BLOCKCHAINS FOR CONDITION MONITORING

B4CM

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Project Plan

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Shift2Rail

Authors

Author(s)	**University of Birmingham (UoB)** John Easton
Contributors(s)	**University of Birmingham (UoB)** Rahma Alzahrani

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Disclaimer

Executive Summary

The overall aim of the B4CM project is to develop and deliver a blockchain-based testbed for the attribution of data costs across organisational boundaries, and to demonstrate the operation of the framework and in the context of the European Rail Industry, enabling future developers to extend the tools produced based on a known working configuration.

The work will primarily be delivered by a full-time PhD student based at the University of Birmingham. In order to ensure industrial relevance, alongside the normal supervision arrangements in place at the University the student will be supported at key points by staff from Iconic Blockchain, a MaaS SME with over three years of experience in the delivery of blockchain solutions for the transportation industry and a founding member of the Travelspirit Foundation.

From the point of enrolment of the project student, the timeline for the delivery of the B4CM project is planned to be 36 months. This mirrors the standard timeline for a PhD programme at the University of Birmingham. The technical delivery is split across three work packages, representing the development of the core framework, the understanding of the relationship between the framework and the business processes of the rail industry, and the implementation of a proof of concept demonstration platform. These technical work packages are supplemented by packages representing the project dissemination activities, and the overall administrative management and coordination of the project.

This document presents the detailed breakdown of the work planned within the B4CM project, the deliverables that can be expected to be received, and the milestones that will be used to verify the timely progression of the activities.

Abbreviations and Acronyms

Abbreviation / Acronym	Definition
JU	Joint Undertaking
MaaS	Mobility as a Service
S2R	Shift2Rail
SME	Small or Medium Enterprise

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1. Background to the B4CM Project

Over the past decade there has been a significant level of investment throughout Europe in the digitalisation of the rail network. This includes the installation of sensors on the infrastructure and vehicles, the deployment of next generation traffic management systems that allow real-time management of the system, and the provision of mobile applications for passengers and staff. Despite the wealth of new data provided by these systems, the railways are still struggling in their aspiration to be an information-led industry due to a lack of traceability of information usage, and the commercial barriers between stakeholders.

Blockchains are a disruptive technology that have the potential to accelerate the development of rail as the primary medium-distance carrier within the wider multi-modal transportation system. Directly funded by the rail industry via the EU Shift2Rail Joint Undertaking, the B4CM project will identify key use cases for the technology within the railways, deliver a blockchain-based testbed that enables the benefits of the technology to be formally evaluated, and demonstrate the value of blockchains in the attribution of data costs across organisational boundaries within the European rail sector.

The overall aim of the B4CM project is to develop and deliver a blockchain-based testbed for the attribution of data costs across organisational boundaries, and to demonstrate the operation of the framework and in the context of the European Rail Industry, enabling future developers to extend the tools produced based on a known working configuration.

B4CM has the following research and training objectives:

Objective 1: To identify and develop use cases that support the application of blockchain in the railway sector;

Objective 2: To develop an implementable blockchain framework for the attribution of data costs in systems crossing organisational boundaries;

Objective 3: To evaluate mechanisms for the incorporation of the developed blockchain framework into the financial processes of the European rail sector;

Objective 4: To develop a testbed, demonstrating the operation of the framework in the context of rail sector, enabling future developers to extend the tools produced based on a known working configuration;

Objective 5: To disseminate the findings of the project and the lessons learned to influence best practice in innovation and technology uptake in a key and evolving field within the European rail sector;

Objective 6: To support the development of a researcher in gaining a PhD and thus generating a skilled specialist valuable to the European rail sector.

This document, the B4CM project plan, is a response to all six of the stated objectives and outlines the actions that will be taken in the successful delivery of the project outcomes.

2. Objective / Aim of Deliverable

This deliverable will provide a detailed public summary of the work programme to be completed during the B4CM project.

The document, which is split into several sections, will first provide a detailed description of each of the work packages, followed by summaries of the complete timeline of the work, the main milestones used for assessment of progress, and the technical reports to be delivered.

3. Description of Work and Associated Delivery Plans

Activity within the complete B4CM project is split across 5 work packages. The first three of these, work packages 1 – 3, represent the activity associated with the development of the core software framework, the development of the necessary understanding lining that framework to the business processes of the rail industry, and the implementation of a proof of concept demonstrator respectively. Work package 4 encompasses the industrial and academic dissemination activities needed to ensure that the project delivers the expected impacts, while work package 5 provides the necessary administrative support.

Across the work packages, the outcomes of the project are captured in a series of 8 deliverable documents, the majority of which are due in the latter half of the project timeline. The timely progression of the work will be verified based of a series of 10 project milestones, as with the formal deliverables the majority of the milestones fall in the second half of the project plan. The full timeline for B4CM is presented in section 4 of this document, with a summary of the milestones given in section 5, and the deliverables listed in section 6.

The remainder of this section of the document will present the plans for each work package in detail.

3.1 Work Package 1 (WP1) – Development of a Framework for Cross Boundary Data Accounting

Work package 1 represents the (generic) development of a blockchain-based framework for the accounting of data transactions within a multi-stakeholder railway environment. The main effort is divided into 3 tasks: the first centres on supporting the student while they build an understanding of the operational ICT context of the rail industry, developing an awareness of the classes of systems commonplace within the sector and how they interact in order to provide an operational railway system; the second key task focusses on the selection of tooling appropriate to the system being developed, with particular consideration being given to the “enterprise ready” credentials of the various candidates, leading to implementation of the core components of the framework; the third and final task will centre on the support within the framework for understanding the nature, origin, and ownership of the data being handled, and in particular ensuring that any data that enters the network can be audited allowing revenue chains to be properly defined. Task 3 enables the construction of appropriate metadata at the APIs to the network, and with this knowledge the remaining components of the generic framework can be delivered.

The detailed descriptions of the tasks are as follows:

Task 1.1 – Analysis of need and use-case development: The work will begin with a period of requirements gathering looking specifically at the needs of the rail industry from an ICT perspective, and focussing on the architectural context in which the framework will sit. Key data relationships associated with the data-use cost model will be identified along with suitable example datasets on which to base the framework. In the intial phases of the work it is anticipated that the student will draw extensively on UK information systems catalogue documents, curated by RSSB; this corpus of documents is well known to the academics leading the research, and will enable the student to

develop their approach to analysis in the context of a known system. Once the formal approach is developed, the student will be tasked with identifying the appropriate European equivalent documents (drawing on the lead academics' relationships with other infrastructure managers including TrafikVerket) to demonstrate that the approach can be generalised. The catalogues will be used to identify a) the types of data interfaces that will need to be supported, b) the formats of the data passing through those interfaces. In this task, IB will provide experience of previous use case development and presentation and provide overall industrial mentoring support for the PhD student working on the project.

Task 1.2 – Tool selection and format definition: This task will see the formalisation of the structure and the expected outputs and reporting mechanisms to be used in the framework development activities later in the work package.

Best practice techniques for software engineering, such as the use of design patterns, will be employed to ensure that the framework may be easily extended after the project. Documentation will be prepared to a professional standard and, as a minimum, will include UML diagrams, a programmer's manual, and auto generated API documentation from fully annotated source code.

An appropriate software stack will be selected drawing, where possible, on technologies already in use within the rail or other industrial environments. The open source Hyperledger business blockchain tools will be used to provide the core of the framework, as these are endorsed by a wide cross-section of the community active in this domain including many commercial providers, such as IBM. It is envisaged that IB will be able to provide best practice experience in the selection of appropriate toolchain components.

Task 1.3 – Incorporation of meta-data and ensuring data provenance: In industrial environments where data is to be used as the basis for making operational decisions it is vital that the origin of the data, the nature of the information it contains, and its intended recipients, are unambiguously understood. UoB has been working on semantic mark-up technologies with applications in the rail industry for many years. This work will be used to define metadata for describing key properties of data resources (e.g. sensor types and configurations, timeframes, geographical locations) within the framework.

From a data security perspective, the cryptographic keys used to identify transactions within the blockchain are invaluable to providing assurance of the identities of the sender and receiver of a transaction, if those keys are themselves held securely. However, many of the other security aspects of cyber-physical systems such as those used in RCM applications are comparably poorly understood. This project will draw on existing knowledge of the specific issues faced in this domain, notably from the recent SCEPTICS project, to ensure that a robust solution is developed.

Timings

Work package 1 will operate through the majority of the first two years of the project, allowing the student time to build an understanding of the industrial environment in which they find themselves. Within this envelope it is expected that 9 months will be required for the completion of tasks 1.1 and 1.2, which will run concurrently. On completion of the first two tasks a further 12 months has been allocated for the more complex implementational

issues of unambiguous data description and provenance in task 1.3. As such, the total time required for work package 1 will be 21 months.

Relationship of task timings to UoB PhD Programme Requirements

The timings selected for work package one take into account the standard control & assessment mechanisms built into the University of Birmingham's PhD programme, with a report primarily focussed on the state of the art in the field of research due after the first 12 months of study, and a second progress review due at the 24 month stage by which time preparation for final implementation / the gathering of experimental data is expected to be underway.

Milestones and Deliverables

Work package 1 includes three milestones and a single deliverable. Detailed timings are shown in sections 4 (project timeline), 5 (summary of milestones), and 6 (summary of deliverables) of this document.

Milestones 1 and 2 are due 9 months after the start of the work package, and represent the completion of the scoping activity and development of the core toolchain respectively. Milestone 3 falls at the end of the work package, and represents the completion of the generic framework including considerations for metadata etc.

The only deliverable from the work package is in the form of a report detailing the implementation of the software framework along with supporting documentation. Complete code (in external repositories) will be linked enabling future development etc. to take place.

3.2 Work Package 2 (WP2) – Relationships Between the Framework and Business and Commercial Processes

Work package 2 will establish how the framework developed in WP1 fits within the wider business context of the rail industry. Drawing on work previously undertaken, it will determine how commercial arrangements best be supported by the technology. Key elements of the work will include methods for encoding business rules within transactions, and mechanisms for remuneration of costs. In order to ensure that the outputs of this work package (which are naturally business environment dependent, and therefore will vary between member states) are transferable, the process for designing and implementing solutions will be based on an initial set of activity diagrams showing the stakeholder interactions to be captured. The processes for turning the activity diagrams into (for example) smart contracts will then be generalised, and the "country specific" elements will be able to be captured using an approach that is commonly employed in software development circles (the activity diagram). The work will be divided into two main tasks, the first centring on mechanisms for the implementation of smart contracts in a reproducible manner appropriate to the sector, and the second evaluating mechanisms by which quantified revenue chains many be effective resolved across stakeholders.

The detailed descriptions of the tasks are as follows:

Task 2.1 – Development of smart contracts: Before a blockchain based solution to the cross-industry data question can be considered feasible, it will be necessary to establish the extent to which contractual provisions directly relevant to the data exchange process

can be implemented within a blockchain. The concept of a “smart contract”, a uniquely addressable script enabling complex functions to be applied during a transaction, is already well established within the blockchain community and allows a definition of a well-formed data exchange to be created. This task will build on work in domains including the Internet of Things, and cloud-based manufacturing, to develop smart contracts appropriate to the European rail sector.

Task 2.2 – Evaluation of payment models: There are a number of established payment models associated with blockchain technologies. Two common solutions are longer term block payments and micropayments. The first of these sees a periodic (e.g. quarterly or annual) evaluation of the transaction log in the blockchain to calculate an appropriate remuneration between participating organisations. Micropayments, in contrast, operate on a shorter-term basis more immediately associated with the transaction. This may work particularly well if, in the future, industry data was to be supplemented on a short term, ad-hoc basis by external providers. Building on existing work on the commoditisation of sensor data for the Internet of Things, this task will evaluate the feasibility of both the longer term and micropayment systems within the framework and establish whether such functionality would be appropriate within the contractual arrangements for the European rail sector.

Timings

Running in parallel with the second half of work package 1, work package 2 is planned to run over a total of 12 months. Of this time, the first 8 months will be devoted to the development of the smart contracts, with the remaining 4 months spent of revenue attribution.

Relationship of task timings to UoB PhD Programme Requirements

Within the University of Birmingham standard PhD assessment process, work package 2 is deliberately timed to begin after the initial progress review, and to be completed in time for reporting in the second review cycle as outlined in the WP1 description.

Milestones and Deliverables

Work package 2 comprises two milestones and a single deliverable.

The milestones relate directly to the completion of the individual tasks and are timed accordingly. The deliverable takes the for of a technical report, and will outlining the process by which business / contractual exchanges may be captured (via activity diagrams) and translated into smart contracts for use within the framework, along with the results of the micropayment models proposed for use in remuneration.

3.3 Work Package 3 (WP3) – Implemented Proof-of-Concept for the European Rail Sector

Work package 3 consists of a single task, the detailed description of which is as follows:

Task 3.1 – Testbed development: A testbed environment will be created in which representative data resources, selected from the national information systems catalogues and using wherever practicable in the same software as the real system, are deployed and connected to the framework using the standard APIs. The APIs will represent standard points of extension, to which any information system may be connected, essentially decoupling the core of the demonstrator from any specific dependency on a given IT system (be it a resource used in the UK, or a system used in another member state). Using these representative information systems will ensure that the proof-of-concept demonstrator is representative of the IT landscape of the European railway sector. Depending on the use cases identified in WP1, additional representative sensor deployments may also be incorporated into the proof-of-concept to demonstrate further extensibility. In this task, IB will support the evaluation of the implemented system.

The testbed will also demonstrate compatibility with the IT infrastructure used in the European railway IT landscape. As previously mentioned, the API model makes it comparatively straightforward to replace one information system being used as a data source, with another that produces the same type of data. In order to demonstrate applicability in the European system, example data models employed in RCM systems on the continent will be used to produce simulated data from those systems, and this will be fed into the demonstrator via an appropriate API. One example system with which this type of compatibility could be demonstrated is Network Rail's Intelligent Infrastructure system, which is based on Schneider Electric's Wonderware SCADA platform (licenses for this software are already held by UoB). In the European context, similar systems for monitoring point movements are widely used, and therefore substituting appropriate data using a model for one of the European systems will be a feasible demonstration of the concept.

Timings

Work package 3 is planned to run for the 12 months from the completion of work package 2, finishing 3 months before the formal end of the project.

Relationship of task timings to UoB PhD Programme Requirements

The timing of work package 3 enables the technical work to be completed 3 months before the student's PhD research thesis is due for submission.

Milestones and Deliverables

Work package 3 includes a single milestone and deliverable, both due 3 months before the end of the project. The deliverable takes the form of a technical report detailing the software produced, how it is applied in an industrial context, and presenting a case study of its use as a demonstration of applicability of the framework within the European rail sector.

3.4 Work Package 4 (WP4) – Dissemination and Engagement

Work package 3 will ensure that the findings of the project are effectively disseminated. A full report on the dissemination approaches to be employed by B4CM is given in project deliverable D4.1, however, the work is also described in brief below.

The detailed descriptions of the tasks are as follows:

Task 4.1 – Development of dissemination materials: The project will initially develop templates for publicity materials to be used throughout the project. These will include acknowledgements that the project has received funding from the EU and will display the relevant logos. Webpages describing the project objectives will also be developed within the first 3 months and these will be updated throughout the life of the project. Project reports will be summarised in newsletter form and released both in hardcopy and via the webpages as the reports are completed.

Task 4.2 – Dissemination of results: This task will be performed in line with the dissemination policy of Shift2Rail using dissemination tools and channels as established by Shift2Rail and its lighthouse projects. To this aim, a dissemination plan will be drafted by M6 of the project and refined while the PhD project progresses.

PhD projects generally generate results at low TRL and hence the results are predominantly disseminated to the scientific and academic communities. However, this study will consider both the development and adoption of blockchains as an underpinning technology and so findings of the basic research suitable for further exploitation will also be presented to industry for further application and development.

In addition to targeted dissemination activities, the annual PhD and early-career researcher academic conference hosted by the University of Birmingham will be used to disseminate the results achieved and refine the plans for the next stages of the project. The study will also feature in Shift2Rail dissemination events as appropriate.

Timings

Work package 4 sees dissemination as an ongoing and evolving activity. As such, the work package will run throughout the lifetime of the project. All dissemination materials will be developed during the first 3 months of activity.

Relationship of task timings to UoB PhD Programme Requirements

No specific linkage, as the University of Birmingham standard process envisages that students will disseminate their work throughout their period of study.

Milestones and Deliverables

Work package 4 contains 3 milestones and 3 deliverables. The milestones fall 3, 6, and 21 months into the delivery of the work, and relate to the production of the project web pages and dissemination plan, and a subsequent review of the dissemination plan following completion of the framework. The initial dissemination plan also forms the first deliverable from the work package, followed by at least one conference and journal paper, both due before the end of the project.

3.5 Work Package 5 (WP5) – Management and Coordination

Work package 5 will provide the administrative support necessary for the completion of the programme of work, and management of any secondment (should we be able to facilitate such a placement, and should it be advantageous to the student, for example as a platform to investigate an industrial case study in detail).

The detailed descriptions of the tasks are as follows:

Task 5.1 – Management of technical progress: This task is related to the management of the technical progress of PhD projects and follows the standard processes and schedules used within the University of Birmingham. In addition to this, project instantiation and progress review meetings with IB will be used to provide industry led guidance and review. The project includes a number of deliverables in addition to the internal progress review documents which will be subject to quality assurance processes before being released.

Task 5.2 – Organisation and management of secondments: The standard UoB PhD programme to be followed within this project allows a mechanism for secondments of up to 6 months. UoB has a standard process for monitoring seconded students which will be used should such a secondment be identified as appropriate. This process includes remote supervision arrangements with the regular supervision panel, alongside progress reviews by the industrial partner.

Task 5.3 – Administrative, financial and contractual management: This task is related to the management of all administrative, financial and contractual obligations within the project in compliancy with the general conditions and provisions set forth in the Grant Agreement and the Shift2Rail JU guidelines. As project coordinator UoB will be responsible for the overall financial and administrative management, overall contractual management including requests for amendments to the Grant Agreement and related contractual duties indicated in the Description of Work. In particular, UoB will report the project's performance at the appropriate stages, maintain and monitor the development of the project budget and report regularly to the other partner and the Commission. A consortium agreement between the University and IB will be drawn up specifying the detailed responsibilities of each partner in the delivery of the work, the rights of each partner in terms of foreground and background IPR, and provision for ongoing knowledge management beyond the scope of the project. Exploitation activities will be reported to the Project Officer as part of the periodic reporting cycle.

Timings

As with work package 4, work package 5 will run throughout the project.

Milestones and Deliverables

Work package 5 includes a single milestone and 2 deliverable documents. The milestone marked the formal start of the project with the signing of the Model Grant Agreement and was completed in month 1. The first of the deliverables is the project plan (this document); the second deliverable is the final report, which will present details of all the key deliverables produced by the project, their intended usage, and any information necessary to reproduce the results. The final report is due by the end of the project.

4. Detailed Project Timeline

The complete timeline for the project is summarised in the Gantt chart in Figure 1. Please note that at the time of writing of this document an amendment to the project (no cost time extension) had been requested to allow for a recruitment delay. The timeline presented assumes that the amendment has been accepted (i.e. the student starts at M13).

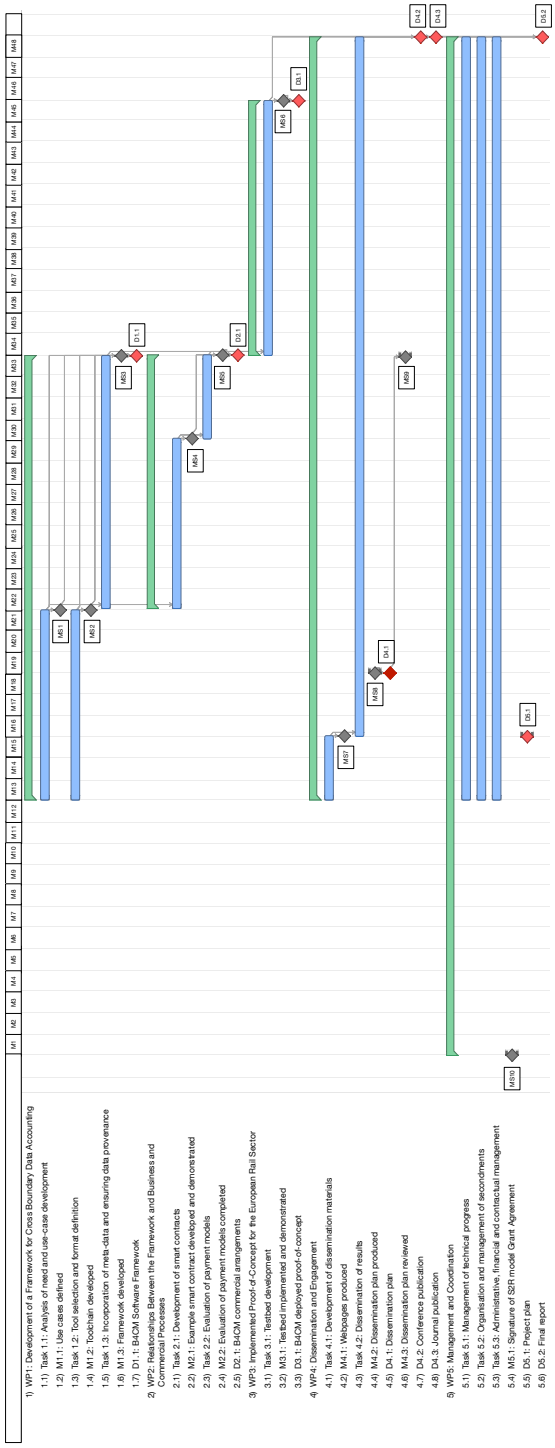

Figure 1: B4CM project timeline.

5. Summary of Key Milestones and Criteria for Achievement

Table 1 presents a summary of the milestones that will be used to verify the progress of the B4CM project. The means of verification is shown in the right-hand column. As with the Gantt chart presented in the previous section, the milestones below assume the requested amendment is approved. Milestones currently completed are shown in green.

Table 1: B4CM project milestones and means of verification.

Milestone number	Milestone name	Related work package(s)	Due date (in month)	Means of verification
M1.1	Appropriate use cases defined and datasets identified.	WP1	21	Approved by PMT
M1.2	Toolchain developed.	WP1	21	End-to-end tests demonstrated to satisfaction of PMT and evidenced in conference paper draft
M1.3	Framework developed.	WP1	33	Approved by PMT and reported in deliverables
M2.1	Example smart contract developed and demonstrated.	WP2	29	Approved by PMT and evidenced in project deliverable D2.1 upon publication (M21)
M2.2	Evaluation of payment models completed.	WP2	33	Approved by PMT and reported in deliverables
M3.1	Testbed implemented and demonstrated.	WP3	45	Approved by PMT and reported in deliverables
M4.1	Webpages produced.	WP4	15	Webpages exist
M4.2	Dissemination plan produced.	WP4	18	Approved by PMT
M4.3	Dissemination plan reviewed.	WP4	33	Approved by PMT
M5.1	Signature of S2R Model Grant Agreement	WP5	1	Signed Grant Agreement

6. Summary of Project Deliverables

Table 2 presents a summary of the deliverable documents to be produced by the B4CM project team, with due dates again based on the timeline specified in the requested amendment. All deliverables are led by the University of Birmingham and are public with the exception of the deliverables associated with work package 4. The WP4 deliverables are classed as restricted, as it is unconfirmed at this stage what the publication rights associated with the journals and conferences will be, however, wherever practical open access versions of these materials will be provided either by the use of open access publications (gold open access) or by provision of pre-print versions of the documents via the project webpages. Submitted deliverables are shown in green.

Table 2: B4CM project deliverables.

Deliverable	Deliverable name	Work package number	Delivery date (in month)
D1.1	B4CM software framework: An implemented software framework and supporting documentation for the monitoring of data exchanges and attribution of associated costs in industrial RCM systems.	WP1	33
D2.1	B4CM commercial arrangements: Technical report detailing how business-specific requirements / arrangements can be captured in smart contracts and deployed within the framework.	WP2	33
D3.1	B4CM deployed proof-of-concept: Technical report detailing the software produced, how it is applied in an industrial context, and presenting a case study of its use as a demonstration of applicability of the framework within the European rail sector.	WP3	45
D4.1	Dissemination plan	WP4	18
D4.2	Conference publication.	WP4	48
D4.3	Journal publication.	WP4	48
D5.1	Project plan (this document)	WP5	15
D5.2	Final report presenting the key deliverables produced by the project, their intended usage, and any information necessary to reproduce the results.	WP5	48

7. Conclusions

This document has outlined the formal plan of work for the B4CM project. The work is being delivered in the form of a PhD studentship, with the student 6 months into their 36-month period of study at the time of writing.

To date, the project is delivering activity to the durations expected, although there was a delay to kick-off as a result of the time taken to recruit the student. The team are confident, that by closely following the timelines outlined in this document, the stated outcomes of the B4CM project can be delivered successfully in around 30 months for the time of writing.