_{vwip}\ \ \forall i\in M, w\in W, p\in Pkg^{II} \tag{4}$$

$$\sum_{p\in Pkg^{II}}\sum_{t\in Pkg^{III}}\sum_{c\in C} y_{rc}\cdot\sum_{i\in M}\frac{d_{cipt}}{kgc_{ip}}\le\sum_{p\in Pkg^{II}} cPkg^{II}_{rp}\ \forall r\in R \tag{5}$$

$$\sum_{v\in V} x_{vwip}+\sum_{p^{in}\in Pkg^{II}} z_{wip^{in}p}-\sum_{p^{out}\in Pkg^{II}} z_{wipp^{out}}\ge d_{icpt}\forall i\in M, w\in W, c\in C, p\in Pkg^{II}, t\in Pkg^{III} \tag{6}$$

$$\sum_{p\in Pkg^{II}} y_{vp}\le ps_v\ \forall v\in V \tag{7}$$

$$\sum_{r\in R} yc_{rc}=1\ \forall c\in C \tag{8}$$

$$\sum_{i\in M}\frac{x_{vwip}}{kgc_{ip}}\le\sum_{r\in R} nF_{rvp}\ \forall v\in V, p\in Pkg^{III}, w\in W \tag{9}$$

$$nPkgvw_{vwip}\ge\frac{x_{vwip}}{kgc_{ip}}\ \forall i\in M, v\in V, p\in Pkg^{II}, w\in W \tag{10}$$

$$pl_{vwip}\ge\frac{nPkgvw_{vwip}}{kp_p}\ \forall i\in M, v\in V, p\in Pkg^{III}, w\in W \tag{11}$$

$$nPkgtr_{wip^{in}p}\ge\frac{z_{wip^{in}p}}{kgc_{ip}}\ \ \forall i\in M, p^{in}\in Pkg^{II}, p\in Pkg^{II}, w\in W \tag{12}$$

$$\sum_{w\in W} nUL_{wcpt}\ge\sum_{i\in M}\frac{d_{cipt}}{kgc_{ip}}\ \ \forall c\in C, p\in Pkg^{II}, t\in Pkg^{III} \tag{13}$$

$$nPkg^{III}_{ct}\ge\sum_{w\in W}\sum_{p\in Pkg^{II}} nUL_{wcpt}\cdot percocc_{pt}\ \forall c\in C, t\in Pkg^{III}, w\in W \tag{14}$$

$$x_{vip}\ \forall i\in M, v\in V, p\in Pkg^{II} \tag{15}$$

$$z_{ip^{in}p^{out}}\in\mathbb{R}^{+}\ \ \forall i\in M, p^{in}, p^{out}\in Pkg^{II} \tag{16}$$

$$nF_{rvp}\in\mathbb{R}^{+}\ \ \forall r\in R, v\in V, p\in Pkg^{II} \tag{17}$$

Eqs. (2)-(5) are capacity constraints and impose that the maximum number of delivered containers *p* from node *r* cannot exceed the node capacity for such containers (2). Eq. (3) defines the production capacity for each supplier. The quantity of product *i* in package *p* delivered by all suppliers is an upper bound for the quantity of product *i* received by warehouse *w* in the same package (4). Eq. (5) dictates an upper bound on the storage capacity of the warehouses. Since the model is order-driven, demand adherence is imposed (6). Eq. (7) allows the supplier to use only the package available in its inventory. Eq. (8) ensures that the flow of empty containers between the customer and the RCP pooler’s facility is unique.

Constraints (9)-(14) link the variables. Eq. (9) defines the number of packages *p* available at the supplier *v*. Eqs. (10) and (11) measure the packaged fruits and vegetables sent from *v* and the number of unit loads. Eq. (12) forced the quantity of product *i* to be transferred from package p^{in} to package *p*, whilst (13) assesses the number of unit loads sent to the customer *c*.

III. Application & Results

C. Case study

The proposed model is applied to a real-world instance from a renowned Italian logistic provider (after called Conor). The selected order profile corresponds to a typical daily order profile handled by Conor for a total of 50’000 [kg] of perishable products. Such an amount of products allows supplying more than 100’000 single meal portions of vegetables and fruit, considering an average portion equal to 0.5 [kg]. The instance comprises four types of fresh fruit or vegetable items (i.e., apple, plum, banana, and salad), four secondary packages, and three types of tertiary packages. The secondary package set (i.e., Pkg^{II}) is composed of two RPCs of different sizes and two non-refillable containers, one made of polypropylene and the other made of cardboard. The tertiary package set (i.e., Pkg^{III}) comprises the two EPALs i.e., EURO 1 and 2, one roll container.

The actors involved are 17 suppliers, 17 RPCs pooler's facility nodes, and 15 customers. The customers involved in the analysis impose orders configuration on Conor, and the cumulated daily demand is shown in Fig. 2. For each customer, such demand is variable in quantity and food varieties, increasing the variability in the order profile.

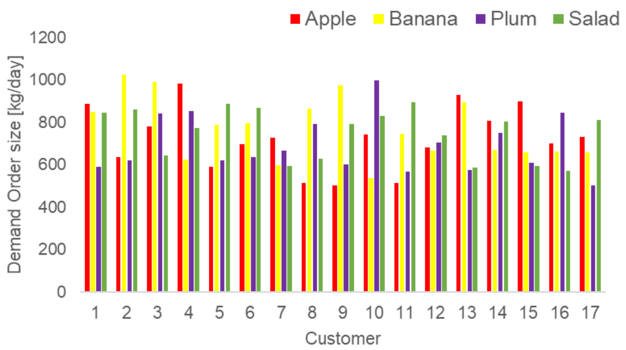

Fig. 2. Demand profile

The following sensitivity analysis on the key parameters enables model proof and validation. This analysis aims to compare the economic convenience of the *Business-As-Usual* scenario (scenario 1) with respect to alternative optima obtained from the changed parameters. Moreover, such analysis allows for investigating how the network's parameters influence the cost contributions.

D. *Sensitivity analysis and model validation*

In the sensitivity analysis, three parameters are modified. Such parameters are the maximum number of secondary package types available at the supplier ($ps_v = [4; 1]$) (i.e., scenario 2), the capacity of the container ($kgc_{ip} = [-5\%;\ 20\%]$) (i.e., scenario 3), and the suppliers' products capacity ($o_{iv} = [0; 100\%]$) (i.e., scenario 4). Such scenarios are compared with the result derived from the analysis of the BAU case provided by Conor (i.e., scenario 1).

The BAU scenario provides the benchmark. Scenario 1 gives an overview of the cost allocation (as shown in Fig. 3). The highest cost item is the transportation of packaged food from Conor to customers, followed by package purchasing cost. The package purchasing cost is so high as Conor fractions incoming orders from suppliers to make them eligible for customer requests. The package disposal cost is measured considering the municipal fees associated to the disposal of one kilogram of solid waste.

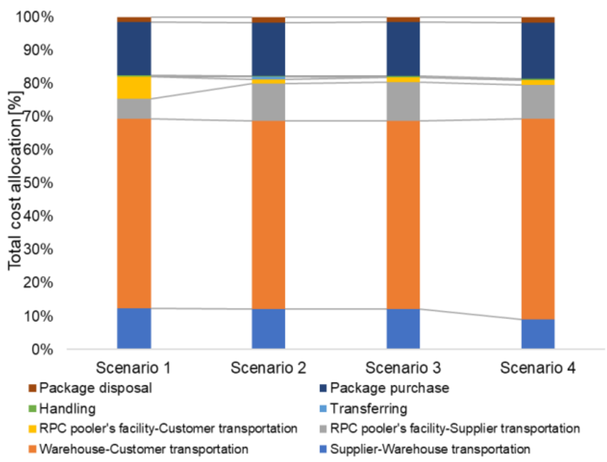

Fig. 3. Relative costs allocation

The variation of the ps_v parameter leads the model to meet demand by increasing flows and triggering new paths over the network. This choice is reflected in increasing transport costs for the routes supplier-warehouse. Reducing the availability of secondary packaging within a facility is equivalent to reducing the range of product-packaging combinations. Moreover, scenario 2 requires package transferring operations because choosing a supplier with the right package is less convenient than changing the package at the warehouse.

The variation of parameter kgc_{ip} leads to increasing the financial outlay to meet the demand. Indeed, the smaller the capacity of containers, the greater the flows necessary to ship the same number of packaged products. Reducing the kgc_{ip} parameter by 20%, the transportation cost increases significantly, as shown in Fig. 4.

By allowing packager to supply any product in the needed quantity (o_{iv}), the model activates the closest suppliers to the cross-docker, minimizing the distances and costs associated with the travelling. Indeed, while allocating the food orders to the suppliers, the model accounts for the cost of delivering empty reusable containers from the pooler to actors, and the different connections triggered by the model allow RPC pooler's facility-customer transportation cost reduction, whilst the transportation cost due to supplier-warehouse routes decrease when the capacity constraint is relaxed. The presented sensitivity analysis provides a reliable model validation and allows further explorative directions of the model, feeding it with new datasets.

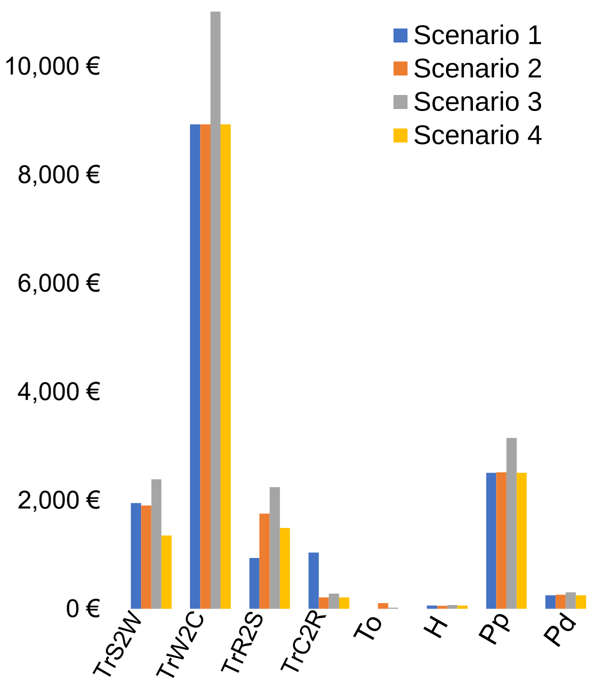

Fig. 4. Cost allocation in € (Legend: Pd: package disposal cost, Pp: Package purchase cost, H: Handling cost, To: Transferring operation cost, TrC2R: Transportation cost from customer to pooler's facility, TrR2S: Transportation cost from pooler's facility to supplier, TrW2C: Transportation cost from warehouse to customer, TrS2W: Transportation cost from supplier to warehouse).

Tab. 1 shows an absolute and relative comparison of the costs incurred in packaging, distributing, and handling fruits and vegetable products. The reference scenario (i.e., S1) quantified the overall cost of an order of packaged food, resulting from the logistics, purchase, and disposal tasks, at 0.31 €/kg. The sensitivity analysis shows a boost of the order cost by up to 25%, when kgc_{ip} decreases. The most significant savings (5.5%, 0.29€/kg) are from relaxing the availability of different products at the supplier thus encouraging an integrated planning of wholesalers' and growers' decisions upstream.

TABLE I
SCENARIOS' COST COMPARISON

	S1	S2	S3	S4
Total cost [€/day]	15'664	15'732	19'465	14'795
Product cost [€/kg]	0.31	0.32	0.39	0.29
Order cost increase [%]	-	0.43%	24.26%	-5.55%

IV. Discussion

E. Model limitations

The MILP model can solve larger networks but not drive the secondary package configuration that the customer requires in the present form. This type of limitation is imposed by the initial database that required a further analysis of the operational business' implication of such decision.

The model is open to adapt to new larger datasets for exploring potential computational limitations or performance.

F. Future developments

The evaluation of possible integrations between supply chain partners would require what-if analyses. These analyses lie on other network's parameters. According to the triple bottom line [12], [13], the three dimensions of sustainability can be promoted while supporting decision-making When it comes to the catering network, sustainability may result from purchasing and ordering policies, or cross-docker's operations, rather than from packaging hierarchy choices.

In order to promote vertical integration strategies and horizontal collaboration [14], [15], the model might refer to an updated performance dashboard including carbon footprint or labor implications of packaging-driven choices.

V. Conclusion

Analyzing the costs allocated to the supply chain's actor in the food catering supply chain (i.e., grower, consolidator, supplier, cross-docker, customer) highlights the role of packaging and package-driven decisions. The purchasing cost is crucial but not the only to be considered. Indeed, disposal, handling, labor, and transferring/handling costs need to be taken into account. These, together with the transportation costs, depend on the utilization and size of the secondary and tertiary packages.

The analyzed contributions favor identifying a total process cost resulting from the packaging hierarchy. By enforcing vertical collaboration and horizontal integration, models like this can drive the choice of packaging oward the most convenient supply operations. This holistic perspective aims at optimizing the distribution of the operational costs of the whole catering supply chain.

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