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Reducing waste generated by international students' mobility

Improving user experience with object detection

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Abstract

International student mobility is on the rise. Even though international exchange programs foster intercultural development, some contend that the environmental impact must be considered more. This work project focuses on one piece of the complex puzzle: overconsumption. In line with SDG 12, we propose an application called Repurpose, aimed at effectively repurposing everyday items new international students buy but would otherwise throw away at the end of their curriculum. The application is tailored to the global Gen Z audience, leveraging AI for convenient experiences and considering the time gap when international students leave and arrive. Due to its scalable SaaS nature and considerate business model, the app has the chance to grow into a critical application for international students worldwide. This report contains both common part prepared by the project team together and an individual part that was about object detection and how it can be implemented in a low code environment to improve the user experience.

Keywords

Entrepreneurship, Innovation, Low-Code, Mobile, and Product Development

Acknowledgments

List of Abbreviations

IPCC   Intergovernmental Panel on Climate Change

UN   United Nations

UNDP   United Nations Development Program

SDG   Sustainable Development Goals

LCDP   Low-Code Development Platform

IT   Information Technology

CRM   Customer Relationship Management

ERP   Enterprise Resource Planning

MB   Multibanco

QR   Quick Response

NOVA SBE   Universidade Nova de Lisboa – School of Business and Economics

GTM   Go-to-Market

U Lisboa   Universidade de Lisboa

ESN   Erasmus Student Network

ETL   Extract, Transform, Load

UI   User Interface

UX   User Expérience

IP   Intellectual Property

List of Abbreviations

API   Application Programming Interface

SQL   Structured Query Language

CNN   Convolutional Neural Network

SSD   Single Shot Detector

YOLO   You only look once

IOU   Intersection over Union

VGG   Visual Geometry Group

SPP   Spatial Pyramid Pooling

ASPP   Atrous Spatial Pyramid Pooling

RFP   Receptive Field Block

FPN   Feature Pyramid Network

ASFF   Adaptively Spatial Feature Fusion

BBox   Bounding Box

MSE   Mean Square Error

BI   Business Intelligence

CO2   Carbon dioxide

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1. Introduction

Having an international experience while completing tertiary education is an experience that affects the student's personal and professional development. It allows the new generation to discover new cultures, perspectives, and lifestyles. In addition, learning about other places' cultures continues to be very appealing and beneficial to people, nations, and our global society. It changes their perspectives on different subjects and brings them closer to knowing exactly how they want to build their professional career and what they want to be in the future.

Even though international exchange programs foster intercultural development, some contend that such programs' environmental impact needs to be considered more (Shields 2019). Shields assesses travel-related emissions and changes that result from a student's consumption (e.g., energy use, food) while studying abroad.

International education indirectly contributes to climate change as aviation contributes around 3.5% to climate change, based on the Intergovernmental Panel on Climate Change (IPCC), the intergovernmental body of the United Nations (Schmidt 2019). There is an ongoing discussion about substituting international students' mobility with online education, but virtual education will not deliver the same experience as an actual exchange program. Ideally, global citizenship is fostered with international education by promoting tolerance and intercultural understanding when attempting to address global problems like climate catastrophe.

International student mobility has grown from 2 million in 2000 to 6 million students in 2020 globally (UIS 2022). More than 300.000 students study, train, or volunteer each semester under the Erasmus+ umbrella (European Commission 2019). The number of students has increased by around 10.000 in Lisbon from 2020 to 2022, reaching more than 128.000 (Pordata 2022).

The United Nations Development Program (UNDP) founded the sustainable development goals (SDG) in 2015. It is a program composed of 17 goals that aim to improve the life quality of human beings on different levels and focuses. Goal number 12 focuses on sustainable consumption and production (DESA 2022). The main idea is to find a method to meet human needs while also considering nature; how we can protect natural resources so that future generations may use them.

Because of these rising numbers of international students and in line with SDG 12, we propose an application called Repurpose, aimed at effectively repurposing everyday items new students buy but would otherwise throw away at the end of their curriculum. As such, we are trying to avoid a significant waste generation at scale with peaks twice per year - at the end of each semester.

The application is the result of months of low-code development and aims to be implemented in different student cities across the globe. It leverages a marketplace model with a key stakeholder: the drop-off location – often a university or campus.

1.1 Goals

In this project, we aim to develop a solution that can help reduce the carbon footprint of international students. Our contribution will focus on responsible consumption. The primary objective is to create an online marketplace that allows the repurposing of typical student items (furniture, stationery, decoration, electronics, kitchen utilities, etc.) by new international students coming in after others have left. This will help reduce waste and make it easier for students to obtain the necessary things when moving to a new location.

Additionally, our solution aims to improve the overall student mobility experience by simplifying acquiring and transferring items. We aim to create a solution that promotes sustainability and convenience for international students.

1.2 Challenges

This section will cover the challenges we have identified when trying to find a fitting solution for the problem.

1.2.1 Bridging the time gap

One of the critical challenges is the often non-overlapping stays of incoming and outgoing international students. In other words, it is pretty standard that an international student leaves the country before the arrival of the new exchange student. The solution should consider this time gap between the two streams of students – entering or leaving a city. This gap is usually around two months (e.g., December and January or July and August).

1.2.2 User convenience

Finding a solution that is easy to use and convenient is essential, especially when targeting a younger audience, such as international students. These students often have busy schedules and may not have much time to spend on complex tasks. As such, a solution that is straightforward and easy to navigate can be highly beneficial.

The target audience of international students is likely to be familiar with using online platforms and apps. This means that if a potential solution is an app, it must be easy to use to appeal to this demographic. To achieve this, the app should be designed with simplicity and ease of use in mind, with a user-friendly interface and clear instructions that make it easy for students to browse, search, and buy or sell items. Additionally, the app should be designed to be flexible

and adaptable, allowing students to customize their experience and tailor it to their specific needs and preferences. This could include personalized recommendations or object detection to deliver a better user experience and outshine comparing platforms.

1.2.3   Safe and secure Communication and Transactions

Ensuring safe and secure communication and transactions between students is critical to the solution. This requires the implementation of a reliable and secure communication channel that can handle sensitive data with care. Any errors or misconfigurations could result in the loss of money for the students, so careful control and monitoring of the transaction flow is essential to prevent fraud and protect users.

1.2.4   Scalability

One essential requirement of our solution is that it should be scalable and adapt and grow as needed to support international students in cities worldwide. To achieve this, the solution will need to be designed and built with scalability in mind, using robust and flexible technology that can support a wide range of users and transactions. This means that the potential solution should not be limited to a single location or restricted by the number of users. Instead, it should be able to support a large and growing user base across a range of areas.

1.2.5   Technology Stack

Nowadays, complex problems often require solutions leveraging technology. On the one hand, considering investing in cutting-edge technology is a smart way to differentiate the business from other possible competitors; yet this comes at a cost. Implementing this technology necessitates using resources such as time, skills, and money.

It is worth exploring various app development options outside the traditional coding paradigms to develop something functional and entirely usable in a limited timeframe. This is a significant factor, as the requirements for conventional app development usually include fluency in one or more programming languages.

1.2.6   Business model

A sustainable solution comes with a sustainable business model. A solution that adds value while also generating money allows growth and expansion. Coming up with a business model that is fair and appealing to potential customers is a difficult task. The challenge here is to generate money from trading secondhand products while simultaneously meeting the user's willingness to pay.

1.3   Document structure

In chapter 1, we give a vision of the context of this thesis. We also present the goals and the challenges of our research. Chapter 2 will introduce the business idea of Repurpose, a secondhand marketplace for international students. In chapter 3, we investigate whether low low-code programs could assist us in our mission. Then, we map the ideal customer journey on our app in chapter 4. Chapter 5 outlines the business plan comprising benchmarking, revenue discussion, and a go-to-market strategy. Technical implementations can be found in chapter 6. The impact is studied in chapter 7. Chapter 8 summarizes early user feedback. Future work and a general conclusion are outlined in chapter 9.

2. Ideation

Starting from the challenges identified above, we gained insight into potential solutions, detailed in section **Error! Reference source not found.**. Combining these insights gave rise to a business idea discussed in section **Error! Reference source not found.**, which should be developed using a mobile app addressed in section **Error! Reference source not found.**.

2.1 Tackling Challenges

The challenges listed above required us to make specific decisions, which combined allowed us to narrow down on a single concrete solution. The time gap, for example, showed the need for physical drop-off locations to store items that can be picked up later. The need for communications, transactions, and scalability led us to rely on a digital solution. Convenience could be achieved by providing a mobile-first experience for international students.

2.2 Repurpose Approach

The solution would be a niche online marketplace tailored towards international students, where the goods of a person moving can be advertised. These can then be repurposed by someone who arrives in the same city later and can buy items in advance. In the meantime, a middleman like a university or a volunteer can store these goods and be eligible for a commission. The items listed will be spread across six categories for the beginning: decoration, outdoor, bedroom, furniture, electronics, and cooking. The number of categories can later be adjusted.

This digital product idea, named Repurpose, is very scalable by nature, as the same technology can be embedded into every major student city worldwide.

2.3   A Mobile Application

Mobile applications are beneficial for reaching and engaging with Generation Z students. This generation, also known as Gen Z, is highly reliant on their mobile devices and is used to accessing information and communicating through apps. Therefore, ideally, Repurpose should be a mobile application available on Android and iOS.

You can find the application via the QR code below.

3. Customer journey model on Repurpose

3.1   User types

Before diving into the journey, note that there are three main user types in our solution: (1) core users that are sellers and buyers, (2) drop-off buddies, and lastly (3) admins. Each user type has its screens and permissions associated. The seller and buyer have access to the listings, the creation of listings, and buying options. Drop-off buddies can manage their inventory and approve or decline new goods at their drop-off location. The admin verifies payments and can intervene when malicious behavior on the platform is reported.

3.2   Sign up and log in

The user experience starts by either signing up or logging in, depending on whether it is a new or existing user. If the student is a new user, they need to create an account by filling in a list of fields such as email, username, password, and university. This information will help us in the future to personalize Repurpose journey for a better user experience.
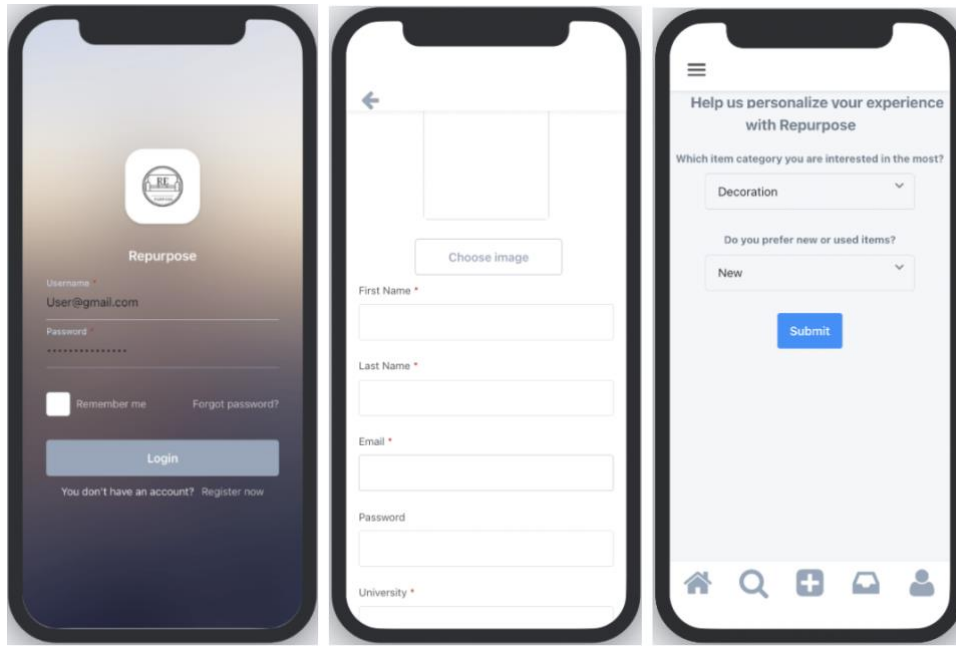
Figure 1: Repurpose Login Screen

To ensure that the information inserted is in the correct format, we have implemented different string-searching algorithms called regular expressions to ensure that we have good-quality data. The same algorithm was implemented on the password to ensure that the user has chosen a strong password that is not easy to hack. Once the student is signed up for the first time, they can personalize the home screen by choosing their preferences regarding the product category and condition. After setting up their preferences, the sorting of the listings will change by prioritizing the user's interests.

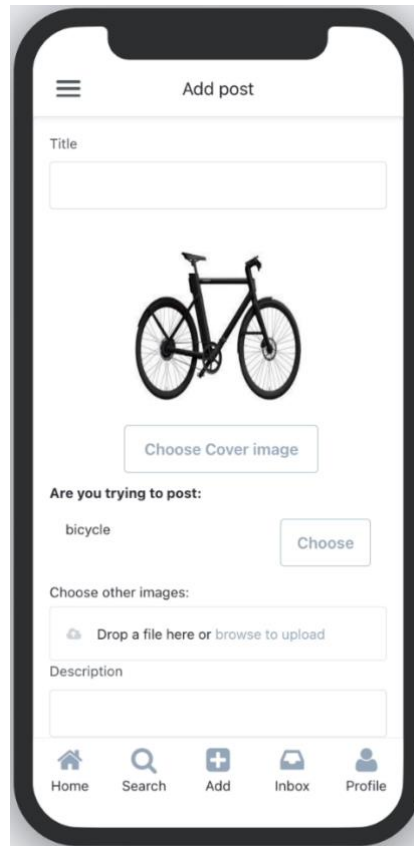## 3.3   Listing Creation amplified Object Recognition

Figure 2: A Listing in Repurpose

Students interested in selling products can quickly post their items by filling in a list of inputs related to the product category, condition, price, and overall description. To improve the user experience of Repurpose, an object recognition feature was integrated to speed up the listing process by auto-filling some of the information related to the item detected within the photo uploaded by the student. The user also can upload multiple images related to the product to highlight all related details.

After setting the price, the user can choose between selling the product in person or via the drop-off option. When selecting "in person", the buyer and the seller need to meet in presence. The seller hands the sold item to the buyer in exchange for the specified price. When done

through the drop-off option, the seller needs to drop off the product in a location that they can select according to their location. Once the selling preferences have been chosen, the listing can be submitted.

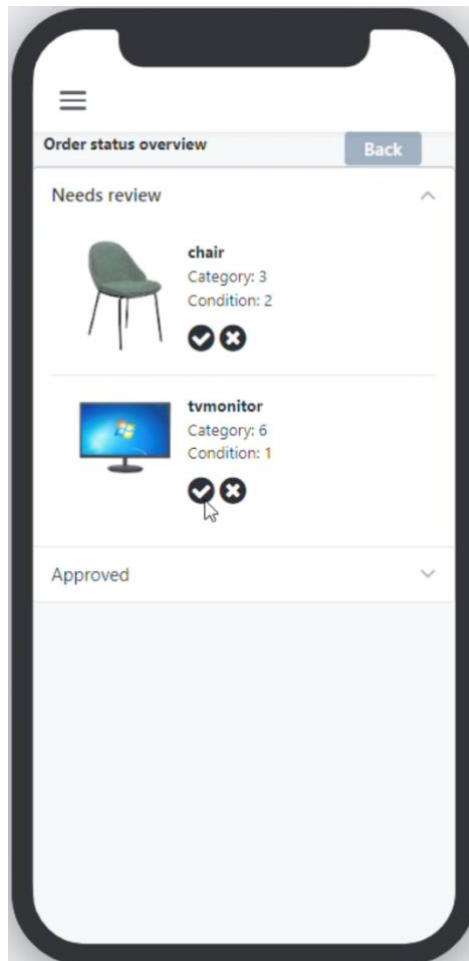## 3.4   Drop-off Buddy Approval

Figure 3: Drop-off Buddy Approval Overview

If the seller chooses the in-person selling preference, the product will be posted directly to the home screen. When selecting the drop-off selling preference, the student needs to wait for the drop-off buddy acceptance. The latter requires to log in to their account and check the item's

description and photos to decide whether they have sufficient space to store it. Once the drop-off buddy accepts the listing, the item will be made available for sale publicly.

In the case of refusal by the drop-off buddy, they need to specify the reason and submit it. The seller will get a notification about the rejection, possibly changing the drop-off location to a newly available location or changing the selling preference to in-person selling.

3.5   Wishlist and Buying

The first step of any student interested in buying a secondhand item is to start checking the home screen where all products will be available. The user can check the product by clicking on its pictures for more details. All product details are displayed with additional photos. The search screen can help filter the items listed by category and condition if they have a clearer idea of what to look for.

If a student is interested but hesitant to buy one of the products listed, they can add it to their wish list, consequently saving the listing for later in a separate folder to be found in the profile. The wish list can be modified, and the user can add and remove any product.

Once the student has decided to buy an article, by pressing the "Buy" button, a popup screen will appear to confirm the article and its price. At that moment, the student needs to confirm the details displayed to proceed to the payment screen. The article will be reserved for the user for three days at this stage. The product will not be available for sale during these days, and the student needs to finish the payment process. If the payment process is not concluded within the deadline, the product will be available again for sale.

At the moment, repurpose does not support in-app transactions. The payment needs to be made outside the application, where the student has a list of payment methods they can use, like bank transfer, Revolut, or MB way. More payment methods will be available in the future.

Once the payment is made, the student must upload and submit the payment proof. This can be a bank statement of the transaction or a screenshot of, e.g., a PayPal transaction. What is essential is that the transaction amount, the transaction receiver, and the transaction titular must be visible in the payment proof file. The student needs to wait for the admin to check the payment proof. Meanwhile, he/they can check the payment status in their inbox screen where the listing is displayed with the payment status "in progress."

3.6 Payment Validation

The administrator needs to check the payment proof uploaded by the buyer, and he can accept or reject the uploaded file. In case of rejection, the buyer must produce another payment proof within the three days deadline. If the payment proof gets accepted, a QR-code will be generated for the buyer to pick up the goods at the drop-off location. The payment status on the buyer's inbox screen will be updated, and the QR code will be added here too.

3.7 Final steps
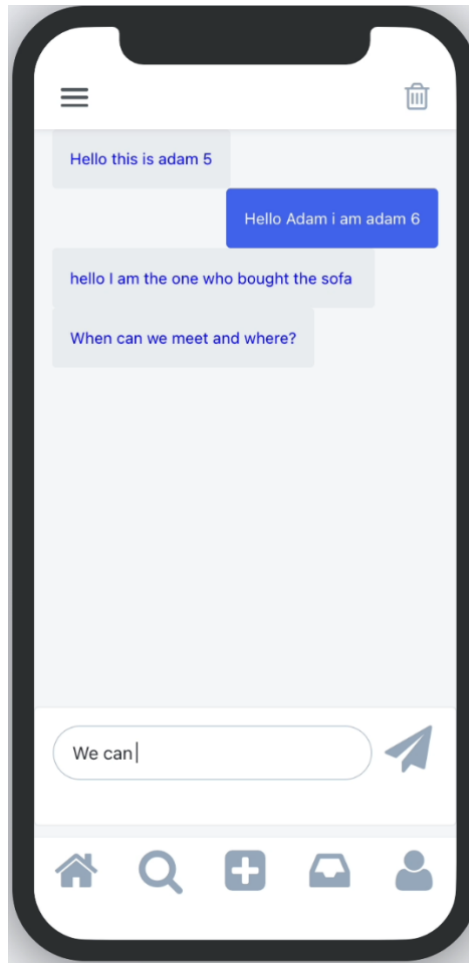
Figure 4: User Chat with Admin

If the product is sold in person, the buyer and seller can chat with each other to arrange a pickup time and place.

If the bought item is stored in a storage location, the exact location of the pickup will be shared. When arriving at the storage location, the buyer can show the drop-off buddy his QR-Code. This is also a safety feature to prevent fraudulent people from showing up at storage spaces. After the buddy scans the code from the buyer, the transaction is completed.

4. Business plan

4.1 Competitive Landscape
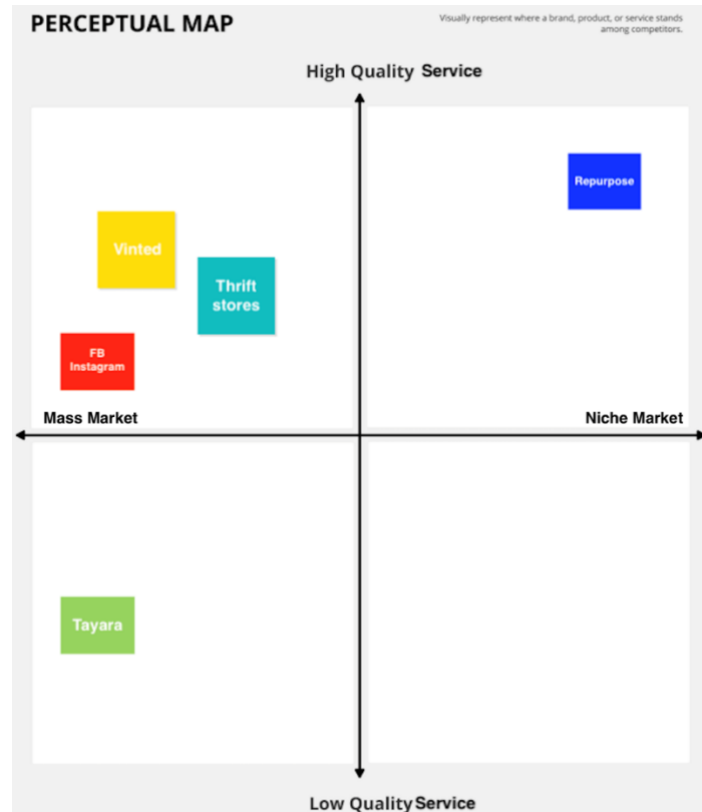
Figure 5: Perceptual Map Classification of Repurpose and Competitors

Benchmarking compares a company's operations or procedures to other firms, startups in the same sector, or even the greater competitive environment. Any service, product, or process may benefit from a benchmarking plan. This plan is used to learn, by comparison, assessing whether there are better approaches, better technologies that can be used, alternative cost-cutting techniques, which are targeted, and if you share the same potential customers, interesting ways to strengthen customer loyalty or more effective methods of increasing profits. (Eloquens 2020).

Determining which factors are most relevant for the benchmarking analysis is essential. This includes understanding the unique characteristics of a company's business operations, clients,

and services to identify significant comparison areas. Common points of comparison among organizations may include factors such as the product or service offered, the scale of the business, the delivery style, the target market segment, and more. Understanding a company's specific features and what sets it apart makes it possible to establish a definite competitive advantage (Starr 2017).

We will evaluate the following two factors: The level of market segmentation (Niche market vs. Mass market) and the service quality level.

4.1.1   Specific Applications

An interesting competitor in the same space is the mobile app "Vinted." Vinted specializes in secondhand clothing and allows users to buy or sell items. It currently operates in sixteen countries, including Portugal. As a previous user, Vinted targets a mass market where everyone interested in buying/selling secondhand clothes can be a potential user. Its service quality is also considered good since its mobile application includes customer support features and its buying experience is well organized to avoid fraud.

On a national level, several mobile apps and platforms offer similar services, such as "Tayara," a Tunisian app that covers a wide range of product categories and does not have a specific target market. Tayara is also targeting the mass market, but its service quality is low since the trading process has no security measures, which makes its users prone to fraud.

Some other companies in the same space as Vinted and Tayara include Depop, ThredUp, and Poshmark. Depop is a popular app for buying and selling secondhand clothing, particularly among younger users. ThredUp is a fashion resale website that offers a wide range of secondhand clothing and accessories. Poshmark is another app-based platform for buying and selling secondhand clothing, focusing on high-end and designer items. These competitors

demonstrate the potential for success in the secondhand marketplace and can provide valuable insights for the development of Repurpose.

4.1.2   Social Media

Social media channels, such as Facebook and Instagram, are commonly used for buying and selling secondhand items because they provide a large and easily accessible audience. These platforms allow users to easily create listings and promote their items to a wide range of potential buyers. Additionally, social media channels often have built-in features, such as hashtags and search functions, which make it easy for users to discover and find items that are relevant to their interests. Overall, the widespread use of social media for buying and selling secondhand items makes it an essential consideration for any company operating in this space.

WhatsApp groups are also one of the very well-known ways of selling and buying products within small communities like dormitories, schools, and students from the same bachelor's or master's program. For example, NOVA SBE students use a WhatsApp group to sell and buy secondhand items.

4.1.3   Amazon

Amazon is a crucial player in the e-commerce market and should be considered in the development of Repurpose. Amazon's vast selection of products, convenient shopping experience, and widespread customer trust make it a significant competitor in the online marketplace. Furthermore, Amazon has several features, such as Amazon Marketplace and Amazon Prime, specifically designed to facilitate the buying and selling secondhand items. Therefore, understanding Amazon's offerings and approach to the secondhand market can provide valuable insights for the development of Repurpose.

4.1.4 Thrift stores

Thrift shops, also known as charity shops or secondhand stores, are a vital consideration in the development of Repurpose. Thrift shops offer a physical location where customers can browse and purchase secondhand items, providing an alternative to online-only platforms. Additionally, thrift shops often have a loyal customer base and a reputation for offering good value and supporting charitable causes. Therefore, understanding the appeal and advantages of thrift shops can provide valuable insights for the development of Repurpose and help to differentiate the app from competitors. Thrift shops target something other than the mass market since their customer base depends on the shop's physical location. Adding to that, their service quality is variable depending on after sales support level of each location.

4.1.5 The competitive Edge of Repurpose

Repurpose has several competitive advantages, including its creators' understanding of the needs and preferences of international students. The app's focus on this specific market will enhance the user experience and make it easier for users to find what they want. Additionally, the creators' connections to networks such as Erasmus+ and NOVA SBE will help accelerate the commercial launch and reach potential users more quickly.

The competitive advantages stated will allow the Repurpose application to be positioned on the top right of the perceptual map (Figure 6) with increased quality service thanks to its admin support and high exclusivity through its niche targeting.

4.2 Revenue model

In this section, we will discuss the financial aspects of the app in more detail. A revenue model must be implemented to support ongoing development and hosting costs. Additionally, the compensation for drop-off buddies must also be considered.

4.2.1 Commissions

We plan to take a 5% commission on all transactions made through the drop-off feature, with 2% going to the drop-off buddy and the remaining 3% going to Repurpose. This would provide a steady stream of income that scales with the volume of transactions on the platform.

4.2.2 Subscriptions

In addition to the commission-based model, we also plan to offer a Repurpose Premium option for buyers and sellers. This premium version will include a notification system that alerts users when items matching their search terms are listed. For sellers, the Premium version will reduce the commission rate to 2%, making it more appealing for those with many items to sell, such as at the end of a semester.

4.3 Go-to-market Strategy

A go-to-market (GTM) strategy is a plan that outlines the actions and approaches a company will take to bring a new product or service to market and achieve its business goals. The GTM strategy typically includes various activities, such as market research, product development, pricing and positioning, distribution, sales and marketing, and customer support. Such a strategy aims to help a company effectively launch and promote its products or services in a way that maximizes its value and appeal to the target market, ultimately leading to increased sales and revenue.

4.3.1 Product-market fit Validation in Lisbon, Portugal

While specific data on the total number of international students in Lisbon is not available, it is known that the University of Lisbon (U Lisboa) and NOVA University Lisbon each have a significant number of international students. U Lisboa welcomes over 9,000, and NOVA

University Lisbon welcomes over 3,000 each year (ULisboa 2022; Universidade NOVA de Lisboa 2022). The high number of international students at these universities makes Lisbon a prime location to launch an app geared toward this demographic.

Before launching in any city, various drop-off locations need to be created. An initial starting point for this would be Nova SBE, the academic institution where the authors of this thesis are currently studying. We count on them because it is a school that encourages its students to create value from innovative products. More than 60% of the campus are international students from more than 70 countries (Exchange from Nova SBE - Exchange Programs | Nova SBE, n.d.). The Repurpose application aligns with the school's vision of encouraging entrepreneurship as a mindset the new generation should adopt.

As the product or service becomes more successful, additional drop-off locations can be added to other campuses and universities in the city to increase exposure. The financial support from the stimulus should assist in the expansion.

Once validation has been achieved, the next step is to expand the product to other cities and countries. This can be accomplished through the use of networks and partnerships. In the following section, we will discuss some of the networks that can assist in this process.

4.3.2 Partnerships for Growth

The GTM strategy could also include targeted marketing and outreach efforts to promote the app to international students and encourage adoption. This could consist of partnerships locally with student organizations and cultural associations, as well as targeted advertising on social media and other relevant platforms.

Moreover, the Erasmus program is one of the major exchange enablers. It was one of the primary causes, if not the leading cause, behind the increase in the number of exchange students from inside and outside Europe and between continents like Africa, Asia, and America. A collaboration with the Erasmus program could increase the Repurpose market share, expand its user base by accessing a critical number of new potential users and support our product branding in Portugal in the short term. The application could be used worldwide in the long term, which also fits our expansion strategy.

The Repurpose platform has the potential to operate not only in Portugal but also at different universities around the world. With the help of the Erasmus program, the Erasmus Student Network (ESN) around the world, and the Nova SBE school's bilateral agreements with other universities in 50 different countries (NOVA SBE 2022), the Repurpose application will have the ability to expand worldwide.

Overall, a phased launch and targeted marketing efforts can effectively introduce the app to international students and drive adoption and engagement.

5. Technical Implementation

5.1 Driving User Experience with Object Detection

5.1.1 Machine Learning and Deep Learning for Object Recognition

Machine learning is one of the essential branches of artificial intelligence. It has found widespread application in various fields, especially computer vision. Deep learning, as a subset of machine learning, has been getting increasingly adapted in recent years. The primary objective of deep learning, as the name implies, is to achieve "high-precision extraction of complex data features" (Yan 2020) by constructing a deeper network structure. The deep learning model relies on several neural networks commonly used in object recognition technology. Furthermore, while we are witnessing an exponential data volume increase, machine computing capabilities have improved significantly. With this evolution, the deep learning algorithm became one of the few algorithms capable of performing tasks such as object detection that was previously unachievable for a lengthy list of other algorithms.

5.1.2 Image Interpretation with Convolutional Neural Networks (CNN)

The image information is primarily obtained through the interpretation of remote-sensing images, essentially extracting semantic information from images. Because the data extracted at the pixel level and the information extracted at the visual level do not always match, this creates the problem of the "semantic gap", which is the mismatching between the two image representations: the real-world representation versus the language representation at the pixel level (PCMag 2022). Consequently, this problem was approached by proposing an "image analysis method based on objects/regions" (Yan 2020)where a deep learning algorithm has reached high accuracy results. Deep learning models, such as VGG, Res-Net, and U-Net, have already been developed, lowering the cost of image segmentation and increasing the speed of

creating deep learning networks. All these models are derived from Convolutional Neural Networks (CNN). CNN is a deep learning algorithm used mainly for classification and computer vision tasks. It revolutionized image classification and object recognition tasks by offering a more scalable approach where matrix multiplication was used to identify objects within an image (IBM Cloud Education 2020). Some studies have used CNN to reach an "automatic segmentation of remote sensing images" (Yan 2020) with over 90% pixel-level accuracy. Other studies have suggested integrating CNN with different algorithms to reach high precision at boundary detection, facilitating the detection of objects within an input image.

In summary, the power of machine learning in object recognition is exceptionally high, which allows it to be incorporated into different areas. It succeeded in disrupting the traditional way of approaching today´s problems.

5.1.3 Introduction to Object Detection

Finding instances of items of a specific class inside a picture is the challenge of object detection models. Modern techniques of object detection can be divided into two primary categories: Two-stage and One-stage methods:

1. Two-stage approaches prioritize accurate detection. Faster R-CNN, Mask R-CNN, and Cascade R-CNN are three examples of such models. Faster R-CNN is the latest algorithm in the R-CNN series. It is an algorithm that uses the Region Proposal Network (RPN), which efficiently exchanges full-image convolutional features with the detection network. It synchronously predicts the object bounds and scores at each position of the object (Ren et al. 2016).

2. One-stage algorithms focused more on inference speed, like SSD (Single Shot Detector), Retina-Net, and YOLO (You Only Look Once). The SSD method detects objects in an

image using a single deep neural network. It divides the output space of bounding boxes into a set of default boxes with changing aspect ratios. SSD surpasses the need of the region proposal network, which makes it faster. Still, at the same time, it employs the multi-scale features and default boxes to regain the level of accuracy needed (Hui 2018). Moreover, Retina-Nets is a model that has been shown to work well with dense and small-scale objects. It has become increasingly popular with aerial and satellite imagery detection (Tsung-Yi Lin et al. 2016). Closing with YOLO, which is a well-known object detection algorithm used by researchers all over the world. When generalizing from natural images to other domains, such as artwork, this algorithm outranks other detection methods, such as dimension-based partitioning and merging clustering (DPM) and R-CNN.

From the object detection models stated, we chose the YOLO algorithm that focused on both speed and accuracy within its object detection process, which made it a good fit for our mobile application, especially when it comes to improving user experience within the Repurpose application("Object Detection | Papers With Code" 2022).

5.1.4 Introduction to the YOLO model

YOLO (You Only Look Once) is a modern object detection algorithm that has proven its speed and accuracy. It has almost become a standard method of detecting objects in computer vision. Previously, people used sliding window object detection that focused on seeing where an object is in an image by running it over the input image repeatedly with varied "window sizes", which means by different rectangle sizes until it detects the object. The sliding window approach had a significant computational overhead. It must harvest many areas and run Conv-Net for each of them separately. Increasing the window and stride size makes it quicker but at the expense of accuracy (Datalya 2018). Then, faster versions such as RCNN, fast RCNN, and faster RCNN

were invented. In 2015, YOLO was created, which leapfrogged all previous object detection algorithms (Patel 2020a).

To simplify, consider an image classification problem in which we must determine whether an image is of a person. In this case, the neural network will try to output a direct result where a Boolean value of 1 means that the algorithm detected a person and 0 when a person was not found. However, when we want to enrich our output by including object localization, we are not only referring to the existence of the object but also the bounding box or, in other words, the position of an object within the image. In this case, the neural network output can be structured as a vector that combines the initial Boolean value with the coordinate of the object's center. After implementing the changes, we can train a neural network to classify both the object and the bounding box. Until now, we could use a list of images to train the neural network so that when a new image is introduced to test its accuracy, it will output the vector containing information about object detection and object localization.

One of the exceptional cases that can encounter the algorithms is when multiple objects exist in the same image. Many algorithms have failed to detect all of the objects within an image properly since it requires a complex implementation to guarantee the accuracy of the result. The YOLO algorithm, in this case, came in handy and succeeded in following an approach where all objects within the same image are detected. The YOLO algorithm approaches the image by splitting it into n-by-n grid cells and attempting to determine whether there is an object in each grid cell. When it finds an object, it begins to construct the vector. Each training image will have n*n vectors (Patel 2020a). When we can use this to train the neural network to predict the detected objects. Unfortunately, this approach has created some issues. The algorithm may detect multiple bounding rectangles for a given object. To solve this problem, the algorithm was boosted by using the concept of IOU (Intersection Over Union), which is taking the

rectangle with the highest accuracy level and then, for that same class taking all other rectangles and attempting to find the overlapping area using IOU score (Patel 2020a)

The YOLO algorithm is a high-speed and accurate algorithm that can detect objects quickly, even on a video clip at 40 frames per second.

5.1.5   Object Detector Model Architecture

Traditional object detector models are typically composed of an input which is the uploaded image, and a backbone which is a network that takes the image as an input and extracts the feature map from it (Figure A). It can implement convolutional neural networks like the VGG algorithm, Resnet with 50 layers (Resnet-50), Darknet52, an open-source neural network, or ResNext50, a 50-layer residual network.

The backbone itself has subsets which are the neck and the head. They help to improve feature discriminability and robustness. The neck contains additional blocks. For example, we mention Spatial Pyramid Pooling (SPP), a pooling layer that aids in releasing the network's fixed-size restriction. The features are combined in the SPP layer, producing outputs with fixed lengths injected into the fully connected layers. Using this method, the convolutional features won't need to be computed repeatedly (He et al. 2015).

Moreover, the Atrous Spatial Pyramid Pooling (ASPP) module can be used as a part of the neck blocs. It is a semantic segmentation module that resamples a given feature layer at various rates before convolution (Chen et al. 2017). Also, the Receptive Field Block (RFB) is a module that enhances the deep features discovered by lightweight CNN models so they can support quick and precise detectors (Liu, Huang, and Wang 2018).

The neck also contains Path-aggregation blocks like a Feature Pyramid Network (FPN). This feature extractor produces proportionally scaled feature maps at various layers in a fully

convolutional manner from a single-scale image of any size as input (Lin et al. 2017). Also, the Adaptively Spatial Feature Fusion (ASFF) is a technique that learns how to suppress contradiction between disparate feature scales by spatially filtering conflicting data, enhancing the scale-invariance of features (Liu, Huang, and Wang 2019).

When it comes to a head, it contains two types of prediction models: dense prediction, called One-stage model, where YOLO is the most reprehensive model, and sparse prediction, or the Two-stage model, where R-CNN is one the most representative two-stage object detectors models.

5.1.6   YOLOv4: a faster, stronger, and more accurate object detector model

The first version of the YOLO model was invented in 2016. Then after around one year, a faster and more robust version was introduced, which succeeded in detecting objects on video at 67 frames per second. In 2018, a third version was released, presenting an improvement in rapidity and accuracy. Then in 2020, Alexey Bochkovskiy, Chien-Yao Wang, and Hong-Yuan Mark Liao created the YOLO V4 model. It not only provides powerful, fast, and accurate detection of objects within the user's uploaded photo but also consumes less GPU power. Modern neural networks do not operate in real-time and necessitate using many GPUs for training with large mini-batch sizes. This problem was addressed by YOLO V4's convolutional neural network, which runs in real-time and requires only one conventional GPU for training with the possibility to detect the object on video of 40 frames (Patel 2020b). The fourth version of the YOLO model can anticipate up to 9000 known and even unknown classes. The real-time classification model will distinguish several things from a picture and draw a border box around each object. Adding to that, It is simple to train and implement in a production system. This version of the YOLO model has succeeded in increasing the average precision level by 10% compared to the previous

version and also increased its frame per second (FPS) to 12% more than the third version (Orac 2020).

5.1.7 Selection of architecture: YOLO V4 architecture

Following the object detector model architecture, the YOLO V4 backbone was constructed of CSPDarknet53, which is a CNN model that uses a split-and-merge strategy on the feature map of the base layer, which consequently allows for more gradient flow through the network (Bochkovskiy, Wang, and Liao 2020a). SPP block was also used since it dramatically expands the receptive field, separates the most critical context features, and nearly wholly maintains network operating performance (Bochkovskiy, Wang, and Liao 2020b). In place of the FPN that was used in YOLOv3, YOLO V4 is using the Path Aggregation Network (PANet) as a technique of parameter aggregation from various backbone levels for different detector levels; it attempts to improve information flow to cut down the information path between low and high layers which, consequently, contribute to a faster processing time (Shu Liu et al. 2018). Concerning the head, Yolo V4 kept the same prediction model used in the previous version YOLO V3 based on dense prediction where each pixel is labeled (Sercu and Goel 2016).

5.1.8 YOLO V4 model´s specificities: Training strategies and plugins

YOLO V4 solved the problems that earlier iterations experienced. In this regard, YOLO V4 employs a comprehensive framework of training strategies known as the bag of Freebies to increase object detection accuracy without increment latency at inference time (Shah 2020). One of the strategies used is data augmentation, which makes the input image data more variable so that the model is more resilient to images taken in various situations. Two main data augmentation methods are used: Photometric Distortions, which focus on changing image

parameters like brightness, Contrast, and Saturation, and Geometric Distortions, which randomly scale, rotate, or flip the input image.

Adding to that, object occlusion is a significant challenge. And for that, several techniques for data augmentation were developed to address these issues, like Random-Erase and Cut-Out method, which is based on choosing a rectangle at random from a picture, then filling it with the value zero on the pixel level. Hide-and-Seek and Grid-Mask are methods based on choosing out several rectangle portions of an image randomly or evenly, then changing them to zeroes (Shah 2020). Also, the Drop-Out technique was used by disabling a group of neurons during training to prevent over-fitting by selecting alternative network routes. Adding to that, other methods were based on combining different photos when enhancing data, like Mix-Up, which superimposes and multiplies two photos using various coefficient ratios, and Cut-Mix, which covers the rectangle-shaped portion of other photos where an image has been croppedWhile Cut-Mix merges only two training photos, Mosaic data augmentation merges four training photos in specific ratios into one (Solawetz 2020). Then it modifies the label to fit the size of the mixing area (Shah2020). It was the first new data augmentation technique featured in YOLO V4. It enabled the model to learn how to recognize objects at a lower scale than usual, and it was also influential in training since it reduced the requirement for a sizeable mini-batch size.

Another issue was addressed in the bag freebies, like the inherent bias challenge (Shah 2020). One of the factors that cause semantic distribution bias in datasets is the imbalance in data across classifications. In other words, if the data distribution is biased, it might tilt the training towards non-optimal convergence, and failure to generalize address this problem for one-stage object detectors, the focal loss was used. It is an upgraded version of Cross-Entropy Loss (CE) that addresses the class imbalance problem by giving more weight to complex or easily misclassified cases and less weight to simple examples like Background objects. As a result,

Focal Loss decreases the loss contribution from simple instances while emphasizing the need to rectify misclassified cases (Anwla 2020). The other main factor was the failure to indicate the degree of linkage between multiple categories where smooth labeling was used to address this problem by improving model resilience and performance when training with mislabeled data.

At each training phase, the objective function, also known as a loss function, is used to "punish" and lead the model toward a better convergence. As a third strategy, the objective function of Bounding Box (BBox) regression was implemented as part of the bag of freebies techniques (Shah 2020). The basic score mentioned in this strategy was the mean square error (MSE) that was used to "perform regression on center point coordinates and height and width of the BBox" (Shah 2020). Unfortunately, regression conducted on individual points ignores an object's coverage area, and the loss accumulates according to the item's size. As a solution to the overlapping bounding boxes, the rate of intersection over union (IOU) loss was a potential solution. Over time, several versions of IOU loss rates were developed, like the generalized IOU loss, Distance IOU loss, and the complete IOU loss that considers three metrics simultaneously: overlapping area, the distance between center points, and aspect ratio (Shah, 2020).

YOLO V4 model also used plugins and post-processing modules that slightly raise the inference cost but significantly improve the object detection's accuracy (Trivedi 2020). These plugins were called "Bag of Specials" (BoS). In other words, the term bag of specials refers to a collection of modules that marginally increased the processing time and power needed for the model but considerably increased the accuracy level of the model. One of the plugins used for the Yolo V4 backbone was "Mish", an activation function that proved that it is better than the Rectified Linear Unit (ReLu) activation function which is the most famous activation function

within CNN models. Mish activation function maintains negative values, stabilizing the network gradient flow and solving the Dying ReLU problem. Thanks to its smoothness, it is unbiased toward the initialization of weights and learning rate, allowing for superior generalizations (Trivedi 2020). The implementation of Mish as an activation function within the YOLO V4 resulted in noticeable accuracy increases. Despite being more expensive, the Mish function has outperformed ReLU in deep layers. The attention model was also part of BoS as one of the methods used to improve the model performance (Trivedi 2020). The spatial attention model (SAM) has lately been employed in CNN models to direct the network's attention away from the entire and onto the object within the input image. This module assists in answering the where and what questions by instructing a network to emphasize contextual information around an object and which traits are significant. CSP connections like CSPDarknet53, SPP model, and FPN were also part of BoS plugins used with the YOLO V4 model (Trivedi 2020).

Although this combination of different plugins increased the processing time and the GPU power needed but from another perspective, it contributed to a high increase in terms of accuracy level in object detection tasks.

5.1.9   Implementation: UbiOps and OutSystems

In the past few years, different coding languages have been created to serve other areas of technological development. Python is one of the most known coding languages for various purposes like web development and data analysis. It is further used for front-end and back-end development and machine learning purposes. The YOLO V4 model was developed principally using python. To set up the YOLO V4 model, a list of prerequisites needs to be installed to guarantee a smooth and correct run of the model like CMake, CUDA cuDNN, OpenCV, cuDNN… (Joseph 2022). Currently, Python code cannot be executed in a low-code

environment. Setting up an environment to run the code necessitates significantly different abilities than developing low-code apps. OutSystems provides several plugins that support Python or R code. One of these plugins is the UbiOps plugin, which supports Python or R code and empowers OutSystems apps to run machine learning models like YOLO V4.

UbiOps is a Dutch software firm that helps data scientists to deploy scalable, dependable, and secure Python and R scripts. OutSystems is now able, with the help of UbiOps, to construct scalable and robust data science-based applications (UbiOps 2022).

Several steps should be followed to integrate YOLO V4 within our OutSystems application (Figure B). It starts with deploying a pre-trained version of YOLO V4 with the COCO dataset, which is one of the most extensive object detection datasets with 91 classes of objects. Crucially, we must identify inputs and outputs and include the YOLO V4 algorithm code. With UbiOps, this step is dealt with by utilizing a created package that will be imported. The next step will be the creation of an authentication Token to make our deployment specific to only our application. The next step will be the consumption of the UbiOps REST endpoint.

Using a specified URL that needs to include the application's name in the development and the generated authentication key, a list of methods needs to be created to process the image uploaded within our OutSystems application (UbiOps 2022).

An Authorization header needs to be added to the Headers and Authentication tab so that the security token can be added to every request or method created.

The object detection logic within the OutSystems application starts by adding a camera plugin to the add-post page to store the input image as a blob (Figure C). Then, the image stored will be sent to the UbiOps API endpoint through a POST method to get the request ID (Figure C). Another POST method should be created to count the object available in the image. The list of

objects will go through a JSON_Listify method, where the path will replace the identified objects with a list of name/value pairs sent through another POST method. After running the YOLO V4 code integrated within the UbiOps plugin, a list of objects detected that match one or more of the COCO dataset classes will be sent back using a GET request to the API endpoint (Figure C). The list of the objects identified will be rendered in the Add-Post screen. Suppose one of the suggestions proposed by the YOLO V4 model matches the item posted. In that case, the user can choose it to facilitate the item posting feature, where a particular input will be auto-filled according to the item identified. As the last step, the application must be published to test it using the web or mobile versions using the QR code available within the PWA section. To ensure the long-term usefulness of the object detection functionality, the mobile application admin can manage the model created through the UbiOps dashboard (Figure D), where he can have an overview of the number of deployments, pipelines built and the successful/failed daily requests.

6. Impact

Repurpose's vision is to inspire and empower the new generation to make more environmentally-friendly decisions. We are committed to driving positive change toward a healthier, more sustainable environment. As a community, we are dedicated to promoting small initiatives and actions that can significantly impact us. We believe that working together can create a brighter and more sustainable future for all.

6.1 Emissions

It primarily tries to reduce students' carbon footprint and CO2 consumption by encouraging them to adopt the reusability concept giving items a new life. This will cut down energy and resources used for producing new products and consequently scale down future waste.

For example, a study was made on the secondhand concept within the fashion industry. One of the interesting findings is that fast fashion production generates 20% of the world's wastewater and 10% of the world's carbon emissions, which is higher than the total emissions of international flights and marine shipping (Okafor 2022). More precisely, and as an example, a cotton t-shirt requires around 713 gallons (2,700 liters) of water to be made (Astoul 2021). Also, we should mention that only 15% of worn textiles are recycled, with the remaining 85% ending up in landfills or burnt. And most objects require a considerable amount of time to decompose in landfills, possibly hundreds of years (Astoul 2021). This demonstrates even more how our actions harm the ecosystem.

6.2 Financial impact

Additionally, this concept will help students save money and generate profit for the drop-off buddy. In other words, we have designed an economic cycle where everyone benefits without

harming the environment. By promoting sustainable practices and encouraging the reuse of goods, we aim to create a win-win situation for all involved. According to many resellers' pricing strategies, products in perfect condition are priced at 70% of their original price. In comparison, items that are used and have seen better days are priced at 30% of their original price (Stephenson 2005). According to Erasmus plus program, the average installation cost for an exchange student is 1000€ (Public Health in Disasters 2022). Based on these numbers, an exchange student that buys most of the items/products needed during his exchange experience through repurpose application can save at least 500 €.

7. Early user feedback

Incorporating user feedback from a diverse group of users can help ensure that the Repurpose mobile application caters to the needs and preferences of a wide range of users. This can lead to a more successful and well-received product. Additionally, gathering feedback from different perspectives and points of view can provide valuable insights that can help improve the functionality and usability of the application. We collected this feedback through Nova School of Business and Economics live demos. This approach allowed us to observe the user's journey within the application.

The goal was to get more insight into the UX in different use cases: account creation, selling, and buying. For each scenario, we focus on the time spent, whether the user will ask for help and the specific suggestions for improvement.

7.1   Perceived Strengths of the app

Firstly, the object detection feature was well-received by most participants, who found it exciting and innovative. Many were interested in how the AI technology behind the feature worked. Participants also appreciated that using the object detection feature reduced the time required to post an item, as many fields were automatically filled.

In addition to the object detection feature, participants appreciated the ability to quickly contact the help center and make inquiries or report suspicious items for sale. They also liked the option to message the seller after purchasing an item and arrange a meeting to exchange the product.

7.2   Current Weaknesses

Participants mentioned several areas for improvement in the application. Many suggested that the app's aesthetic design could be more colorful and engaging to encourage users to spend

more time using it. Some participants found the login process too lengthy, and others had trouble using the object detection feature, which didn't always correctly identify items. Additionally, some users felt that the available drop-off locations were limited, and others wanted a broader range of categories to choose from. Finally, many participants expressed concerns about the manual payment verification process and its ability to scale up as the number of users grows.

8. Conclusions

In this work project, we proposed a way to reduce waste generated by international students. The solution is a mobile app developed in the OutSystems low-code environment that is scalable and can be implemented in student cities worldwide.

While the fundaments of the application and its business model are built, future work is necessary to (1) grow on and (2) satisfy user needs. Growth can be achieved by implementing a sound go-to-market strategy. While we did not discuss it in detail in our text, we laid out a roadmap for further development efforts:

1. Improve the aesthetic design of the application by defining a unified theme for the user interface.

2. Develop a marketing strategy to attract more drop-off buddies quickly, focusing on social media platforms like Facebook and Instagram and starting talks with institutional partners like Erasmus+.

3. Expand the list of categories to include new categories based on the specific needs of different schools and countries.

4. Implement a more flexible monetization process that considers factors such as the product's size, the product, the condition of the product, and the user's subscription type.

5. Rethink the payment process and consider implementing an AI system to verify payment proofs automatically.

6. Prepare a list of must-have items for international students based on their geographical location to facilitate their integration into the local lifestyle.

7. Analyze data collected through the application to understand users' needs and personalize their experience within the app.

These objectives will help Repurpose grow and expand while offering a high-quality user experience.

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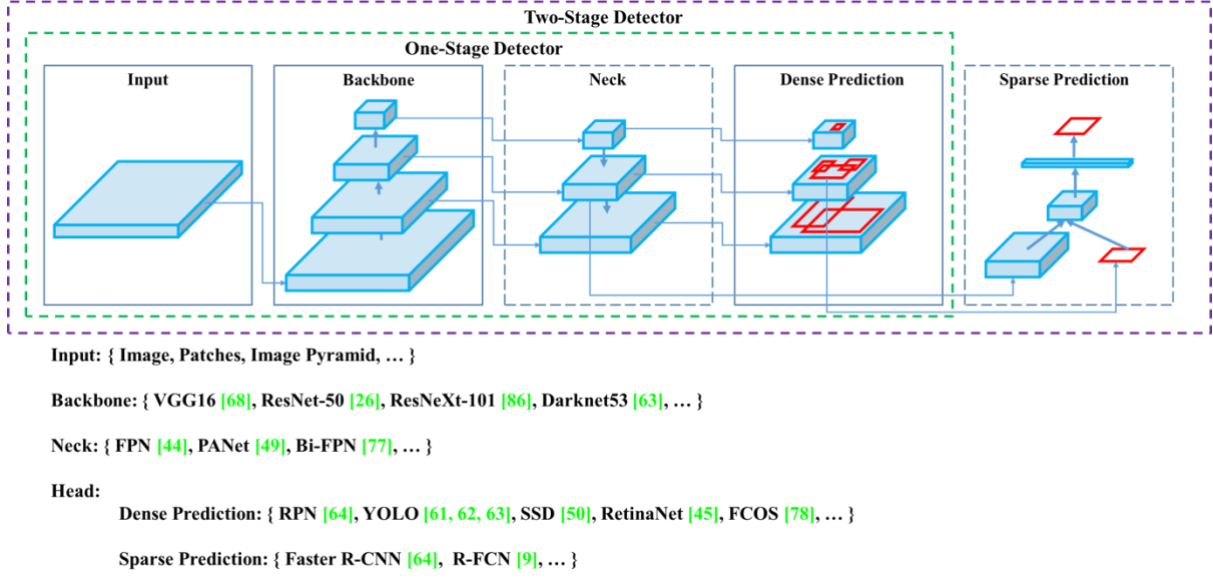
Appendix

Input: { Image, Patches, Image Pyramid, … }

Backbone: { VGG16 [68], ResNet-50 [26], ResNeXt-101 [86], Darknet53 [63], … }

Neck: { FPN [44], PANet [49], Bi-FPN [77], … }

Head:

    Dense Prediction: { RPN [64], YOLO [61, 62, 63], SSD [50], RetinaNet [45], FCOS [78], … }

    Sparse Prediction: { Faster R-CNN [64], R-FCN [9], … }

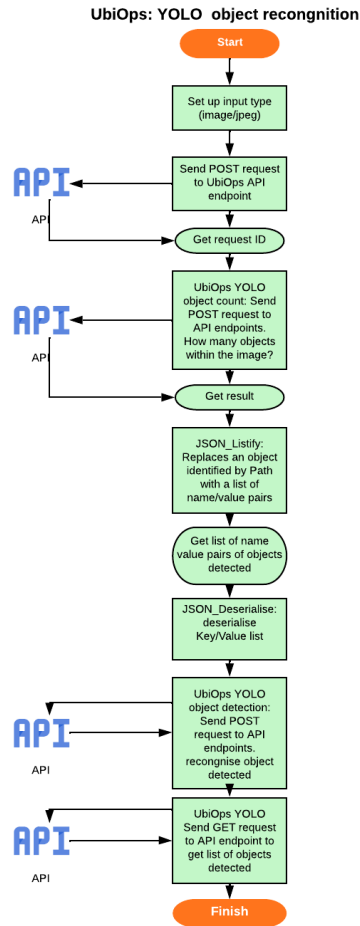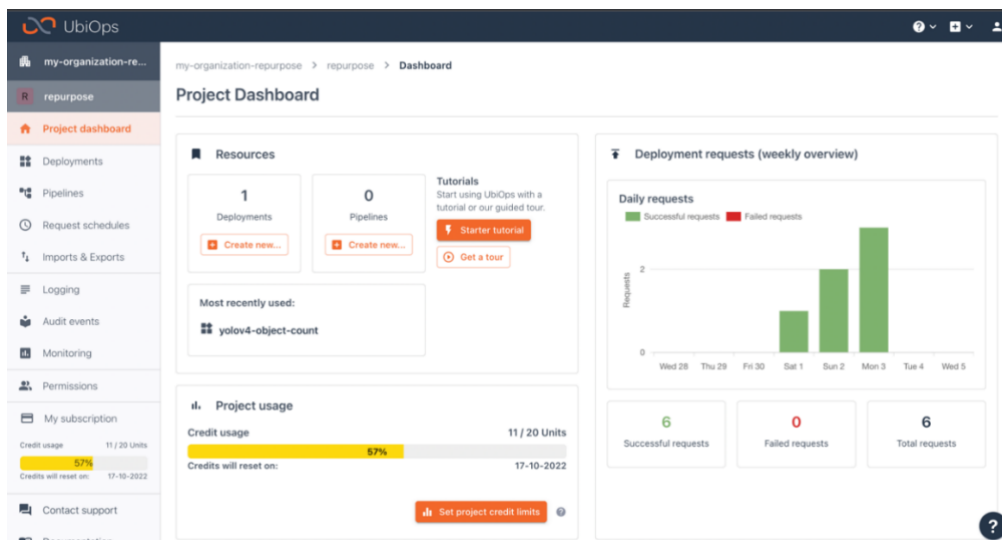Figure A: YOLO architecture

Figure B: UbiOps implementation

Figure C: Object detection process

Figure D: UbiOps Project dashboard