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Reducing waste generated by international students' mobility

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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.

Keywords

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

Acknowledgments

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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
AWS	Amazon Web Services
IaaS	Infrastructure-as-a-Service
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
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.

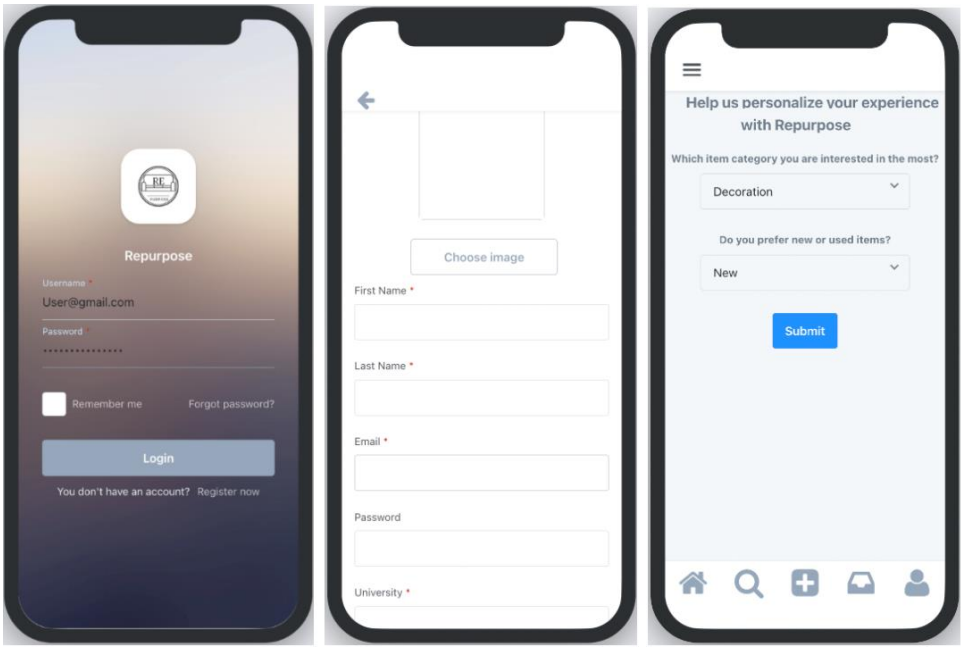

Figure 1: Repurpose Login Screen

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

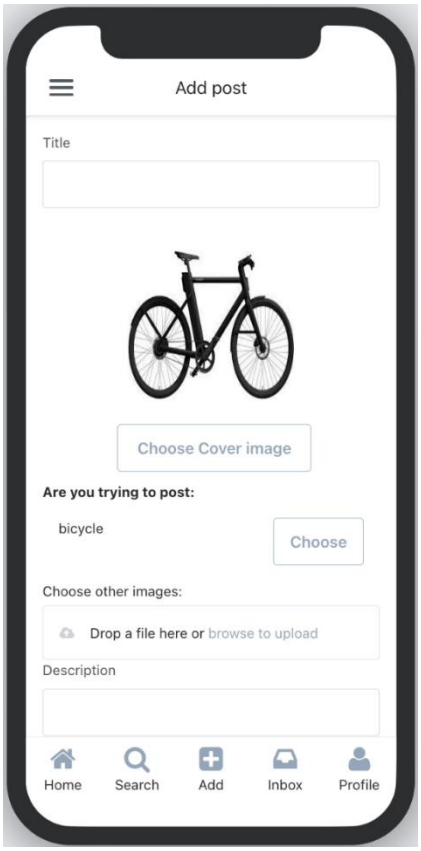

Figure 2: A Listing in Repurpose

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

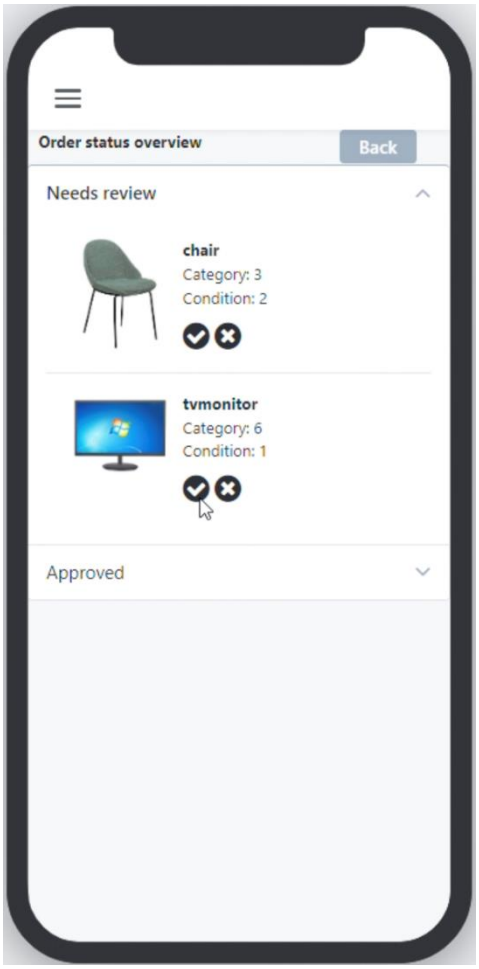

Figure 3: Drop-off Buddy Approval Overview

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

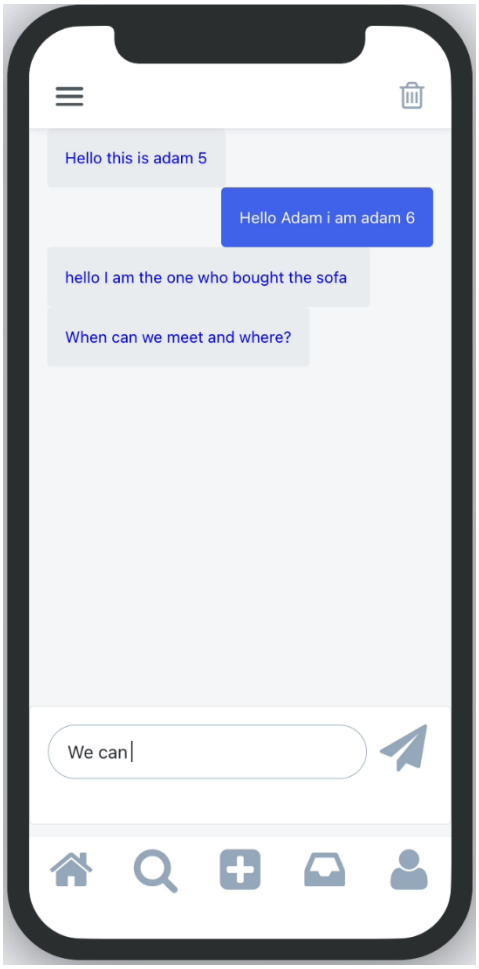

Figure 4: User Chat with Admin

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

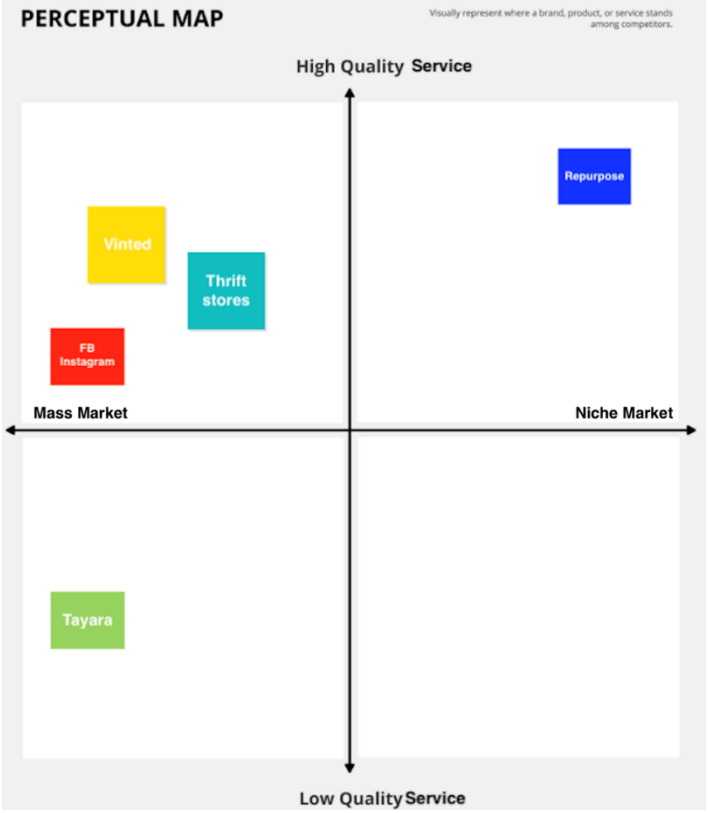

Figure 5: Perceptual Map Classification of Repurpose and Competitors

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 5) 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. 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.

5.1 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.

5.2 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 €.

6. 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.

6.1 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.

6.2 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.

7. 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.

References

Anwla, Praveen Kumar. 2020. “Focal Loss in Object Detection | A Guide To Focal Loss.” 2020. https://arxiv.org/ftp/arxiv/papers/2006/2006.01413.pdf.

Astoul. 2021. “How Second-Hand Shopping Can Save The Planet - Green With Less.” 2021. https://greenwithless.com/second-hand-shopping-planet/.

Bochkovskiy, Alexey, Chien-Yao Wang, and Hong-Yuan Mark Liao. 2020a. “YOLOv4: Optimal Speed and Accuracy of Object Detection.” 2020. https://arxiv.org/pdf/2004.10934v1.pdf.

———. 2020b. “YOLOv4: Optimal Speed and Accuracy of Object Detection,” April. https://doi.org/10.48550/arxiv.2004.10934.

Cahyadi, Amelia, and Adi Prananto. 2015. “Reflecting Design Thinking: A Case Study of the Process of Designing Dashboards.” *Journal of Systems and Information Technology* 17 (3): 296–306. https://doi.org/10.1108/JSIT-03-2015-0018.

Caseiro, Nuno, and Arnaldo Coelho. 2019. “The Influence of Business Intelligence Capacity, Network Learning and Innovativeness on Startups Performance.” *Journal of Innovation and Knowledge* 4 (3): 139–45. https://doi.org/10.1016/j.jik.2018.03.009.

Chen, Liang-Chieh, George Papandreou, Iasonas Kokkinos, Kevin Murphy, and Alan L. Yuille. 2017. “DeepLab: Semantic Image Segmentation with Deep Convolutional Nets, Atrous Convolution, and Fully Connected CRFs.” 2017. https://paperswithcode.com/method/aspp.

Datalya. 2018. “Object Detection with Sliding Window Algorithm | Data Science Blog.” 2018. https://datalya.com/blog/machine-learning/object-detection-with-sliding-window-algorithm.

Dedić, Nedim, and Clare Stanier. 2016. “Measuring the Success of Changes to Existing Business Intelligence Solutions to Improve Business Intelligence Reporting,” 225–36. https://doi.org/10.1007/978-3-319-49944-4_17ï.

DESA. 2022. “Ensure Sustainable Consumption and Production Patterns.” 2022. https://sdgs.un.org/goals/goal12.

Eckerson, Wayne. 2010. “What Are Performance Dashboards? The Context for Performance Dashboards.”

Eloquens. 2020. “Benchmarking Templates & Methods.” 2020. https://www.eloquens.com/category/strategy/benchmarking-templates/504.

Elshan, Edona, and Ernestine Dickhaut. 2021. “An Investigation of Why Low Code Platforms Provide Answers and New Challenges” 2024.

He, Kaiming, Xiangyu Zhang, Shaoqing Ren, and Jian Sun. 2015. “Spatial Pyramid Pooling in Deep Convolutional for Visual Recognition.” 2015.

Hui, Jonathan. 2018. “SSD Object Detection: Single Shot MultiBox Detector for Real-Time Processing.” 2018. https://jonathan-hui.medium.com/ssd-object-detection-single-shot-multibox-detector-for-real-time-processing-9bd8deac0e06.

IBM Cloud Education. 2020. “What Are Convolutional Neural Networks? | IBM.” 2020. https://www.ibm.com/cloud/learn/convolutional-neural-networks.

Joseph. 2022. “A Gentle Introduction to YOLO v4 for Object Detection in Ubuntu 20.04.” 2022. https://robocademy.com/2020/05/01/a-gentle-introduction-to-yolo-v4-for-object-detection-in-ubuntu-20-04/#Why_we_use_YOLO.

Lin, Tsung-Yi, Piotr Dollár, Ross Girshick, Kaiming He, Bharath Hariharan, and Serge Belongie. 2017. “Feature Pyramid Networks for Object Detection.” 2017. https://arxiv.org/pdf/1612.03144v2.pdf.

Liu, Songtao, Di Huang, and Yunhong Wang. 2018. “Receptive Field Block Net for Accurate and Fast Object Detection.” 2018. https://paperswithcode.com/method/rfb.

———. 2019. “Learning Spatial Fusion for Single-Shot Object Detection.” 2019. https://arxiv.org/pdf/1911.09516v2.pdf.

Luo, Yajing, Peng Liang, Chong Wang, Mojtaba Shahin, and Jing Zhan. 2021. “Characteristics and Challenges of Low-Code Development: The Practitioners Perspective.” *International Symposium on Empirical Software Engineering and Measurement*. https://doi.org/10.1145/3475716.3475782.

NOVA SBE. 2022. “Exchange from Nova SBE - Exchange Programs.” 2022. https://www.novasbe.unl.pt/en/programs/exchange-programs/exchange-from-nova-sbe.

“Object Detection | Papers With Code.” 2022. 2022. https://paperswithcode.com/task/object-detection.

Okafor, Jennifer. 2022. “10 Reasons to Buy Second Hand Rather Than New.” 2022. https://www.trvst.world/sustainable-living/10-reasons-why-you-should-buy-second-hand/.

Orac, Roman. 2020. “What’s New in YOLOv4?” 2020. https://towardsdatascience.com/whats-new-in-yolov4-323364bb3ad3.

OutSystems. n.d. “Architecture | Evaluation Guide | OutSystems.” Accessed December 10, 2022. https://www.outsystems.com/evaluation-guide/architecture/.

Patel, Dhava. 2020a. “What Is YOLO Algorithm? | Deep Learning Tutorial 31 (Tensorflow, Keras & Python) - YouTube.” 2020. https://www.youtube.com/watch?v=ag3DLKsl2vk.

———. 2020b. “Yolov4 Object Detection - How It Works & Why It’s So Amazing! | OpenCV Python | Computer Vision - YouTube.” 2020. https://www.youtube.com/watch?v=_JzOFWx1vZg.

PCMag. 2022. “Definition of Semantic Gap.” 2022. https://www.pcmag.com/encyclopedia/term/semantic-gap.

Pordata. 2022. “Municípios: Alunos Matriculados No Ensino Superior: Total e Por Sexo | Pordata.” 2022. https://www.pordata.pt/municipios/alunos+matriculados+no+ensino+superior+total+e+por+sexo-305-1416.

Public Health in Disasters. 2022. “Tuition Fees and Scholarships.” 2022. https://publichealthdisasters.eu/tuition-fees-and-scholarships/.

Ren, Shaoqing, Kaiming He, Ross Girshick, and Jian Sun. 2016. “Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks.” 2016. https://arxiv.org/pdf/1506.01497v3.pdf.

Sahay, Apurvanand, Arsene Indamutsa, Davide Di Ruscio, and Alfonso Pierantonio. 2020. "Supporting the Understanding and Comparison of Low-Code Development Platforms." *Proceedings - 46th Euromicro Conference on Software Engineering and Advanced Applications, SEAA 2020* 2 (August): 171–78. https://doi.org/10.1109/SEAA51224.2020.00036.

Sanchis, Raquel, Óscar García-Perales, Francisco Fraile, and Raul Poler. 2020. "Low-Code as Enabler of Digital Transformation in Manufacturing Industry." *Applied Sciences (Switzerland)* 10 (1). https://doi.org/10.3390/app10010012.

Schmidt, Anthony. 2019. "The Cost of International Education." 2019. https://www.anthonyschmidt.co/post/2019-5-10-the-cost-of-international-education/.

Sercu, Tom, and Vaibhava Goel. 2016. "Dense Prediction on Sequences with Time-Dilated Convolutions for Speech Recognition," November. https://doi.org/10.48550/arxiv.1611.09288.

Shah, D. 2020. "YOLOv4 | Bag of Freebies | Object Detection | VisionWizard." 2020. https://medium.com/visionwizard/yolov4-bag-of-freebies-dc126623fc2d.

Shields, Robin. 2019. "The Sustainability of International Higher Education: Student Mobility and Global Climate Change." *Journal of Cleaner Production* 217 (April): 594–602. https://doi.org/10.1016/J.JCLEPRO.2019.01.291.

Shu Liu, Lu Qi, Haifang Qin, Jianping Shi, and Jiaya Jia. 2018. "PANet Explained | Papers With Code." 2018. https://arxiv.org/abs/1803.01534v4.

Solawetz, Jacob. 2020. "Data Augmentation in YOLOv4." 2020. https://blog.roboflow.com/yolov4-data-augmentation/.

Starr, J. 2017. "The Four Phases Of Successful Benchmarking." 2017. https://www.fieldtechnologiesonline.com/doc/the-four-phases-of-successful-benchmarking-0001.

Stephenson, James. 2005. "Pricing New, Used and Collectible Goods for Sale." 2005. https://www.entrepreneur.com/starting-a-business/pricing-new-used-and-collectible-goods-for-sale/76160.

Sutner, Shaun. 2018. “What Is a Business Intelligence Dashboard (BI Dashboard)?” 2018. https://www.techtarget.com/searchbusinessanalytics/definition/business-intelligence-dashboard.

Trivedi. 2020. “YOLOv4 - Part 3: Bag of Specials | VisionWizard.” 2020. https://medium.com/visionwizard/yolov4-version-2-bag-of-specials-fab1032b7fa0.

Tsung-Yi Lin, Piotr Dollár, Ross Girshick, Kaiming He, Bharath Hariharan, Tsung-Yi Lin, Priya Goyal, Ross Girshick, and Kaiming He. 2016. “How RetinaNet Works? | ArcGIS API for Python.” 2016. http://arxiv.org/abs/1708.02002 arXiv:1708.02002.

UbiOps. 2022. “Machine Learning with OutSystems: Object Detection App.” 2022. https://ubiops.com/machine-learning-with-outsystems-object-detection-app/.

UIS. 2022. “Outbound Internationally Mobile Students by Host Region.” 2022. http://data.uis.unesco.org/.

ULisboa. 2022. “About Us.” 2022. https://www.ulisboa.pt/en/about-us.

Universidade NOVA de Lisboa. 2022. “Facts and Figures.” 2022. https://www.unl.pt/en/nova/facts-and-figures.

Vincent, Paul, Kimihiko Iijima, Mark Driver, Jason Wong, and Yefim Natis. 2019. “Licensed for Distribution Magic Quadrant for Enterprise Low-Code Application Platforms,” 1–35.

Waszkowski, Robert. 2019. “Low-Code Platform for Automating Business Processes in Manufacturing.” *IFAC-PapersOnLine* 52 (10): 376–81. https://doi.org/10.1016/j.ifacol.2019.10.060.

Yan, Shuqi. 2020. “Machine Learning for Object Recognition-Systematic Literature Review.” *Environmental Science*.

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MAARTEN DE WINTER

Architectural, infrastructural and practical considerations for developing a data-centric low-code application

Work project carried out under the supervision of:

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Abstract

Low-code development platforms provide a high-level and visual approach to produce applications, often benefiting turnaround time and enabling early user validation. While generally speeding up development processes, low code ecosystems all have their own architectural and infrastructural flavors. As there is a rise in popularity of various low-code environments, we deem it relevant to discuss the approach of one key player: OutSystems. Our discussion will be made tangible by means of example application Repurpose, a waste elimination app developed recently aimed at international students.

Keywords

Low-code, mobile, architecture, digital

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1. Literature review

Developing a mobile app can be a challenging process for several reasons. First, creating a user-friendly and intuitive app requires a deep understanding of user experience design and the specific needs and preferences of the target audience. This can be particularly challenging when developing an app for a global or diverse user base. Second, creating a high-quality app requires a solid technical skill set, including expertise in software development and programming languages such as Java and Swift. Finally, developing and launching a mobile app can be time-consuming and resource-intensive, requiring significant investment in both time and money. These challenges can make creating a mobile app a complex and difficult process.

We want to investigate low code as a development approach for these reasons. This section discusses the different considerations when developing in a low-code environment. First, we explain what low-code development entails. Then we zoom in on practical, infrastructural, and architectural considerations.

1.1 Low-code Development Platforms

Low code development platforms (LCDPs) allow developers to create applications without extensive hand-coding. Instead, developers use a visual interface to design the app's user interface, business processes, business logic, and data models. This approach, known as "drag-and-drop" development, allows for greater agility and flexibility than traditional hand-coding methods. LCDPs are particularly useful for rapid prototyping and building applications requiring complex functionality without much custom coding. Overall, LCDPs can be valuable for developers who want to create applications quickly and efficiently. (OutSystems, s.d.). LCDPs allow individuals with limited technological backgrounds to build and deploy desktop and mobile applications relatively easily (Sanchis et al. 2020; Waszkowski 2019). This new

paradigm in app development is welcomed by many enterprises, as it allows them to respond to changing business needs and market conditions more quickly and effectively (Sanchis et al. 2020).

According to a Gartner study in 2019, three-quarters of large enterprises will use at least four low-code development tools for IT application development and citizen development initiatives by 2024. Furthermore, they claim that more than 65% of application development activity will be generated through LCDPs (Vincent et al. 2019).

1.2 Practical Considerations of LCDPs

Although the growth and adoption of LCDPs have been impressive, there still needs to be a greater understanding of how to apply these tools effectively, particularly among small and medium-sized enterprises (Elshan and Dickhaut 2021). Using a SWOT-analysis framework, we will summarize the literature about the strengths; weaknesses; opportunities; and threats of low-code application development in a business context. This framework allows us to organize and evaluate the existing literature on this topic.

1.2.1 Strengths

The Link between IT and Business Departments

Common LCDP languages can help break down silos and bring IT and business teams together. By using red language and a set of tools, these teams can work together more effectively to develop applications focused on end users' needs. This can allow tech-savvy business employees to work on less demanding development tasks while the IT department focuses on more complex and challenging issues. As a result, the use of LCDPs can help to improve collaboration and communication between IT and business teams, enabling them to work together more effectively to develop high-quality applications. (Elshan and Dickhaut 2021).

Speed

The use of LCDPs can often lead to faster delivery of tangible results compared to traditional development approaches. This is due to several factors, including more efficient requirements analysis, the ability to reuse front and backend artifacts developed in previous projects or by the online community, and the ability to make rapid changes and adaptations to the app (Elshan and Dickhaut 2021).

Competitiveness

Leveraging LCDPs and tech-savvy specialist employees is a solution for the IT workforce shortage and, overall, also contributes to digitization in companies wanting to position themselves for the future. This approach also fits well with the needs of startups, who can use LCDPs to quickly validate the product market fit of their business ideas (Elshan and Dickhaut 2021).

1.2.2 Weaknesses

Dependency

One of the potential drawbacks of using LCDPs is the risk of vendor lock-in. Because they often do not provide the generated code, app producers rely heavily on the vendor and their deployment services. This can make it difficult to switch to a different vendor or platform if necessary. Additionally, low-code application projects are not easily migrated to other LCDP environments, limiting the flexibility and adaptability of these tools. Lastly, the use of LCDPs is subject to market dynamics, as the field is still relatively new. This means that LCDP firms may stop operating their platforms or significantly increase prices, which can impact the viability and sustainability of low-code application projects. (Elshan and Dickhaut 2021).

Limited Functionality

Another potential limitation of low code development platforms (LCDPs) is the limited scope of their applications. Although LCDPs are potent tools that can be used to develop a wide range of applications, their capabilities are still somewhat limited compared to traditional development approaches. Not all applications can be developed using LCDPs, and some projects may require custom coding or other specialized tools to achieve the desired functionality. (Elshan and Dickhaut 2021). Consequently, classic development work will still be necessary, explaining the low in 'low code.'

User Interfaces

Deviating from the default user interface provided by the LCDP or making them beautiful and easy to use can be challenging (Elshan and Dickhaut 2021).

Numerous heterogeneous platforms

Because hundreds of LCDPs on the market have unique features and capabilities, it can take time for decision-makers to choose the best tool for their needs. This requires a thorough understanding of the capabilities and limitations of different LCDPs and the specific requirements of the business problem at hand. Without this understanding, organizations may choose an LCDP that is not well-suited to their needs, leading to suboptimal results and wasted resources. (Sahay et al. 2020)

1.2.3 Opportunities

Digitization and Modernization

One of the key benefits of using LCDPs is that they allow organizations to tackle digitization cost-effectively. By using LCDPs, organizations can automate repetitive, manual, and error-prone tasks, leading to efficiency gains and long-term cost savings. LCDPs can also help make

complex digitization projects more feasible and attractive, as they provide an easy-to-use and low-risk way of developing and deploying the application. Digitization projects previously deemed too complicated can now gain a renewed interest in a low-code context (Elshan and Dickhaut 2021).

Employee Empowerment

Another advantage of LCDPs is that they can empower employees to take ownership of digitization efforts, even with minimal training and limited programming knowledge. Because LCDPs provide a user-friendly, visual interface that allows employees to develop and deploy applications without the need for extensive coding skills, they can help to break down barriers and encourage greater collaboration between IT and business teams. This empowerment can generate a sense of enthusiasm and excitement among employees, as they can contribute to their organization's digitation in a meaningful way (Elshan and Dickhaut 2021).

1.2.4 Threats

Resistance

Adopting low-code development platforms (LCDPs) in a company can be seen as a potential threat to existing jobs. It may be met with skepticism from IT staff, who may prefer their traditional methods over using a tool that guides and limits their work. Additionally, using LCDPs may result in IT personnel being tasked with additional maintenance work, potentially leaving them feeling under-challenged and unfulfilled. (Elshan and Dickhaut 2021).

Shadow IT

When employees from specialized departments develop their own solutions, it can increase the risk of shadow IT. This can result in a fragmented portfolio of apps that are difficult to manage and maintain. Additionally, these apps may not be subject to regular compliance and safety

checks, potentially jeopardizing security and data protection. Lastly, shadow IT can make it difficult for a company to maintain a consistent corporate identity (Elshan and Dickhaut 2021).

Technical debts

These platforms may only sometimes adhere to programming best practices, data protection, compliance, and governance rules, potentially saving time and money in the short term but leading to negative consequences in the long term. For example, as noted by Elshan et al. in their paper, LCDPs sometimes conform to established software development practices that minimize redundancies in code, making maintenance more difficult.

1.3 Infrastructural considerations of OutSystems

OutSystems is an LCDP that allows users to create desktop and mobile applications that can run in the cloud or on-premises. It offers many built-in widgets and features, including publishing applications with a single click. Some applications that can be developed using OutSystems include billing systems, customer relationship management (CRM) systems, enterprise resource planning (ERP) systems, operational dashboards, and business intelligence solutions. (Sahay et al. 2020).

We highlighted general practical considerations about low code development in section 4.2. In section 4.3 and section 4.4, we will discuss infrastructural and architectural properties specifically for OutSystems, respectively. IT infrastructure is the hardware, software, facilities, and service components that support the delivery of business systems and IT-enabled processes (Gartner, s.d).

When using OutSystems, users can deploy and run their applications in the cloud or on-premises. Applications that are running on-premises are installed and run locally on a company's computers and servers, whereas cloud-based applications are hosted and run on a

vendor's servers. OutSystems also supports hybrid deployment options that combine on-premises and cloud-based components. The choice of deployment option will depend on various factors, including the size and complexity of the application, the amount of data it will generate, and the availability and scalability requirements of the application.

Applications built using OutSystems can be hosted within the proprietary OutSystems Cloud infrastructure, which provides a managed environment for developing, testing, deploying, and running mobile and web applications. The physical infrastructure of OutSystems Cloud is hosted on Amazon Web Services (AWS) by default, but customers can also choose to use other infrastructure-as-a-service (IaaS) providers. OutSystems' internal architecture abstracts the IaaS layer, allowing applications to be portable across different providers. This will enable customers to use the IaaS provider of their choice, allowing them to take advantage of each provider's specific features and capabilities.

Regardless of the infrastructure type selected, an OutSystems deployment requires both a platform server and an application server. The platform server is responsible for taking the visual models, elements, and features built in the OutSystems environment and performing all

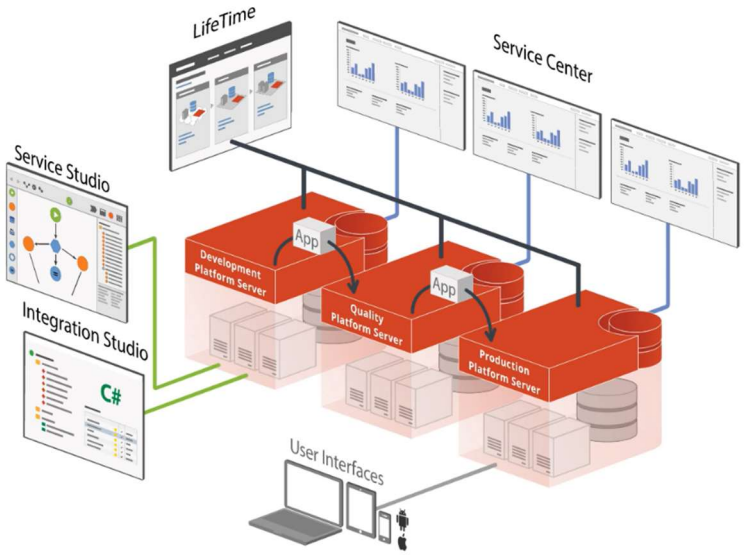

Figure 1: Outsystems Deployment Process

the necessary steps to generate, standardize, optimize, compile, and deploy the application code (e.g., HTML, CSS, JavaScript, SQL, and .NET) to a web application server or package it into a native mobile app. This allows developers to focus on creating and customizing the application without worrying about the deployment process's underlying infrastructure or technical details.

OutSystems provides a tool called Lifetime that allows users to set up different environments for their applications. It is common to have separate development, test, and production environments, as shown in the graphic above. This enables developers to test and validate different versions of their applications before releasing them to the public. This is an essential step in the development process, as it helps ensure that applications are stable, reliable, and ready for use by users. By using separate environments for development, testing, and production, developers can ensure that their applications are properly tested and validated before release, reducing the risk of errors or problems.

1.4 Architectural Considerations of OutSystems

The architecture of a system refers to the design of its components and the relationships between them, whereas the infrastructure relates to the underlying components that make up the system.

When designing the architecture of an application, it is crucial to identify all application, business, and user requirements and model them appropriately. Additionally, it is necessary to investigate potential integration points with legacy applications or databases. When relying on a single technology like OutSystems, finally, one should evaluate what can be done natively using the platform and what will need to be done manually. This will help ensure that the system's architecture is well-designed and able to support the application's requirements.

1.4.1 Requirements

Requirements engineering is a complex topic that involves identifying, documenting, and analyzing the requirements for a system or application. There is a wide range of approaches to requirements engineering, and interested readers are encouraged to consult the relevant literature for more information. When developing applications using OutSystems specifically, a few critical considerations should be considered related to requirements.

Firstly, from the user stories, it should be clear whether a “reactive web app” or a “mobile app” should be developed. A reactive web app is a responsive web-based application that runs in a web browser and requires an internet connection. It is designed to be able to run on a variety of devices and screen sizes. Reactive web apps can be developed using a single development paradigm for both web and mobile and are suitable for applications that do not require access to devise hardware or sensors or the ability to work offline (OutSystems n.d.). In contrast, mobile apps are compiled into native Android or iOS applications using the Apache Cordova framework. This allows developers to create mobile apps that offer a native mobile user experience, access to device hardware and sensors, store data locally, and work offline. Mobile apps can be distributed in two ways: as a native app package downloaded from an app store or as a progressive web app (PWA) directly installed from a website without needing an app store.

During the requirements engineering phase, it is vital to identify and document the users who will interact with the application and the permissions each user type should have. This will help ensure that the application is appropriately and correctly configured to the appropriate level of access, features, and functionality they need. For example, some users may be able to access specific actions or pages, while others may not. It is also essential to consider how user permissions will be managed and enforced within the application and to design the application's architecture and security controls to support these requirements.

When developing mobile applications with OutSystems, it is crucial to consider which native device capabilities should be leveraged using Cordova plugins. Cordova plugins allow mobile applications to access the hardware and sensors of the device they are running on, such as the camera, GPS, and contacts.

1.4.2 Integrations

OutSystems offers a variety of integration options to meet the needs of different applications. These include prebuilt connectors for SAP and REST, and SOAP integration solutions. OutSystems also supports exposing and consuming REST APIs and SOAP web services. Out-of-the-box connections are available for popular databases such as SQL Server, Oracle, MySQL, and DB2. Users can leverage open-source connectors or the Integration Studio for more specialized integrations to connect to other software, apps, or databases (OutSystems n.d.).

1.4.3 Feasibility in low code

Research has shown that there may be limitations to what low-code platforms can offer, mainly when dealing with complex problems (Luo et al. 2021). They might lack customization possibilities, or coding is necessary at some point, eventually and unexpectedly.

OutSystems relies on its community and its Forge repository of downloadable components to address the potential limitations of low-code platforms. These components are open-source extensions that include wrappers for public open-source software development kits (SDKs), libraries, and plugins. In addition to these pre-built components, OutSystems allows developers to extend the platform with custom code, including JavaScript, CSS and HTML, C#, and SQL. This will enable developers to add custom functionality and overcome any platform limitations.

To avoid unnecessary surprises, it is thus essential to analyze whether the problem can be solved alone on the platform. If not, one should be mindful of the implications.

1.4.4 Data modeling

Creating a data model is a crucial first step in building an OutSystems application. The entity-relationship (ER) model defines the application's data persistence requirements and provides an overview of the entities and their attributes. During the data model construction, several configurations must be made, including defining relationships between entities, determining the cardinality of those relationships, identifying primary keys, and setting delete rules. Once the data model has been created, developers can build the user interface (UI) using templates and pre-made building blocks. This process is further discussed along with examples in chapter 6.

2. Architectural, infrastructural, and practical decisions

In this section, we take the considerations listed into account and combine these with decisions explicitly made for the Repurpose application made in the OutSystems environment.

2.1 Practical Decisions

No further elaboration is needed for the strengths and opportunities of working with LCDPs, as they are perceived as the main drivers to choose for low code. Including them here would bias the discussion. In what follows, we will address how we deal with the weaknesses and threats of LCDPs in the OutSystems context.

2.1.1 Weaknesses

Numerous heterogeneous platforms. A recent survey has made an overview of the most potent LCDPs, comparing functionalities such as graphical user interface, interoperability possibilities, security support, collaborative development support, scalability, etc. While OutSystems is included in this shortlist and is thus a good choice, the report shows that other competitors still perform better across the evaluation areas (Sahay et al. 2020). We expect that the number and quality of these reports will only increase, enabling companies to make an educated choice according to their needs.

Dependency. OutSystems claims to be the only solution that offers “no lock-in.” Their discussion on this topic is threefold. (1) As the platform does not use a custom runtime engine to run generated applications, they do not rely on OutSystems anymore to run. (2) All visual model data artifacts are mapped directly into database native concepts. OutSystems enables data access through any standard ETL, BI, or another third-party database tool. (3) Furthermore, the code of the applications is also generated towards a standard architecture (e.g., ReactJS for

the front end, C# for the back end). Applications are deployed into a standard web application server of choice. These guarantees should assure customers that their IP is not lost if they ever stop using OutSystems, and applications will continue to run as-is in their environment. However, nothing is said about extracting or transferring the codebase or visual building blocks toward another low-code environment.

Limited functionality. Nevertheless, a feasibility mapping of the requirements might help grasp the development scope. The OutSystems functionalities can be extended by relying on OutSystems Forge, a library of open-source components to download.

User interfaces. As the idea of this app is an internal university application embedded in international mobility contexts, UI expectations are lower than a commercial app. Therefore, we prioritize UX over UI on the roadmap: a convenient buying process for all stakeholders.

2.1.2 Threats

Shadow IT. Implementing this app into academic institutions might bare some fragmentation risk as they often already rely on a combination of various separate apps. At NOVA SBE, for example, Moodle, NetPa, Outlook, Jobteaser, etc. However, the student hub page provides students with an overview of all available apps and thus can include our app. We will also have to ask the administration to perform compliance and safety checks. Lastly, we can tweak the design to fit the brand guide.

Resistance. Given that Repurpose solves a problem outside of the core activities of NOVA or other academic institutions, we can count on flexibility to work with the application. In fact, this application might create additional jobs.

Technical debts. This might be the most important consideration. The application was developed in a few months and should be implemented on campus by 2023. However,

maintenance is not guaranteed since the founders will graduate and leave Lisbon. A new local manager who can take up operational tasks and ensure quality and safety has to be appointed.

2.2 Infrastructural decisions

For the Repurpose application, we have chosen a cloud infrastructure via OutSystems Cloud rather than relying on on-premises servers. This allows us to develop, test, deploy, and run mobile and web applications without worrying about dealing with the administrative aspects of the platform technology.

The Lifetime tool allows us to easily push app versions from the development environment to the test environment and finally to the production environment.

2.3 Architectural Decisions

2.3.1 Requirements

User stories of the format “As a … I want to …” were collected in a Kanban board in Trello. This allowed us to work on individual parts of the needed functionalities while developing.

The user stories clarified that we needed to choose a mobile app. Since users often take photos of the items they want to sell with their phones, it is convenient to put the listing online from the same device. The PWA distribution method allows for easy and cost-free distribution. If the business model is validated, we can buy distribution licenses through the Google Play Store and the Apple App Store.

Since we need camera access natively on devices, we rely on the Cordova plugin. At the moment, we do not use other Cordova plugins. This might come later.

The following text describes the three types of users in the application: admins, students, and drop-off facilitators (called "drop-off buddies" in the app). Students are the "core users" and

have the same access and rights in the app, while admins and buddies have additional rights. Students can be buyers, sellers, or both.

In the application, the admin is essential, particularly in buying. The admin is responsible for verifying payment and the amount received with the listing price. The admin also manages user reports about stolen or misrepresented products and suspected fraudulent behavior. The admin can delete posts that don't align with the app's terms and conditions. Admin access is only granted through promotion by a system administrator, and for security reasons, admins cannot promote other users to the admin role.

Buyers and sellers in the application have the right to post listings, purchase items, and user settings for their accounts. These settings allow for basic account management, such as resetting passwords or updating personal information. They can also search for specific items using the search bar or filtering by category and condition. Additionally, buyers and sellers can chat with the support team for help with any issues they may have within the app. If they come across a suspicious post, they can report it to the admin for action.

Drop-off facilitators, or "buddies," are authorized to manage a storage location. During the registration process, buddies must register themselves along with the location they manage. When a user wants to store something at a buddy's location, the buddy can accept or reject the request based on space availability. Only after accepting the seller's request will the listing be publicly available on Repurpose.

A summary is provided in the figure below.

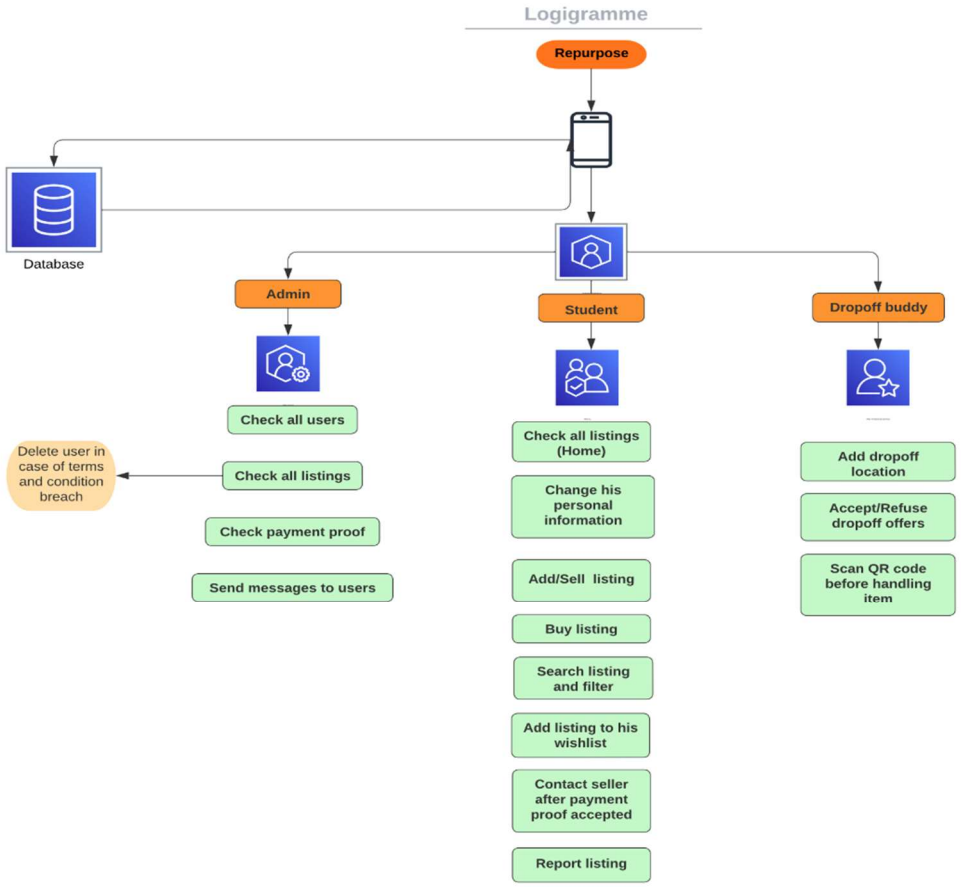

Figure: Repurpose Logigramm

2.3.2 Integrations

The product is new and, as such, does not currently require integration with legacy business applications or code. However, it utilizes an API for object detection (UbiOps YOLO) to recognize the items in the listing's photo and automatically fill in relevant fields.

2.3.3 Feasibility in low code

While it was expected that enabling payments within the app would be straightforward, a significant amount of time was spent researching the best approach. Ideally, users could use their PayPal or credit card to pay for an item immediately. However, during the short development period, it became clear that customizing OutSystems Forge assets for our product

would take too much time. As a result, we implemented a temporary solution for handling payments independently. This is an area that requires further work in the future.

Apart from the above, all the required functionalities are in place with limited use of open-source components from Forge.

2.3.4 Data modeling

To begin the development of the application, we started by defining the backbone of the data model. This is a relational database that is queried using SQL commands. The main concepts stored in the database include listings with photos, users of different types, wish lists, and drop-off locations. This data model forms the foundation of the application, enabling it to persist and manage the information necessary to support its functionality.

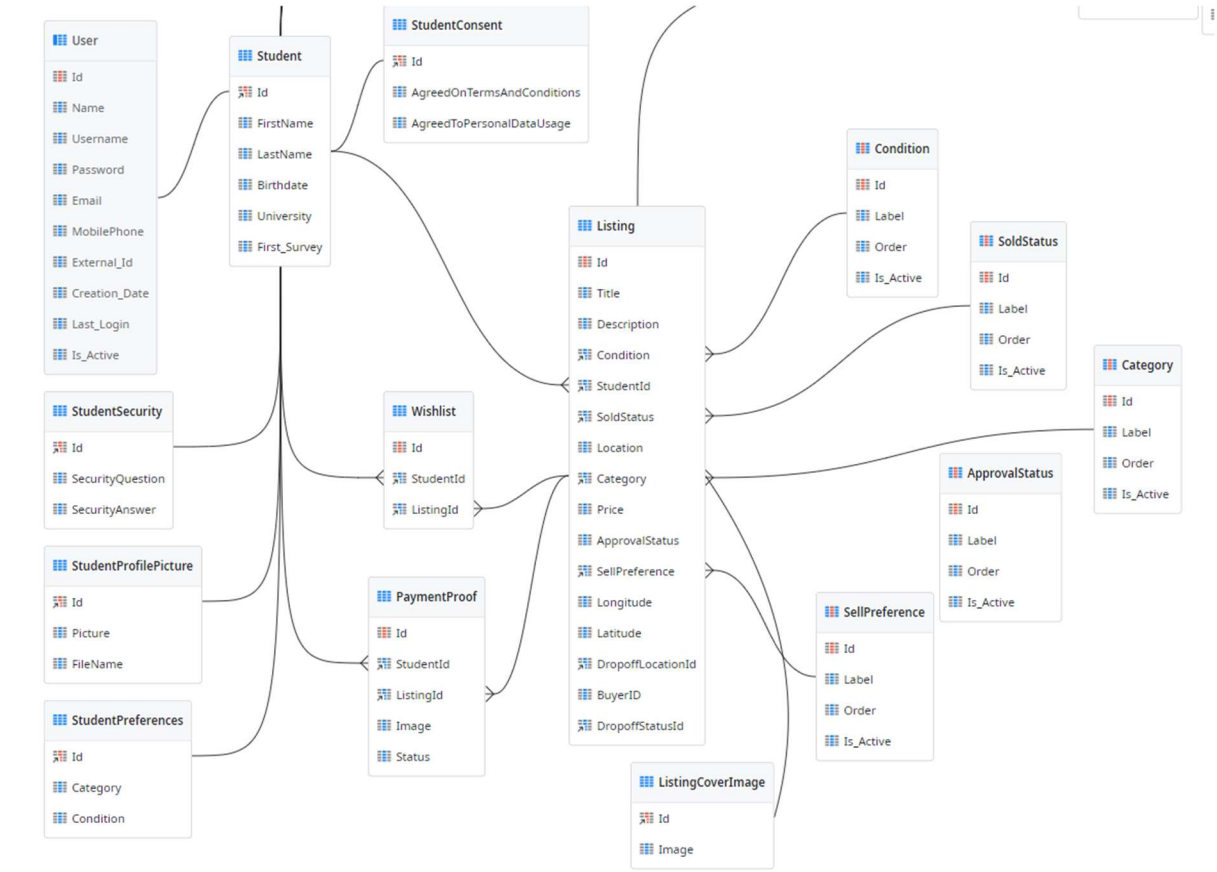

Figure: Repurpose Data Model

The data model includes two highly connected tables: the Student table and the Listing table. The Student table consists of core users, including buyers and sellers. It inherits attributes from the User table, a default component in OutSystems. The Student table is also linked to several other tables that store security data, buying preferences, and agreements. A student can be linked to one or more listings either as a seller, through a payment proof as a buyer, or by saving an item to their wish list. The Listing table contains various attributes and static entity types, such as Category. Users can only select from predefined categories when creating a listing.

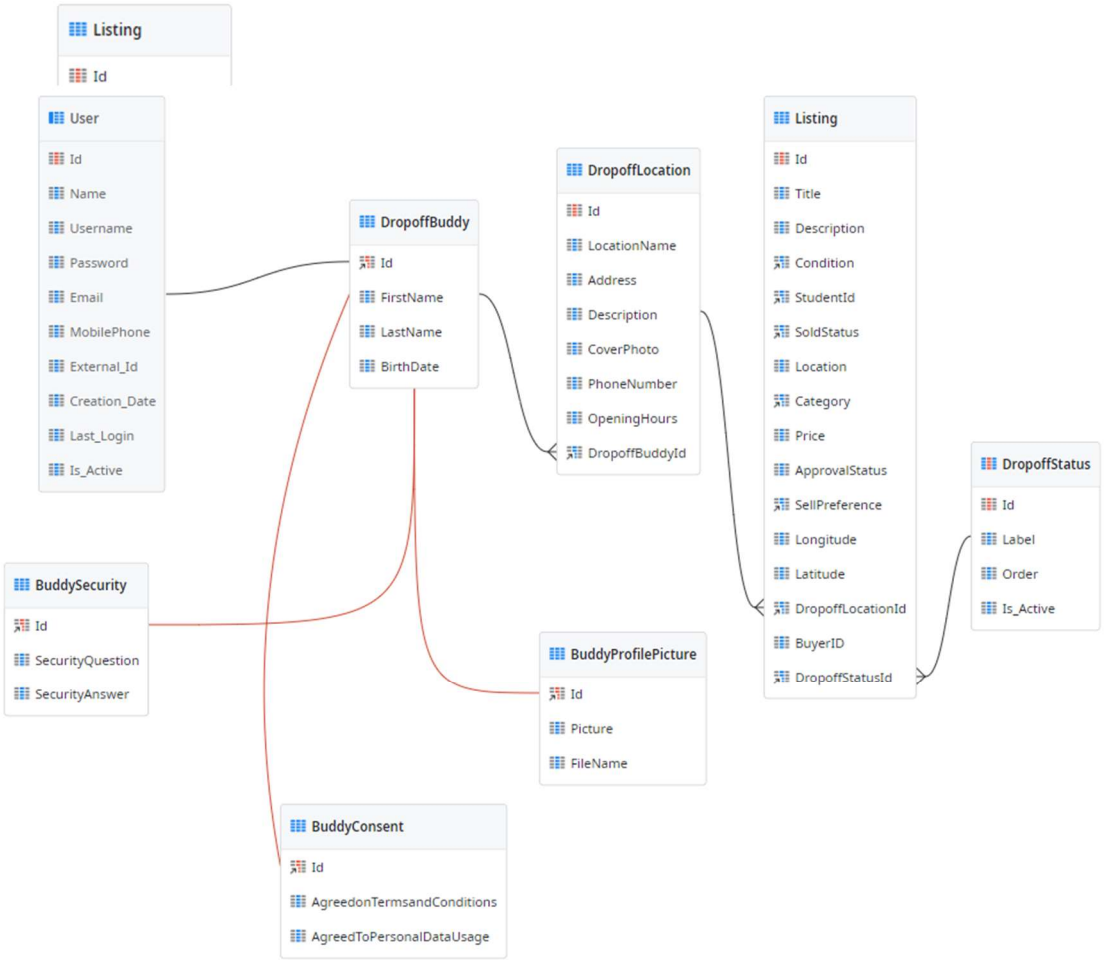

Figure: Drop-Off Buddy Database Relations

The Listing table is connected to several image tables, including one that stores a dedicated cover image shown as a thumbnail on the listing overview page and another that stores all additional photos that the seller wishes to include. This allows the application to manage and display the images associated with a listing flexibly and efficiently.

The data model also includes an implementation for drop-off locations, as shown in the figure below. The drop-off buddy inherits all properties from a typical user in OutSystems and can be the owner of multiple drop-off locations. A drop-off location can contain multiple listings, and the drop-off status provides information on whether a listing has been approved for drop-off.

Currently, only one person can own a drop-off location, which may be a limitation for facilities with multiple admins.

References

DESA. 2022. “Ensure Sustainable Consumption and Production Patterns.” 2022. https://sdgs.un.org/goals/goal12.

Elshan, Edona, and Ernestine Dickhaut. 2021. “An Investigation of Why Low Code Platforms Provide Answers and New Challenges” 2024.

Luo, Yajing, Peng Liang, Chong Wang, Mojtaba Shahin, and Jing Zhan. 2021. “Characteristics and Challenges of Low-Code Development: The Practitioners Perspective.” *International Symposium on Empirical Software Engineering and Measurement*. https://doi.org/10.1145/3475716.3475782.

OutSystems. n.d. “Architecture | Evaluation Guide | OutSystems.” Accessed December 10, 2022. https://www.outsystems.com/evaluation-guide/architecture/.

Sanchis, Raquel, Óscar García-Perales, Francisco Fraile, and Raul Poler. 2020. “Low-Code as Enabler of Digital Transformation in Manufacturing Industry.” *Applied Sciences (Switzerland)* 10 (1). https://doi.org/10.3390/app10010012.

UIS. 2022. “Outbound Internationally Mobile Students by Host Region.” 2022. http://data.uis.unesco.org/.

ULisboa. 2022. “About Us.” 2022. https://www.ulisboa.pt/en/about-us.

Universidade NOVA de Lisboa. 2022. “Facts and Figures.” 2022. https://www.unl.pt/en/nova/facts-and-figures.

Vincent, Paul, Kimihiko Iijima, Mark Driver, Jason Wong, and Yefim Natis. 2019. “Licensed for Distribution Magic Quadrant for Enterprise Low-Code Application Platforms,” 1–35.

Waszkowski, Robert. 2019. “Low-Code Platform for Automating Business Processes in Manufacturing.” *IFAC-PapersOnLine* 52 (10): 376–81. https://doi.org/10.1016/j.ifacol.2019.10.060.