INTER IIT
TECH MEET 13.0

MID PREP

FedEx®

OPTIMAL CARGO MANAGEMENT FOR FLIGHTS

About FedEx

FedEx, a global leader in logistics and transportation, has built an extensive infrastructure to meet the demands of modern commerce and e-commerce, reaching more than 220 countries and territories. With an annual revenue of $87.7 billion, the company operates with a workforce of over 500,000 employees and handles an average of 16 million shipments daily.
Its global network comprises more than 200,000 motorized vehicles and 698 aircrafts, connecting over 650 airports worldwide, ensuring efficient and fast delivery across various service lines, including express and ground services. FedEx operates more than 5,000 facilities, and its website attracts 80 million visitors monthly, managing over half a billion daily package tracking requests.

FedEx revolutionized the logistics industry with its pioneering express air service in the 1970s, introducing time-definite, overnight delivery. This model disrupted traditional shipping and set the company apart. Over the years, FedEx expanded its portfolio through strategic acquisitions, such as Flying Tiger Line and Caliber System, to include diverse services like FedEx Ground, FedEx Freight, and FedEx Office. This expansion allowed FedEx to offer comprehensive solutions, from small-package delivery to international freight.

In addition to its core services, FedEx operates specialized divisions like FedEx Custom Critical and FedEx Logistics, providing solutions for urgent and sensitive shipments. The company also serves industries such as healthcare, aerospace, and automotive, where the need for secure and timely deliveries is critical.
FedEx offers various shipping options, including FedEx International Priority and Economy services, catering to different customer needs in terms of budget and delivery time. For example, express options typically deliver in 2-3 business days, while economical options may take 4-5 days. FedEx's ability to handle large shipments, such as those up to 1,000 kilograms, along with services like returns management and hazardous goods transportation, shows its versatility in meeting industry demands.

FedEx continues to innovate, particularly in the e-commerce space, where it helps businesses scale with flexible solutions.

The company's FedEx E-commerce Solutions provide end-to-end support, while services like FedEx Priority Alert and Delivery Signature Options ensure enhanced security for valuable shipments. Furthermore, FedEx's commitment to social responsibility is demonstrated through its global giving initiative, FedEx Cares, which has pledged $200 million to support communities worldwide.

Strategic decisions, such as acquiring TNT Express to strengthen its European presence and distancing itself from Amazon, reflect FedEx's drive to remain independent and adapt to changing market conditions.

Under the leadership of CEO Raj Subramaniam, following founder Frederick W. Smith's transition, FedEx continues to prioritize customer-centric innovation and operational efficiency. This adaptability, combined with its vast infrastructure, positions FedEx as a critical player in the logistics and transportation industry, enabling it to support businesses and individuals in a fast-paced, globalized marketplace.

Background

FedEx selected the Unit Load Device (ULD) optimization problem for the Inter IIT Tech Meet 13.0 due to its potential to significantly enhance operational efficiency, reduce costs, and improve service reliability across its logistics network. ULDs are standardized containers used in air shipments, varying in shape and size, and have strict weight and volume limits. Properly packing these devices ensures efficient use of space, minimizes costs, and guarantees that Priority Packages, which are of higher precedence, are shipped without delay.
The challenge is to decide which packages to load into which ULDs, while considering the weight limits, package dimensions, and ensuring that Priority Packages are not compromised.

The optimization of ULD packing offers several key benefits to the logistics industry. First, it increases efficiency by maximizing the available space in each ULD, allowing more goods to be transported per flight. This reduces the number of shipments required and leads to better resource utilization.

By reducing the number of ULDs needed, operational costs, such as fuel, labor, and handling fees, are significantly lowered. Fewer ULDs also mean less storage and transportation costs, directly impacting the bottom line.

In addition to cost savings, ULD optimization improves timeliness. Properly packed ULDs ensure that no packages, especially Priority Packages, are left behind, resulting in faster delivery times. This is especially crucial for time-sensitive shipments, improving customer satisfaction and overall service reliability.

Moreover, efficient ULD usage leads to higher profitability. By handling more shipments per trip without significantly increasing costs, logistics companies can generate additional revenue. Furthermore, optimizing the use of ULDs reduces inefficiencies, directly benefiting the company's financial performance.

Environmental sustainability is another key factor driving FedEx’s interest in ULD optimization. More efficient packing means less fuel is consumed per shipment, leading to a reduction in carbon emissions. This aligns with FedEx's commitment to sustainability and environmentally friendly logistics practices.

The key constraints in optimizing ULDs include not exceeding weight limits, ensuring all Priority Packages are shipped, and fitting the packages within the ULD’s dimensions.
The optimization solution seeks to balance these constraints while minimizing costs, including the risk of packages being left behind or the need to spread Priority Packages across multiple ULDs.

In summary, FedEx's selection of the ULD optimization problem stems from its potential to streamline logistics operations, reduce operational costs, and enhance customer satisfaction. By improving space utilization, increasing efficiency, and ensuring timely deliveries, the optimization of ULD packing offers significant advantages for both the company and its customers.

Packing Unit-Load Devices for Air Shipments

The packages that are being transported are usually stacked inside large standard sized containers, called Unit Load Devices (ULDs), that are then loaded onto the aircraft.
These ULDs are available in various standard sizes, meant for carrying different types and quantities of packages. Each of them have specific shapes, dimensions, weight, volume and a limit for how much load they can carry. Some of the varieties of ULDs are shown in the pictures below:

Figure: 1. A picture of ULDs at an airport (Source: www.fedex.com)

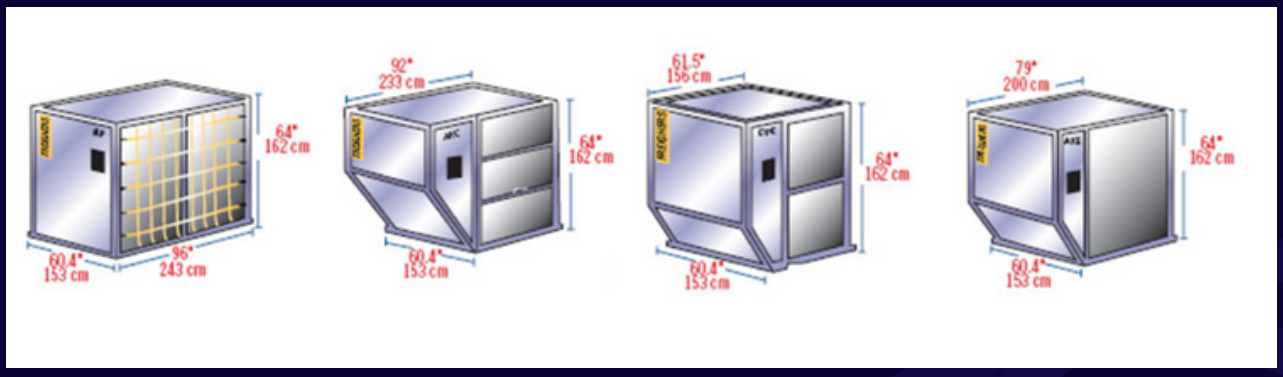


Figure 2: ULDs come in different shapes and sizes

Many ULDs have tapered or rounded edges on one of their sides in order to enable full utilization of space inside the aircraft. For the purposes of this problem statement, assume that all available ULDs are cuboidal in shape. The packages, which are smaller in comparison to the ULDs, also come in various shapes and sizes.

Again, assume that all packages are cuboidal in shape and they can only be oriented along the axes inside a ULD. That means the edges of the package must be parallel to the walls of ULD (and not inclined at other angles).
Thus, there are 6 possible orientations for each package inside a ULD.
It is further given that there are two types of packages: Priority and Economy. Priority Packages are higher valued than Economy Packages. If there are more packages than space available then Priority Packages are given priority. Also, Priority Packages should be grouped into as few different ULDs as possible so that they can be unpacked and delivered faster.

Problem Statement

For a given flight, a given set of ULDs that must travel in that flight, and a list of packages that need to be flown in that flight, we would like to decide which package should be packed in which ULD and how it should be packed (coordinates and orientation inside the ULD).
A solution must satisfy all the following requirements:

1. Total weight of all packages in a ULD should not exceed its limit.
2. None of the Priority Packages must be left behind (some economy packages can be left behind).
3. All packages assigned to a particular ULD must fit into that ULD.

Amongst the many possible solutions that satisfy the above requirements, the one with the lower ‘total cost’ is preferable. Total cost has the following components and are explained later below:

1. Cost of packages left behind
2. Cost of spreading the Priority Packages into too many ULDs

Inputs

The following inputs are provided:

1. **List of ULDs:** A list of ULDs is provided in the following tabular form

ULD Identifier	Length (cm)	Width (cm)	Height (cm)	Weight Limit (kg)
ULD-1				
...				
ULD-m				

Table: 1. Format of a table describing ULD attributes

2. **List of Packages:** A list of packages is provided in the following tabular form

Package Identifier	Length (cm)	Width (cm)	Height (cm)	Weight (kg)	Type (P/E)	Cost of Delay
P-1						
...						
P-n						

Table: 2. Format of a table describing package attributes

3. Cost ‘K’ for each ULD that carries a Priority Package in the solution. Thus, for example, if a total of 7 ULDs have one or more Priority Packages in them, a total cost of 7K is incurred.

Expected Output

As an output, it is expected that for each package we get:

1. The ULD identifier in which it must be loaded or NONE in case it can not be loaded.
2. The coordinates of the cuboidal packages inside a ULD using the following convention.

Also expected in the output is the total cost incurred of the proposed solution. This cost is the sum of (a) delay-cost of all packages that could not be loaded plus (b) the cost of spreading Priority Packages in multiple ULDs, computed as K x (number of ULDs that have Priority Packages).

Convention for Representing a Package Position Inside a ULD

In this competition we are assuming that a package inside a ULD will be aligned along its axes. This assumption makes it easy to represent the position of a package inside a ULD by means of coordinates (three dimensional) of its two diagonally opposite corners. In this convention we follow two rules:

1. The coordinate system is aligned to the axis of the ULD with the origin (0,0,0) at the front, left, bottom corner.The length of the ULD is measured along the x axis, width along y and height along the z axis.

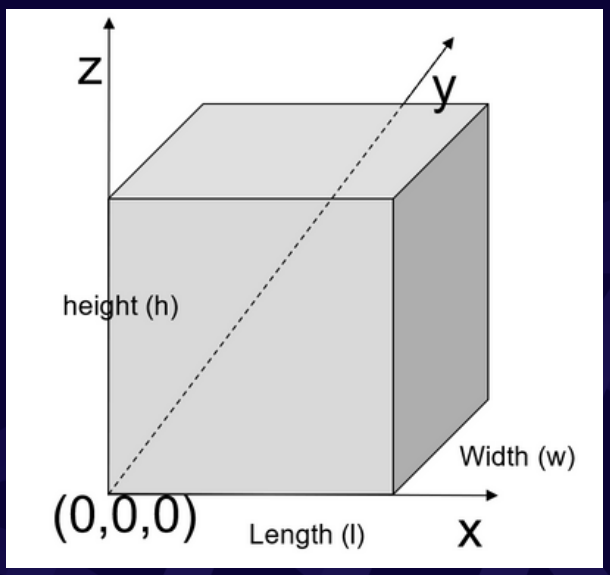


Figure 3: Coordinate axes for a ULD

2. For placing a package, we need to specify the reference corner of the package which is selected as follows in our convention. Amongst the eight corners of the package, select the ones that will have the smallest z-coordinate when placed inside the ULD.
Amongst all such corners, select the one that has the smallest y value.
The position of the package is specified using the coordinates of the reference-corner and the corner diagonally opposite to it. For instance, a package of size (2x25x2) with location specified by (5,0,0)-(30,2,2) will be placed like this inside ULD at the bottom surface, 5cm to the right of the origin:

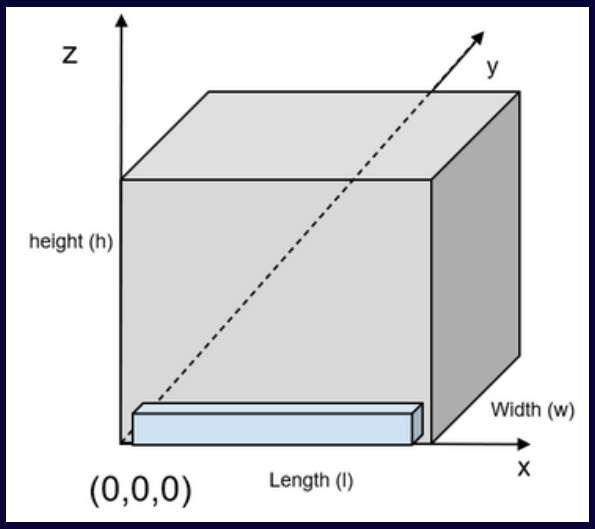


Figure 4: Package inside a ULD

Faces (sides) of the packages may touch the walls of the ULD, as well as sides of other packages, for compact packing.

Example: Here is a fictitious toy example of only 2 ULDs and 4 packages. Suppose K=40 and the other inputs are as follows:

ULD Identifier	Length (cm)	Width (cm)	Height (cm)	Weight Limit (kg)
ULD-1	100	80	80	250
ULD-2	100	80	80	250

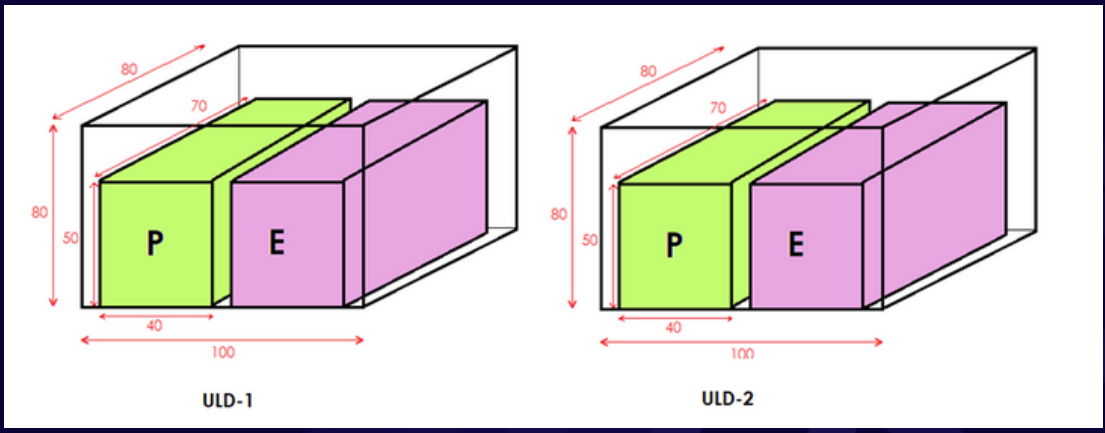
Table 3: ULD attributes for Example Problem

Package Identifier	Length (cm)	Width (cm)	Height (cm)	Weight (kg)	Type (P/E)	Cost of Delay
P-1	70	40	50	100	Priority	-
P-2	70	40	50	100	Priority	-
P-3	70	40	50	150	Economy	20
P-4	70	40	50	150	Economy	30

Table 4: Package attributes for Example Problem

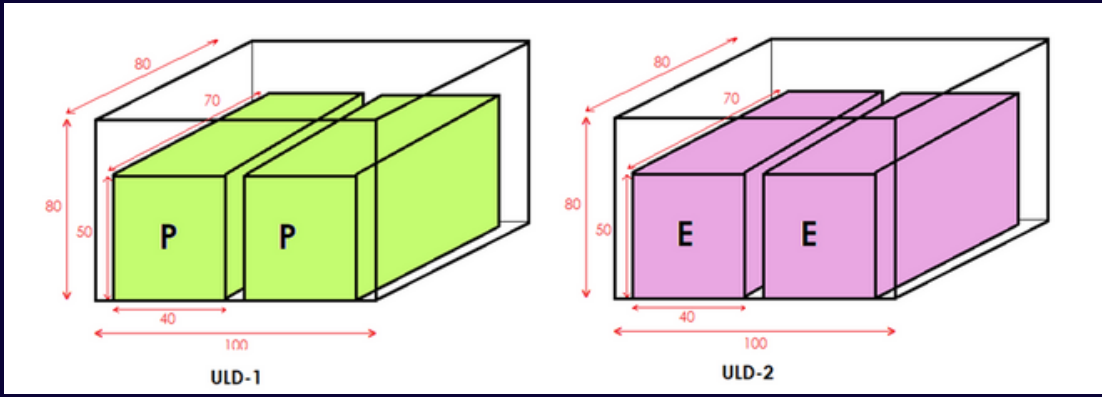
Three feasible solutions (not necessarily optimal) are provided for illustration purposes.

Solution-1
Both the ULDs get one Priority package and one Economy package each.



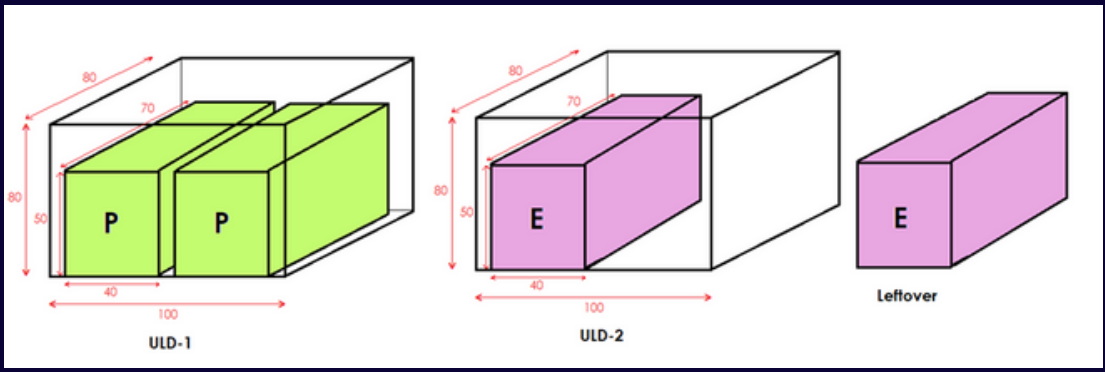
Here, the position of P-1 in ULD-1 according to our convention is: (5,0,0) - (45,70,50) and that of P-3 in ULD-1 is (45,0,0)-(85,70,50). The cost of this solution is (40x2) 80 as there are two ULDs with Priority packages and no package is left out.

Solution-2
One ULD has two Priority packages, and the other has two Economy packages.



The cost of this solution is 40 as only one ULD has priority packages, and no package is left out. However, this solution is not acceptable because the second ULD is loaded beyond its capacity of 250KG

Solution-3
Here, one ULD has two Priority packages, while the other one has only one Economy package (P4).



The cost of this solution is (40 for Priority +20 for delaying package P3) 60 units.

Challenge Problem Data

The full problem data (Challenge Problem Data) that will be used to judge the winners will be released on 18th November. It will include about 9 ULDs of different sizes and no more than 500 packages. ULDs will not be bigger than 240 x 320 x 240 cm3 and package dimensions will vary from 4cm to 100cm (along each of the three coordinates).

Solution Deliverables

The following must be submitted in the final solution:

- Each contesting team should prepare a short report on the method they used to solve the problem. The method should be explained in simple, concise English so that it is understandable by non-experts. It can be supported by technical details including details of the algorithm, flowcharts, example computations, figures etc. The report should mention the difficulties faced and the ideas tried. The report should also clearly mention any limitations or drawbacks of the proposed approach. This report should be submitted in a PDF format (up to 10 pages).

- Code used to solve the problem, without any third-party or commercial libraries should also be shared. Code can be in any programming language. A short how-to on running the code must accompany this submission.

- Finally, the output obtained by solving the challenge problem released for the competition should be submitted in the following format.

Output Format

Participants will be required to submit a plain text file in the following format:

1. The first line of the file should contain total cost (an integer value) computed for the solution, the total number of packages packed in all ULDs and the number of ULDs with Priority Packages separated by commas (no spaces).

For example:10200,380,4

2. Subsequent lines should contain details of one packet per line in the format: Package-ID,ULD-ID,x0,y0,z0,x1,y1,z1
where Package-ID is the ID of the package, ULD-ID is the ID of the ULD to which the packages is assigned, (x0,y0,z0) are the coordinates of the reference corner of the package and (x1,y1,z1) are the coordinates of the diagonally opposite corner (see convention above). If a particular package is not allotted to any ULD then its ULD-ID should mention NONE and the coordinates be -1,-1,-1,-1,-1,-1.

Evaluation Criteria

The teams will be judged on the following criteria:

- Quality of the solution to the challenge problem submitted in the above format **(60%)**. Solutions should try to meet all primary requirements (all priority packages must be shipped, weight of ULDs should not exceed the limit, all selected packages must be fully inside their respective ULDs and no two packets should spatially overlap). Cost is a secondary goal.
- Quality of presentation and the following question and answer session **(20%)**.
- Quality of the report submitted **(15%)**.
- Quality of the code submitted **(5%)**.