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LEAN PACKAGING

Executive Summary

Lean Packaging is a project developed in collaboration with the coffee company Lavazza, aiming to cut void space and waste in e-commerce shipments without sacrificing product protection, costs, or customer choice. It targets compliance with the EU Packaging and Packaging Waste Regulation (PPWR), which from 2030 caps unused volume per parcel at 40%. Lavazza's baseline is $\sim 31.3\%$ fill ($\sim 68.7\%$ empty), showing a clear gap.

We built a governance simulator that mirrors demand, generates realistic orders and, through a 3D bin-packing algorithm, selects feasible boxes to quantify void ratios. On this base we pursued two intertwined tracks.

Upstream, a digital banner at checkout recommends a coherent add-on to use the residual capacity of the assigned carton, incentivized by a small discount. Simulations indicate that about 80% of critical orders can be optimized without changing the outer box, with $\sim 5\%$ better space utilization and $\sim \text{€}11$ higher order value when the suggestion is accepted; under prudent assumptions this yields $\sim \text{€}50\text{k}$ extra annual margin for a $\sim \text{€}10\text{k}$ one-off investment (payback ~ 2.01 years).

Downstream, we designed an adjustable carton: a single pre-cut sheet (single-wall corrugate) that yields 12 formats, four bases by three heights, assembled quickly with perforations and folds. Dimensions were tuned on Lavazza's mix to minimize average void using the simulator, and laser-cut prototypes validated assembly; durability and sustainability test plans are set for industrialization.

Combined, the digital banner reduces poorly packable baskets, while the adjustable carton absorbs residual variance. The strategy narrows the PPWR gap, lowers corrugate and filler, improves immobilization and unit economics, and supports sustainability messaging.

Next steps: A/B-test the banner in one EU market; in parallel industrialize the carton with suppliers (die-cuts, alignment guides, tests); then scale in waves based on measured outcomes.

Key Words

E-commerce, EU PPWR Compliance, digital nudge, adjustable carton, sustainability

Lean Packaging

Reducing void space and waste in Lavazza's online shipments to be compliant with the EU PPWR regulation.

A dual solution combining digital and physical innovation:

PHYSICAL LAYER

Optimizing through Box Design

Adjustable cartons made from a single pre-cut sheet adapt to different order sizes, minimizing void space and filler use while ensuring product protection and full recyclability.



DIGITAL LAYER

Optimizing space from the Start

Smart recommendations on the cart page suggest complementary items that fit within existing packaging, boosting average order value and reducing environmental impact.



Impact

+29,2%
packaging efficiency

from **69%** to **40%**
void space

+€80k
net annual benefit
(payback 2 years)

Compliance with
EU Packaging &
Waste Regulation

~18
tons CO₂
saved over 5 years

Project description written by the Principal Academic Tutor

The overall objective of the project is to develop an e-commerce packaging system that ensures a satisfactory user experience, protects products during transport, and remains cost-efficient. The solution must also comply with emerging regulatory requirements, in particular the upcoming European Packaging and Packaging Waste Regulation (EU PPWR), which sets a maximum limit of 40% empty space inside e-commerce packages. The project adopted an integrated approach that leveraged the diverse expertise of the team members, supported by both academic and corporate tutors. Throughout the process, various innovative solutions were explored, focusing on materials and structural design, with the goal of minimizing overpackaging without compromising product integrity. An in-depth analysis of key competitors was carried out to map the packaging solutions currently used in the e-commerce sector. This phase included the study of real-world cases, international benchmarks, and a comparative assessment of materials, volumes, and strategies adopted to reduce overpackaging. The objective was to identify best practices as well as the limitations of existing solutions, in order to guide development toward truly innovative and competitive approaches. Subsequently, an experimental testing phase was initiated, involving the design and evaluation of different prototypes. The tests carried out enabled a comparison of the performance of these solutions in terms of volumetric efficiency and ease of use.

Team Description by Skill

The team comprises five members with complementary backgrounds, each contributing their strengths and technical knowledge:

- **Giacomo Barilari**, Management Engineer, took the lead in developing the simulator and the digital solution.
- **Maddalena Ghiotti**, Mathematical Engineer, applied her expertise to optimize the dimensions for the physical solution and guided its modelling.
- **Anna Lavagnino**, Team Controller and Management Engineer, oversaw the project budget and carried out the business/economic assessment.
- **Aayat Malik**, Environmental Engineer, addressed sustainability and compliance aspects.
- **Laura Mezzoli**, Aeronautical Engineer and Communication Coordinator, contributed across streams and managed internal and external communication.

Each project activity involved multiple team members and iterative reviews with peers and tutors. In this way, knowledge was shared across the group, alternative viewpoints were considered, and each member had the opportunity to grow beyond their original field of expertise. Thus, specialization provided direction, while collaboration ensured integration and continuous learning.

Understanding the problem

E-commerce has made coffee purchasing convenient, but it has also created a packaging gap: Customers often place small, mixed orders, but warehouses rely on a limited set of fixed size cartons. This results in a lot of partially filled boxes. In our baseline measurement for Lavazza, simulated orders using today's four standard cartons achieved ~31.3% average fill (~68.7% empty), well outside the EU's direction of travel. The forthcoming EU Packaging and Packaging Waste Regulation (PPWR) caps unused volume at 40% and counts fillers as empty; meeting that bar will require different choices both upstream (how orders are composed) and downstream (how boxes adapt).

Scale matters: Coffee is among Europe's most purchased beverages and with its online share growing quickly, reducing the environmental footprint of its shipments has become crucial. Considering the EU "at home" coffee volume and making some assumptions on the online penetration and the amount of product per parcel, it can be estimated that about 300 million parcels are shipped across Europe per year, leading to over 30,000 tons CO₂ emissions in terms of corrugated carton. This is just an estimate that doesn't account for returns or transport but clearly underlines the necessity of an intervention. Hence, more efficient packaging would result in reduced material consumption, lower filler use, higher truck load factors and lower emissions.

Competitor checks confirm that this is a systemic issue, not a Lavazza one-off. Test orders from Nespresso, Illy, and Segafredo routinely arrived with 50–80% empty volume, often stabilized with paper filler. Cylindrical tins and soft pouches aggravated dead space inside rectangular cartons; minimum order policies sometimes helped pack density but did not eliminate voids. In short, the status quo fails on regulation, efficiency, and perception.

Problem statement: How can we redesign Lavazza's e commerce pack out so that it (i) stays under 40% empty space, (ii) protects products, (iii) does not raise logistics cost or complexity, and (iv) communicates sustainability credibly to customers?

Goal

Our goal is to rethink the current inefficient packaging concept, designing a solution that consistently ships at or below the 40% empty-space threshold without hurting product protection, customer choice, or day-to-day operations. We approach it from both ends. Upstream, we help customers complete their carts with a small, relevant addition that fits the leftover capacity of the box already assigned at checkout. Downstream, we replace the fixed cartons with a pre-cut, height-adjustable design that can form multiple base and height combinations quickly, without knives or increasing logistics complexity. Throughout, we hold to a few non-negotiables: products must arrive intact under normal handling; materials should remain recyclable and as close to mono-material as possible; pack-out can't slow the line or add training overhead; the customer journey must stay simple; and the change has to pay for itself by lowering corrugate, filler, and DIM-weight exposure. A simulator ties it all together: it sets the baseline, quantifies what each change delivers, and guides the choices we scale first.

Exploring the opportunities

Before committing to a direction, we reviewed what is already available, what strategies the competitors are adopting, and what would work inside Lavazza's operations. This scan surfaced four families of options and the trade-offs behind them.

- **Digital shaping at checkout:** A light, context-aware recommendation on the cart page proposes one complementary item that fits the remaining capacity of the already-assigned box. It removes void at the source, adds no extra clicks, and creates a natural moment to communicate the packaging benefit.
- **Variable-height and other adjustable cartons on the market:** Off-the-shelf variable-height boxes are easy to source and reliably trim vertical void; however, they rarely solve lateral gaps without inserts and many require manual cutting, which slows pack-out and raises safety concerns. They are useful benchmarks but not a full answer for mixed coffee orders combining tins, sleeves, and pouches.
- **Alternative physical concepts:** We assessed modular dividers/inserts, right-size/on-demand box-making equipment, and reusable shippers. Inserts improve immobilization but increase piece count and labor; on-demand machines right-size well but introduce capex, maintenance, and a parallel material stream; reusable packaging can work in closed loops, but adds reverse-logistics complexity that is non-trivial for home delivery.
- **Competitor benchmarking:** Test orders with major brands revealed high empty-space ratios with paper fillers, especially when cylindrical or flexible formats met rectangular cartons. Minimum-order thresholds improved density in theory but did not eliminate void in practice.

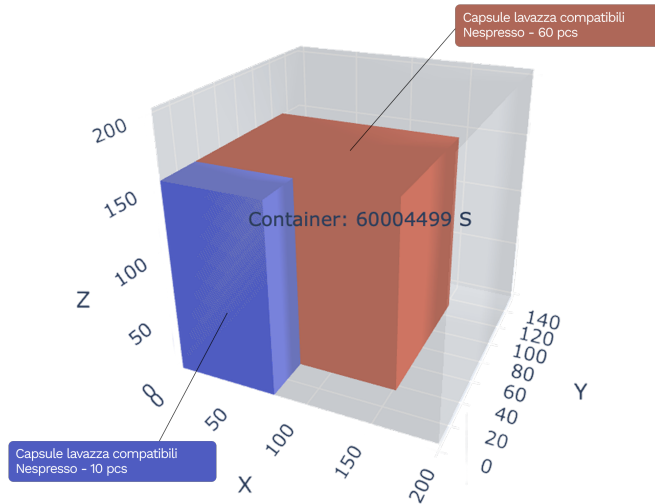
Given these findings, we converged on a hybrid path: remove a large share of void upstream with a simple digital nudge and absorb residual variance downstream with an adjustable die-line that changes both base and height without proliferating SKUs. This combination meets all the relevant constraints (protection, recyclability, speed, simplicity, and cost) while leaving room to tune details market by market.

Generating a solution

We designed and tested a two-track solution supported by an in-house simulation tool.

A. The simulator

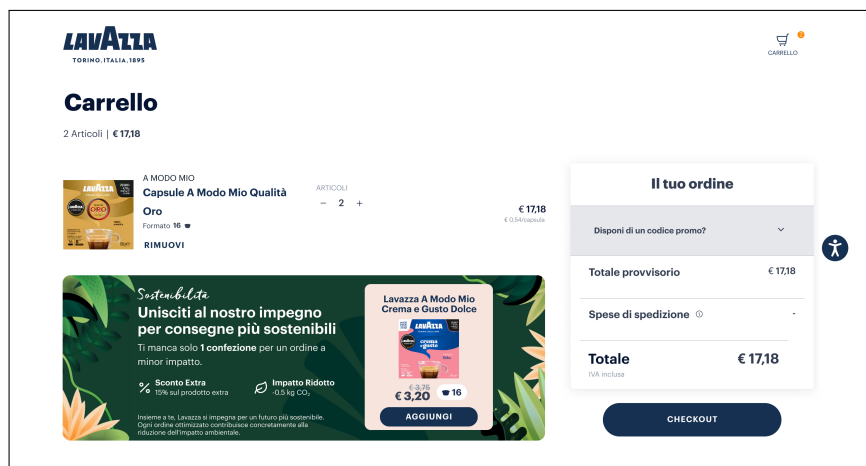
First we built a simulator to quantify the size of the problem with the current four cartons, in realistic conditions, and to give us a safe place to test ideas before touching operations. This tool mirrors the catalogue with exact dimensions and weights, models how different customer types compose orders, and uses three-dimensional bin-packing to assign the smallest feasible carton or, if needed, split the order on multiple boxes. From there it reports filled volume, empty space, and compliance rates. Once the baseline was clear, we used the same tool to design and compare solutions on a level field: to see how much the checkout nudge could lift utilization at different acceptance rates, to optimize the adjustable die-line dimensions, and to decide the order of roll-out steps that deliver the most benefit with the least disruption.



Simulator view

B. Digital path: “Complete the box”

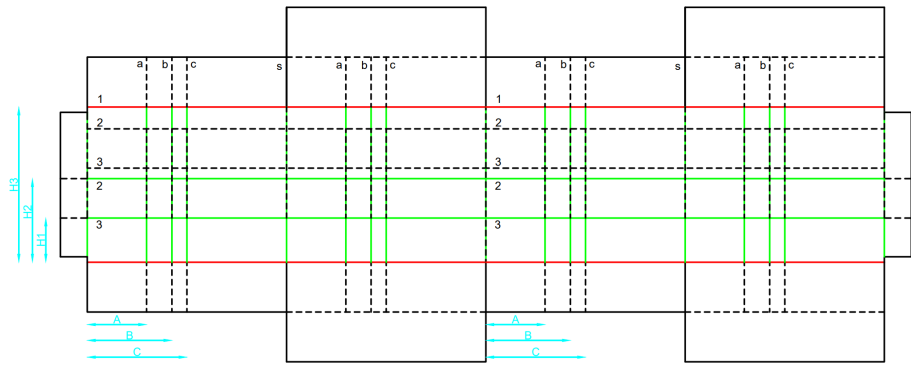
At the cart page, a dynamic banner proposes one complementary item that fits the residual capacity of the already-assigned box. The nudge is framed as a packaging-efficiency plus sustainability action, supported by a modest incentive, and designed to add zero extra clicks to checkout. In testing, a large share of critical orders became optimizable without changing the external carton. The feature is simple to A/B test, can be tuned to inventory priorities, and creates a concrete moment to communicate the benefit to customers.



Checkout demo view

C. Physical path: one sheet, twelve formats

On the line, we replace the fixed cartons with a pre-cut, height-adjustable die-line that yields twelve formats from one sheet: four bases by three heights, assembled by hand. Packers choose the base, then reduce height by tearing along pre-marked lines; offcuts can be shredded as in-box paper filler when needed. To avoid guessing dimensions, we used the simulator to first scan a wide grid of base/height parameters and then refine to a set that reduces void without multiplying SKUs. Materials stay in single-wall corrugate for recyclability, with paper-tape closures to keep the stream simple. Shipping tests were carried out to assess whether the solution provides satisfactory product protection.



Physical solution design

D. Combined impact and roll-out

The digital path shrinks the population of poorly packed carts before they reach the line; the adjustable die-line then absorbs the residual variance with minimal operational friction. Together they move shipments toward the empty-space threshold, cut corrugate and filler per parcel, improve load factors and emissions, and strengthen unit economics. The roll-out is staged: A/B-test the digital nudge in one market and measure acceptance, utilization, and order value; in parallel, industrialize the die-line with suppliers (production die-cuts, alignment marks, durability/recyclability tests); then scale in waves where the data shows the strongest benefit.

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