# **Detailed Project Proposal**

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## Industry Advisor

## **Defining your Project**

**1.1 Project title**

***Help:*** *a brief statement about what you are actually going to do.*

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| Estimating Optimal Penalty Coefficients for QUBO Problems |

**1.2 Background**

***Help:*** *Provide the background to your project. This section should highlight the main topics in the area you are going to research. Essentially what is the project about, what has been done before and why is this project important? ~500 words*

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| Quadratic Unconstrained Binary Optimization (QUBO) is a model that can be used to represent a lot of combinatorial optimization problems including the Travelling Salesman Problem and Quadratic Knapsack. There exists a special type of quantum devices that maps a QUBO problem on a network of qubits. In a process called Quantum Annealing (QA) the estimate of the minima or the maxima of the function is found using quantum fluctuations. There is also a hardware developed by Fujitsu called Digital Annealer, which uses a similar approach as to QA (in fact it is inspired by it) but is classical.  QUBO models are used to represent constrained optimization problems in a single unconstrained function. To satisfy the constrains the penalty function is introduced, which is multiplied by penalty coefficient, which is a positive scalar. This penalty function will worsen the objective function if the state is infeasible depending on severity of the broken constrains. If no constraints are broken, the penalty function will be equal to 0. Th penalty coefficient, P, controls the degree by which the penalty function will affect the overall fitness. If the P is too low, the constraints will be ignored throughout the search and the solution will break the constraints. If P is too large, the algorithm will struggle to move through the search space and the solution found will not be optimal. After the solution has been found, it is easy to verify whether the constraints were broken.    There is an optimal value of P and in general an acceptable number is easy to find. However, finding the optimal P is not trivial. There are several methods for |

**1.3 Motivation**

***Help:*** *To whom is this project important? A project must address a question/problem that generates a small piece of new knowledge/solution. This new knowledge/solution must be important to a named group or to a specific client (such as a company, an academic audience, policy makers, people with disabilities) to make it worthwhile carrying out. This is the* ***motivation*** *for your project. In this section you should address who will benefit from your findings and how they will benefit. ~300 words*

**Example** 1: If you intend to demonstrate that a mobile application that automates class registers at RGU will be more efficient than paper-based registers - the group who would be interested in knowing/applying these findings would be both academic and administrative staff at RGU and they would benefit by time saved and a reduction in their administrative workload.

**Example** 2: You are demonstrating that a particular 3D model design increases realism in 3D environments. The group that would be interested would be games designers or developers of 3D virtual environment applications. The would benefit from producing more realistic environments that could increase sales of their products.

**Example** 3: You have designed a new network topology for IrishOil plc’s new Aberdeen headquarters. The interested group would clearly be IrishOil. They would benefit from easier maintenance and improved security of their computer network.

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| 1. Even though QUBO has been successfully applied to solve synthetic combinatorial optimization problems, a lot of real-life problems can be formulated in such format. 2. There are a number of companies that use QA and DA to solve problems relevant to their businesses. They are encoded in QUBO 3. Examples of such businesses 4. A better value of P coefficient will help to produce feasible solutions (or less infeasible) and also make them a better estimate of the optimum. 5. Example with transport |

**1.4 Aim & Objectives**

***Help:*** *Outline what are the main things your project is going to do and what steps or milestones will be used to achieve this aim. The Aim is unlikely to change throughout your project; however, the objectives are likely to adapt to your ongoing research and development. In particular it is highly likely that you may wish to split objectives into sub-objectives as work progresses. A good clear set of objectives give you something to evaluate your final project against.*

**Example** : For the timetable app outlined above

Aim: To create a functioning attendance application that efficiently automates the taking of class registers.

Objective 1: study existing register system in place at RGU and identify weaknesses

Objective 2: research existing automation technology’s and identify and evaluate those that may be appropriate to taking in class registers

Objective 3: Implement chosen technologies to create prototype application

Objective 4: Conduct user trials to evaluate capabilities of prototype application

Objective 5: Create a refined application incorporating feedback from user trials

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| Objective 1: study QUBO and its role in solving real-world problems.  Objective 2: study the existing methods of estimating the P and critically evaluate them.  Objective 3: implement one of the studied methods.  Objective 4: propose and implement a new method for estimating P.  Objective 5: formulate QUBO for a combinatorial optimization problem and run optimization algorithms with P coefficients generated by an existing method and by new method.  Objective 6: compare the results. |

**1.5 Key Techniques**

***Help:*** *Perform some initial research into the area and outline what techniques you my research in further detail here. The techniques you cover here should include references to the papers where you have sourced the information. The techniques mentioned here are very likely to become the section headers in your literature review.*

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**1.6 Legal, Social, Ethical, Professional and Security issues**

***Help:*** *Here you should discuss any legal, social, profession and security issues that you believe may occur during the course of your project. It is not acceptable to write none in this box, all projects, regardless of focus will have to address issues in one, or more, of these categories. This is an extremely important part of your honours project to which there is no correct answer, this section must be fully discussed with your Honours Supervisor.*

**Example 1** : In the class register example above – there would be a Legal and Security issue with the gathering and storage of student data. There may be a social constraint as you may be relying on a user to have access to a specific technology. There will need to be consideration of user accessibility.

**Example 2** : A 3D model design may have ethical considerations in its evaluation. What if your model made users feel nauseous. Social constrains may again be access to technology or accessibility issues.

**Example 3** : You network design need to adhere to specific company policies. You would need to consider the possibility that your design could be wrong, compromising the company’s security.

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**1.7 Project Plan**

***Help:*** *This is the project plan as to how you will go about achieving the objectives of the project.*

**Example**: In the class register example above the research plan may involve:

Collecting and analysing paper-based registers in a given class on five occasions.

Identifying the error rate average on these occasions

Researching existing automation techniques

Designing and implementing a mobile application that automatically records attendance in class.

Deploying the application in the class on five occasions.

Identifying the error rate average of the mobile application on these occasions.

Comparison of data and summary of findings.

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**1.8 Ethics Form**

***You must include in your signed ethics form in this submission or you will not be able to continue the project.***