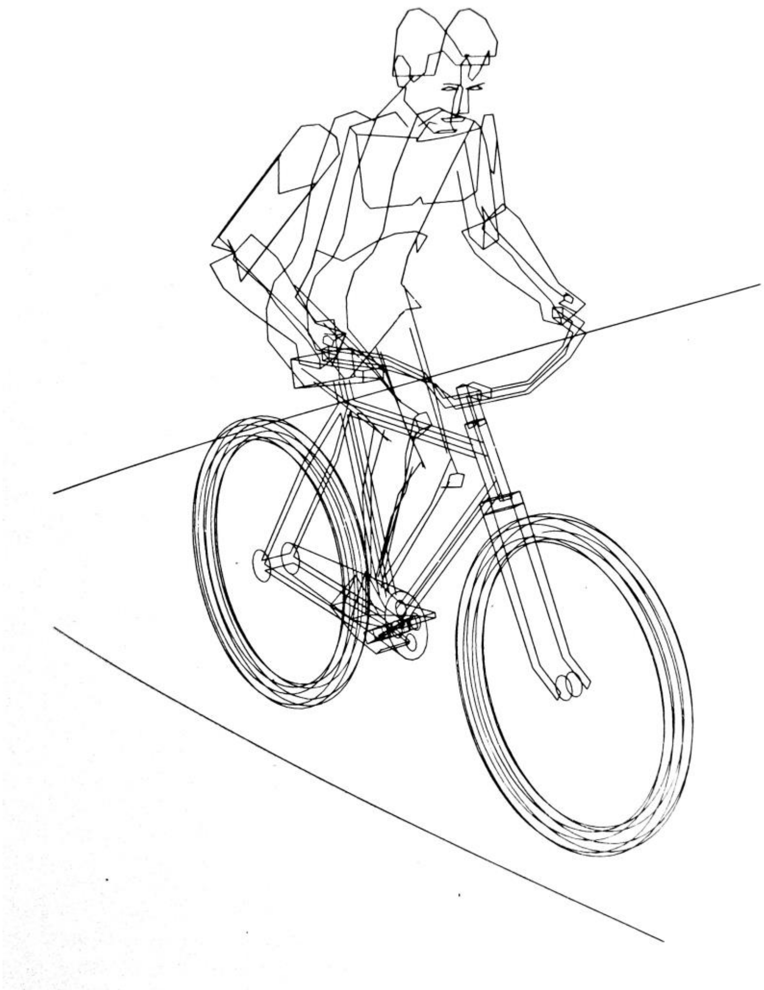

DESIGN OF A DIY BICYCLE KIT

Project Scoping and Planning Report

SUMMARY

Building on the work done in the Adjustabike project in 2019, this project aims to design, prototype, and conduct rudimentary testing on an open source, flexible, build-it-yourself bike kit. Ideally, the kit will be comprised exclusively of standard components and require minimal tooling to assemble.

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Cover image credit: Whitt, Frank Rowland [1] page 179

Background

The structure of a typical bicycle can be divided into five systems: the frame system, the steering system, the braking system, the transmission system, and the wheel system [2]. This project is concerned with designing an open source, fully flexible bicycle frame kit which can easily be assembled from standard parts by a layperson with minimal tooling. The other systems can easily be found second hand or directly from manufacturers and attached to the frame, but the way in which they interface with the frame will need to be considered [3] [4].

This project is building on the work which was carried out in the Adjustabike project in 2019 by a previous student, which was the latest iteration of a series of prototypes developed to explore the concept of an open source build your own bicycle kit [5]. The benefits to a bicycle kit over a traditional frame are that the same components can be re-used when the frame needs to accommodate a different rider, or to construct an entirely different geometry, and that bulky geometries can be deconstructed when not in use to save storage space, and the components repurposed. Furthermore, the geometry of a bicycle frame directly affects its structural characteristics, so the ability to adjust the frame geometry will also allow the user to adjust the handling and stiffness of the bicycle under typical loading conditions [6] [7] [8] (see Figure 8 and Figure 9).

A more in-depth market research study will be undertaken at a later date, but one does not need to look far to find use cases for a frame with flexible geometry. Among the myriad means of human transportation are many bicycle-adjacent vehicles. Some of these, such as a cargo trike or a tandem for a growing child, may only be needed temporarily and may also need to adapt to changing demands. Other machines may not be readily or cheaply available, such as adapted bicycles for people with disabilities, or recumbent cycles (otherwise known as "velocars"; shown in Figure 2), which can give greater speed than a standard bicycle due to their streamlined riding position [1] pg.96.

The Adjustabike frame consists of aluminium profiles from a factory equipment construction system such as item, fastened together by flexible joints through non-destructive clamping mechanisms. Two geometries were modelled: a standard bicycle which was adjustable for rider height, and a cargo tricycle (see Figure 1). In theory many other geometries could be assembled from the same components, but this was left for future development, as was in-depth testing.

Although the Adjustabike provided a thorough proof of concept, it made several compromises on the use of readily available standard parts. The complex custom components which were developed could not be manufactured even with sophisticated CNC machines at one's disposal, let alone by a typical layperson. It was also fairly limited in its documentation, which meant that adaptation by a third party might prove difficult, and that the open source aspect of the concept was not fulfilled to the extent intended. The aim of this project is to readdress the concept with a view to making the kit as open source and accessible to laypeople as possible. To achieve this, the ratio of off-the-shelf to custom components will be increased as much as possible without compromising the functionality and flexibility of the previous design. Ideally, the kit will be comprised of exclusively standard components. An effort will also be made to document the project according to Open Source Hardware best practices [9].

Many similar projects exist, from hobbyists building tallbikes [10] and recumbent bikes in their garage (often by welding together pieces of old bicycles) [11] [12] [13] to build-your-own wooden bike projects [14] [15] [16]. Perhaps the closest in spirit and function to this project are: Infento, who produce mecano-esque kids' cycle kits which can be disassembled and reassembled to create new rides [17] (see Figure 3); OBI, an open source bicycle made from aluminium profiles and 3D printed joints, designed by two Dutch students [18] (see Figure 4); XYZ CARGO, who sell open source, fully customisable cargo cycles which assemble easily but destructively (and therefore have limited flexibility) [19] (see Figure 5); and the BellCycle, a quirky, open source, build-it-yourself bicycle kit which was designed with front wheel drive and handlebars behind the seat, and can be adapted to carry cargo or use electrical power [20] [21] (see Figure 6). The BellCycle was funded by Kickstarter and seems to have received a positive if slightly baffled critical reception from cycling bloggers.

The unique selling point of this project will be that it is as flexible and non-destructive as an Infento kit, as open source and innovative as the BellCycle, and even more accessible than an Atomic Zombie [12] or WoodenWidget [14] project. The benefits of the open source ideology have long been recognised in the software engineering community, and are now beginning to be transferred to open source hardware as well [22] [23] [24]. Aiming for such a high degree of flexibility is part of a larger market trend of designing to cater to customers' increasing desire for customization in their products [25] [26] [27].

Aims and Objectives

The aim of this project is to design a kit with which a lay-person can easily and non-destructively assemble a bicycle with a geometry of their choice, and to ensure that the ratio of off-the-shelf components to custom components is as high as possible, in the interest of maximising the accessibility of the kit to the lay-person. This aim will be accomplished through the following objectives:

1. Investigate available off-the-shelf technologies and use a set of criteria to recommend which would be most suitable for using in the kit.
2. Develop a simplified modelling method to test the combinations of the recommended elements, and use it to:
    a. Demonstrate the feasibility of creating different geometries, and
    b. Make a recommendation on which lengths, angles, and quantities of components which should be included in the 'starter' kit (with the understanding that supplementary components may be used for specialised geometries).
3. Source materials and build a physical (preferably full scale) prototype of one or more geometries.
4. Establish open source documentation, both to allow lay people to use the kit and to allow future development of the project.

Figure 1: Renderings of the Adjustabike in two configurations [5]

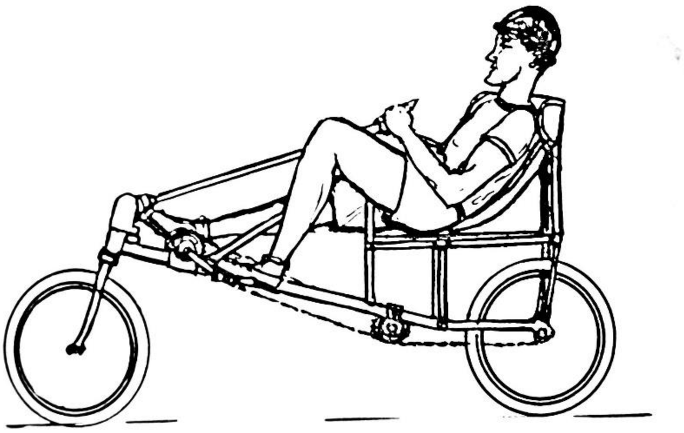

Figure 2: Velocars or recumbent bicycles can be faster than standard bicycles because of the streamlined riding position [1]; page 96

Figure 3a and b: The same Infento kit was used to build both of these trikes [17].

Figure 4: The OBI 0.5 is an open source, 3D printed bicycle [18].

Figure 5: XYZ CARGO configurations [19]

Figure 6: The BellCycle is an open source bicycle kit featuring an unusual design

Figure 7: The SkyWalker tallbike features a ladder which doubles as handlebars, allowing the pilot to remain in control of the bike while climbing up to or down from the cockpit. It was built from scrap bicycle parts by "Radical" Brad Graham, who runs the Atomic Zombie website [12] [10].

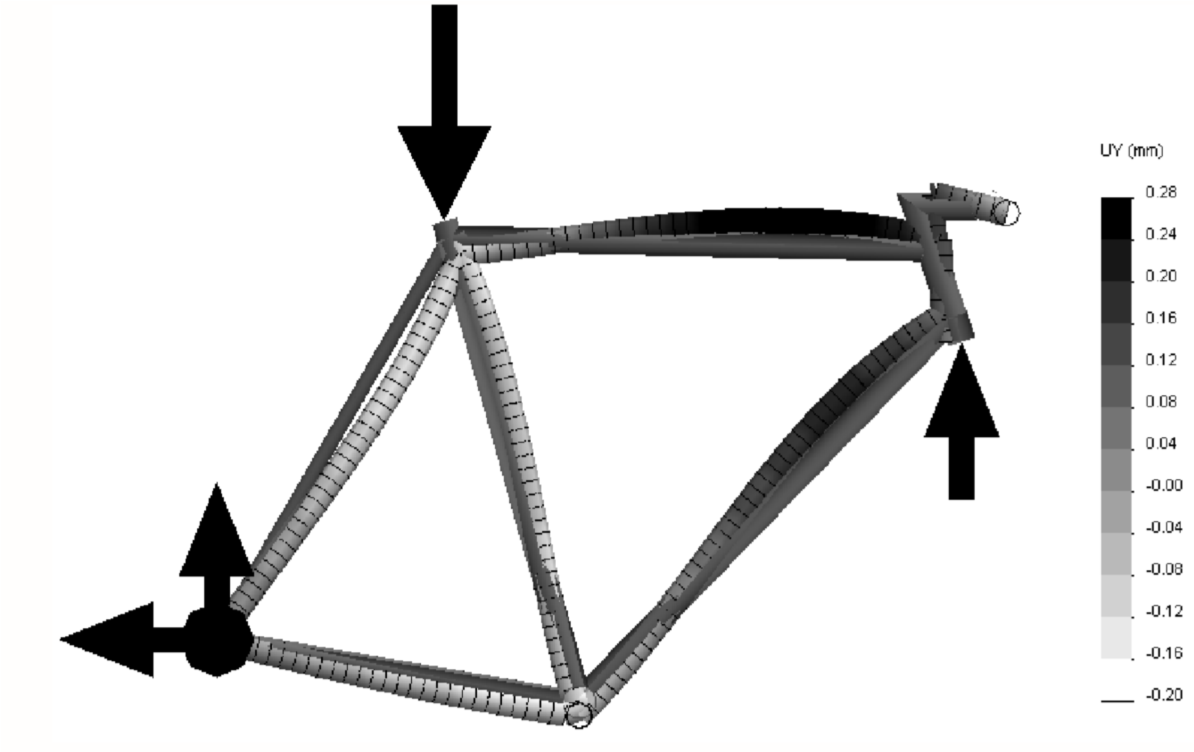

Figure 8: Displacement plot from FEM analysis of a bicycle frame with vertical load at the top of the seat post [8]

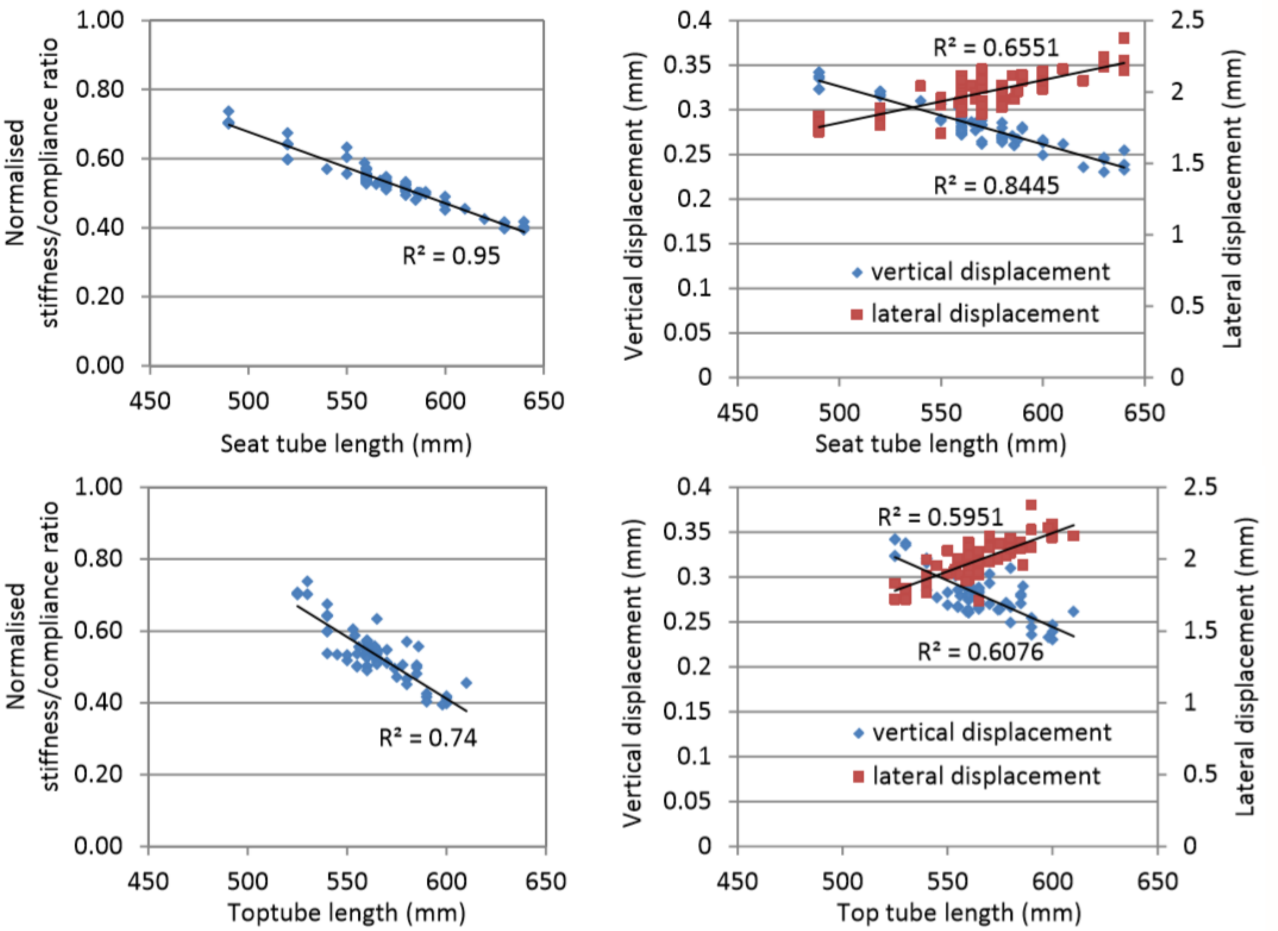

Figure 9: Plots showing how bicycle frame geometry affects the stiffness/compliance ratio and the displacement under load (refer to Figure 8)

Work Plan (Programme and Methodology)

The project will be divided into four Work Packages (WPs), corresponding to the four objectives. WP4 will mostly be completed throughout the project in parallel to the other WPs, bookended with some preparation at the start and finalisation at the end of the project.

WP1 Study of Available Technologies

An investigation will be conducted into available off-the-shelf products which could be used to create the bicycle kit. It should be noted it will most likely not be immediately obvious where to look, because the products of interest will likely be intended for completely different purposes, such as scaffolding. A set of criteria should be developed, such as a high strength to weight ratio, non-destructive joint locking mechanisms which do not require extensive tooling, and low cost. Each of the available products will be rated based on these criteria, and a recommendation will be made on which to take forward. It will also be necessary to investigate how each of the other bicycle systems will interface with the frame.

WP2 Combinatorial Testing

Using a CAD package such as Autodesk Inventor, simplified models of a preliminary set of components from the recommended technology will created based on the characteristics of the existing products obtained from product specifications. The components will be based on the existing products, but may be modified in ways that can easily be achieved with simple tools, such as cutting profiles to length. Different geometries will then be modelled using assemblies of different combinations of these components. The parameters of the components (such as lengths of tubes or angles of joints) may then be adjusted as needed (again, provided the equivalent modifications of the physical components are possible with simple tools), and the next iteration of geometry designs can then be developed using the new set of components. This can be repeated as many times as needed.

The resulting geometries will be analysed to ensure they are fit for purpose, including force calculations and perhaps some rudimentary FEM analysis as in Figure 8 [2] [7] [8], as well as safety, usability, and manufacturing and assembly considerations. Based on these geometries, a 'starter kit' of components will be recommended, with the understanding that supplementary components may be used for specialised geometries. The characteristics and quantities of each component in the kit will be specified.

If time allows, simplified small-scale prototypes of the recommended kit components will be created using additive manufacture or even cardboard prototyping so as to demonstrate the proof of concept for a few of the geometries, as it is unlikely that it will be possible to find the time or material resources to create full-scale prototypes of all of the different geometries. This may also prove to be an easier way of investigating new geometry options than the CAD models.

WP3 Physical Prototyping

The priority during this WP is to build a (preferably full scale) physical prototype of at least one of the geometries that were developed, ensuring that as many as possible of the components used are the exact components recommended in the kit. The purpose of this is two-fold: firstly, to demonstrate the soundness of the design of the components and the geometry, and secondly, to demonstrate the feasibility of sourcing the components and assembling the design using only the resources available to a typical lay-person.

If time permits and the prototype is suitable, simple strain gauges may be used to test if the stresses in the components are as predicted.

WP4 Open Source Documentation

The aim of documenting open source hardware is to ensure that other people have enough information to make, study, develop, and distribute the product [23]. To this end, GitHub will be used throughout the project to keep a log in which to record decisions, test results, and design iterations. Whether this will be carried out using GitHub's inbuilt Markdown capability or by simply uploading and committing a new version of a Microsoft Word document periodically will be determined based on which method is more efficient overall, considering the fact that the project log will serve two purposes: the report for the University project and the open source documentation.

In addition to the project log, the version control functionality of GitHub will be used to track changes in any CAD files by uploading and committing an editable format of the designs as they are being developed. Final designs will be made available on GitHub both in a raw, editable format such as .ipt, .iam, or .dwg files and a flattened, easily viewable format such as .stl or .pdf files. A set of instructions for the lay-person on the use of the kit will also be written, based on best practice [28] [29] (see Figure 10).

This WP will be mostly carried out parallel to the other WPs, including tracking progress, recording test results, and documenting the prototype assembly photographically to provide images for the instruction booklet. However, some time will be needed at the beginning of the project to setup the GitHub repository, research best practice for documentation, and learn the Markdown formatting language. Some time will also be needed at the end of the project to compile the documentation and finalise any front-facing formatting, explanations, and graphics.

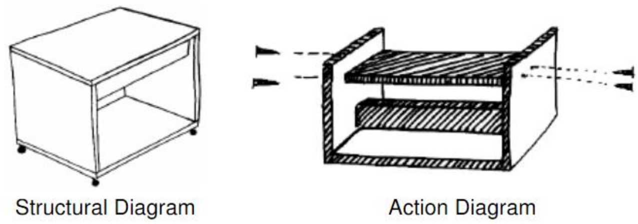

Figure 10: Hand-drawn diagrams showing the assembly of a simple piece of furniture. The Action diagram gives more useful information than the Structural Diagram because it explicitly shows which actions need to be taken [28].

Contingency Planning

WPs 1, 2, and 3 will be carried out in series and are dependent on each other, so contingency planning will be carried out such that the project content will not be compromised due to unexpected results.

If the result of WP1 is that there is no existing technology which can safely be recommended for use in the kit, small changes will be necessary for WP2 and WP3. Either WP2 could use simplified, idealised models of theoretical components in order to investigate the combinatorics and of the kit and characteristics of the geometries, or some custom parts could be designed with a focus on ensuring they are as easy to manufacture as possible. In either case, or if WP3 was simply restricted due to budget or time constraints, small-scale prototypes could be manufactured using additive manufacture in order to show proof of concept, instead of constructing a full scale working prototype.

During WP3, it should be noted that difficulty is anticipated in the sourcing of certain components from off-the-shelf parts – namely, the interfaces between the frame and the other systems – due to tolerance discrepancies and other obstacles. The scope of this project is to demonstrate the feasibility of the overall concept, not to develop precise designs for any custom parts which might be necessary (although the aim is of course to avoid custom parts where possible). As such, rapid prototyping using extruded ABS additive manufacture (or other cost- and time-efficient methods) may be implemented where necessary to manufacture 'placeholder' components which may be developed further at a later stage, so that the larger assembly may be prototyped more effectively.

Predicted Timescale

Note that these dates are preliminary and will likely change as the project progresses.

start date:	*task:*
27/11/2019	***Assessment 1: Project Scoping and Planning***
	WP1
27/11/2019	Research the different types of bike components
02/12/2019	Create a set of weighted criteria for choosing the base technology for the frame kit
07/12/2019	Look for available technologies online
26/01/2020	Look for available technologies in brick and mortar shops
29/01/2020	Score each technology based on the weighted criteria chosen earlier
30/01/2020	Choose products that work well together from the top scoring options
	WP2
03/02/2020	Create simplified CAD models of recommended components
03/02/2020	Develop and refine concepts for one or two initial geometries
06/02/2020	Put together a kit with preliminary angles, lengths, and quantities of components based on concepts
07/02/2020	Create initial and alternative geometries from the kit and assess if they are fit for purpose
10/02/2020	Adjust lengths, angles, and quantities of components in the kit
12/02/2020	Repeat until geometries are optimised
19/02/2020	Analyse final geometries eg. Force calculations
26/02/2020	Decide which components should be in the starter kit and which should be add-ons
	WP3
15/02/2020	Source materials eg tubes
27/02/2020	Cut profiles to length etc.
27/02/2020	Fabricate any custom parts needed
15/02/2020	Source bicycle components eg gears
03/03/2020	***Assessment 2: Preliminary Project Presentations***
05/03/2020	Assemble the bicycle
12/03/2019	Conduct testing, ie strain gauges, feedback from target market
	WP4
27/11/2019	Set up GitHub repository
	Learn MarkDown syntax
	Track progress throughout project
	Write instructions on the use of the kit, based on best practice
	Compile and finalise documantation
	Report
28/03/2020	Compile design logs, test reports, etc.
	Reflect on how the project could be developed in the future
	Plan structure of report
	List and gather all figures needed
	Create report skeleton
	Draft each section
	Revise drafts
	Work on formatting and graphics
	Create bibliography from references (which should be collected throughout)
29/04/2020	***Assessment 3: Final Project Report***
11/05/2020	***Assessment 5: Viva, Final Presentation and Poster***
25/05/2020	Exhibition, External Viva

Gantt Chart

The following Gantt chart was created from the predicted timescale using an online project management app. It will be updated and utilised throughout the project.

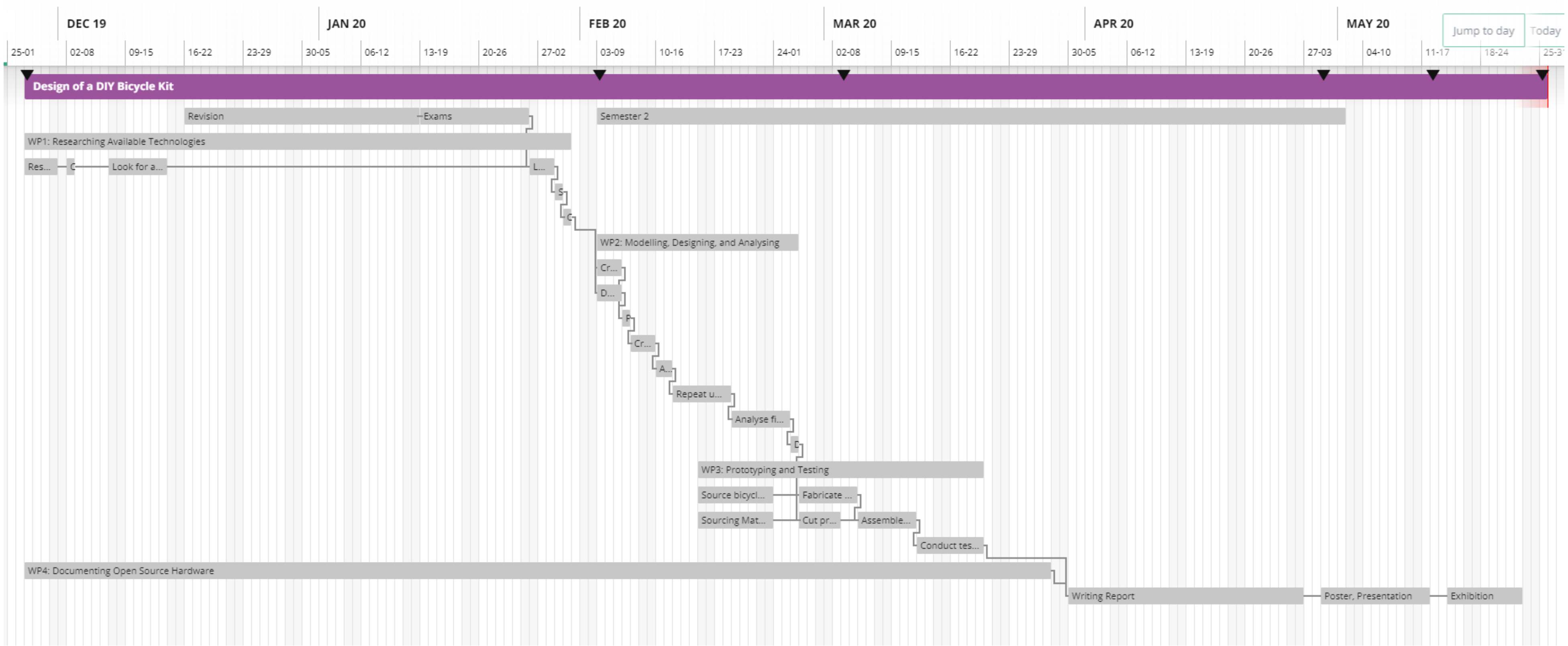

Figure 11: Gantt chart for the project

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