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Work Package
Deliverable sheet

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Contents

TABLES

FIGURES

ABBREVIATIONS

AUV	Autonomous Underwater Vehicle
BMT	BMT Group Ltd.
CF	La Palma Research Centre CL
D	Deliverable (internal ¡VAMOS! deliverable; e.g. 'D6.6' means 'Deliverable 6.6')
Damen	Damen Dredging BV
EFG	European Federation of Geologists
FFE	Fuzzy Front End
GA	Grant Agreement
H2020	Horizon 2020 (an EU research and innovation programme)
HROV	Hybrid Remotely Operated Vehicle
INTRAW	International Raw Materials Observatory (an EU H2020 project)
LARV	Launch and Recovery Vessel
MINATURA	Mineral Deposits of Public Importance (an EU H2020 project)
MV	Mining Vehicle
NPD	New Product Development
PMT	¡VAMOS! Project Management Team
PNA	Positioning, Navigation and Awareness System
R&D	Research and Development
SLAM	Simultaneous Localisation and Mapping
SMD	Soil Machine Dynamics Ltd.
SWOT	Strengths, weaknesses, opportunities and threats
TC	¡VAMOS! Technical Committee
UNEXMIN	Underwater Explorer for Flooded Mines (an EU H2020 project)
WP	Work Package

1 Executive Summary

Deliverable 1.2: Innovation Agenda describes the actions that (1) keep the research and technology development on track within the ¡VAMOS! Project; (2) determine the methodology, results, recommendations and learnings from an end-user market acceptance survey; and (3) determine the overall recommendations for innovation management for the remaining project period and the period that begins after the EC funding ends.

Innovation within ¡VAMOS! began with the idea of a novel mining system for excavating material from flooded inland open-cut mines. Partner organisations have collaborated to realise the technology vision by designing and manufacturing a range of primary and peripheral technologies for the multi-component system. The initial innovative idea was refined continually throughout the design phase. This process was managed by regular communication between co-working organisations, the coordination of technical and appraisal meetings, and the keeping of a technology integration plan. Feedback from external experts at biannual advisory meetings also guided the design and concept refinement.

Targeted market research has shown that mining professionals and potential end-users view the system with a conditional favourability and eagerly await the site-test results. The concept is seen as highly innovative, and stakeholders are hopeful of a high impact if it is proven technologically and economically viable. It is advised that the EC, the ¡VAMOS! PMT, TC and all Partners review and consider implementing the recommendations in Chapter 5. These recommendations concisely synthesise the data gathered during the market research and suggest innovative additions which could improve the system according to stakeholder needs. There will be further market research as part of Work Package 6, once sufficient data is available from the site-tests to address present stakeholder concerns.

2 Introduction

2.1 The ¡VAMOS! Project

Estimates indicate that the value of unexploited European mineral resources at a depth of 500-1,000 meters is ca €100 billion, however, many physical, economic, social, environmental and human constraints have limited their exploitation. ¡VAMOS! will provide a new safe, clean and low visibility mining technique and will prove its economic viability for extracting currently unreachable mineral deposits, thus encouraging investment and helping to put the EU back on a level playing field in terms of access to strategically important minerals. Deriving from successful deep-sea mining techniques, the ¡VAMOS! mining solution aspires to lead to: Re-opening abandoned mines; Extensions of open-cut mines which are limited by stripping ratio, hydrological or geotechnical problems; and opening of new mines in the EU. ¡VAMOS! will design and manufacture innovative automated excavation equipment and environmental impact monitoring tools that will be used to perform field tests in four mine sites across Europe with a range of rock hardness and pit morphology.

¡VAMOS! will:

1. Develop a prototype underwater, remotely controlled, mining machine with associated launch and recovery equipment
2. Enhance currently available underwater sensing, spatial awareness, navigational and positioning technology
3. Provide an integrated solution for efficient Real-time Monitoring of Environmental Impact
4. Conduct field trials with the prototype equipment in abandoned and inactive mine sites with a range of rock types and at a range of submerged depths
5. Evaluate the productivity and cost of operation to enable mine-ability and economic reassessment of the EU's mineral resources.
6. Maximize impact and enable the Market Up-Take of the proposed solutions by defining and overcoming the practicalities of the concept, proving the operational feasibility and the economic viability.
7. Contribute to the social acceptance of the new extraction technique via public demonstrations in EU regions.

2.2 Deliverable D1.2 Innovation Agenda

2.2.1 Objectives

The goal of this deliverable has been to create an innovation agenda for ¡VAMOS! and its technological components. This has included the following objectives:

a) Safeguarding internal innovation processes by encouraging Consortium partners to cooperate with a common understanding of innovative components, goals and processes during and after the EC-funded period;

b) Analysing data from primary stakeholders to enable the Consortium to follow a customer-oriented innovation agenda;

c) Undertaking market-acceptance research, enabling potential users to respond to the external opportunities offered by ¡VAMOS! for the creation of new ideas, processes or products;

d) Identifying key innovation targets as baseline in preparation for D6.6 Future Research Roadmap, drawing inspiration from market and policy requirements.

2.2.2 Approach

Innovation in ¡VAMOS! is understood as *"the process, including its outcome, by which new ideas respond to societal or economic needs and demand and generate new products, services or business and organizational models that are successfully introduced into an existing market or that are able to create new markets and that contribute value to society."*[1] Given the strong emphasis this project has on the development of a new technology system made of multiple innovative components, it can be said that the New Product Development (NPD)[2] phase has included the work undertaken across all development and manufacturing work packages.

The innovation process in New Product Development (NPD) can be described as a step between the 'Fuzzy Front End' (FFE) appraisal phase and final commercial exploitation.[3] The following diagram (figure 1) summarises the features of these natural processes.

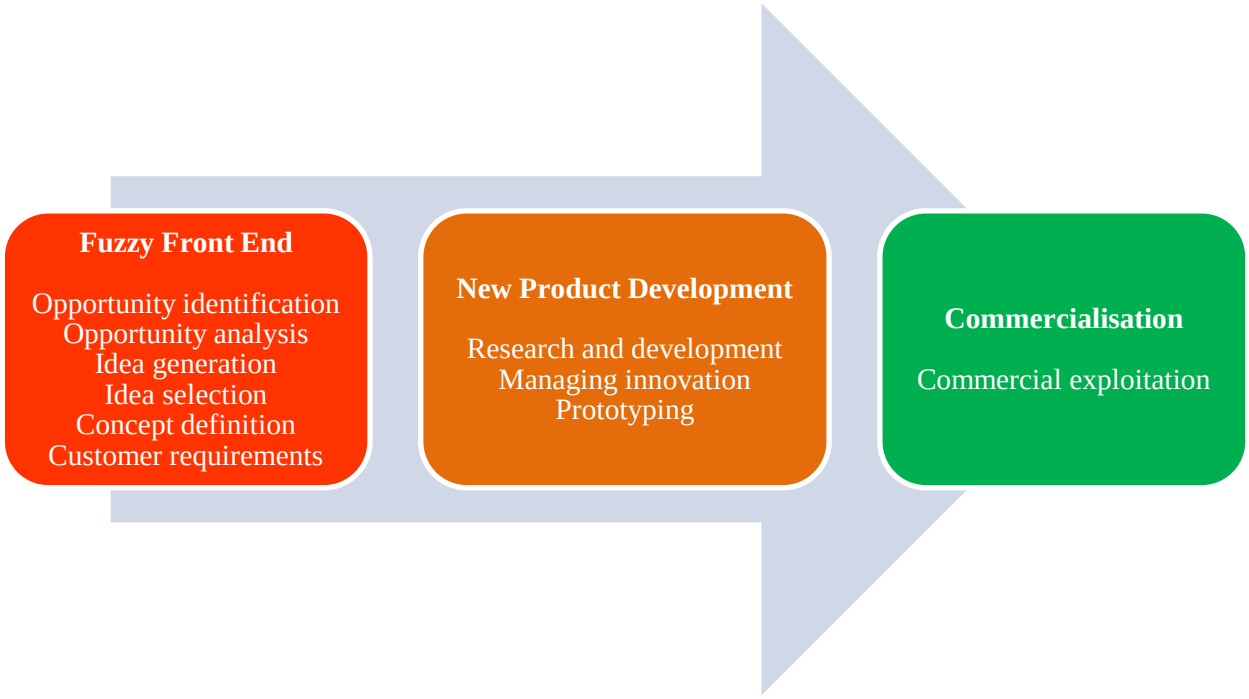

Figure 1. The key stages of the innovation process

The individual steps are not always well defined. In the case of the ¡VAMOS! Prototype, the submission of the original project proposal corresponded to the completion of the FFE appraisal, and the project will be completed before the NPD phase has concluded.

The *key success factors* in NPD can be summarised as follows:

- Uniqueness of the concept
- Solving major customer problems
- Engaging directly with customers

The second and third points are related to 'value engineering'[4], a process that relates the importance customers place on the functional parameters of a product to the cost of the parts contributing to those functions. To support value engineering, developers must understand the value customers place on each function and the cost of manufacturing to provide that function. When making cost and feasibility trade-offs for the final product, it is important to integrate both customer and developer perspectives, hence the need to engage with future customers as in the two stakeholder workshops held in Newcastle and Portugal. This process of external feedback has been facilitated by market acceptance analysis and a shared dissemination strategy. Direct communication with potential customers will continue to be of paramount interest as the ¡VAMOS! product and service strategy takes shape.

In ¡VAMOS!, there is a continued integration of the innovation process with other project tasks such as internal and external communication and formal dissemination and reporting. Through activities in other deliverables such as D6.3 Environmental Impact Analysis and D6.6 Future Research Roadmap, the Consortium is creating a plan to boost its output of innovative products, components and services. The Consortium is also developing a business model for subsequent commercial exploitation (D6.4 – Technology Exploitation Plan.) Together, these actions will identify new methods, products and services that were unforeseen in the original proposal.

To summarise, the main activities in D1.2 Innovation Agenda are comprised of (1) mapping innovative system components for further development, (2) conducting market acceptance research, and (3) analysing research data and writing recommendations based on the findings.

2.2.3 Relationship with Work Package 6

Most related to D1.2 is D6.6 Future Research Roadmap, for which D1.2 can be interpreted as a preparatory phase. The scope of D6.6 includes the following:

- Elaborating on ¡VAMOS! added value: distinguishing features and product differentiation strategies, based on the assessment of market needs and competitors' offers or solutions;
- Synergies with other products, services and initiatives that are currently on the market or that are being developed by other research groups;
- Linking ¡VAMOS! with innovation players, innovation networks and financiers in Europe through continued dissemination and joint EU-project collaborations and conferences;
- Linking ¡VAMOS! innovations with other EU projects, not necessarily only under the raw materials theme, but also under ICT, robotics, space, environmental research and more;
- Linking the Innovation Agenda with project communications by emphasising the innovative components for maximum visibility, and developing new ways of presenting the work of ¡VAMOS! to an external audience.

3 Innovation management

3.1 Innovation targets and strategies

The objective of this task has been to strengthen internal innovation management. This included the definition of innovative project components as well as innovation targets based on a technology vision in which mining operations are performed by intelligent machinery with minimal environmental impact, in the spirit of the ¡VAMOS! underwater mining solution.

The innovation agenda in ¡VAMOS! is based on the identification of emerging opportunities which can generate additional value within budget. The development of the prototype has followed the NPD model; however mid-project identification of emerging opportunities has been typical of the FFE phase wherein *"a crossroads of complex information processing, tacit knowledge, conflicting organizational pressures, and considerable uncertainty and equivocality"*[3] gives rise to innovative solutions to unforeseen circumstances. All these factors are present in a multidisciplinary, multinational consortium such as that of ¡VAMOS!.

This natural approach to innovation will continue to assist the creation of solutions that can be turned into new primary and supplementary products and services that will strengthen the position of the ¡VAMOS! Consortium on the EU market when the commercialisation begins. A continuation of best practices in project management (Work Package 7 – Project Management) and the use of foresight methods such as research road-mapping (Work Package 6 – Market Uptake) will help the Consortium to maintain focus on continual innovation of the components and services of ¡VAMOS!.

Innovation management cornerstones:

- Managing external opportunities, such as adapting the ¡VAMOS! technology and its individual components for new technology scenarios that were not foreseen in the original proposal, based on feedback from within the project consortium and from external stakeholders;
- Managing internal opportunities, such as maximising access to partner expertise, identifying unforeseen potential for cooperation within the Consortium and for linking system components;
- Increasing the visibility and networking around ¡VAMOS! innovations so that internal and external contributors with different skills and knowledge can help to innovate the best ideas;
- Understanding and monitoring the barriers to realising ¡VAMOS! innovations, and developing strategies to tackle these barriers;
- Developing suggestions for the continued development of ¡VAMOS! either as a follow-up project or as sub-projects defined for individual systems components;
- Mapping financial instruments and EU funds suitable for continuation or co-financing of ¡VAMOS! and/or its individual components.

Innovation in ¡VAMOS! has been predominantly managed by the Technical Manager through biannual interorganisational technical meetings and regular communication between technical partners. Additionally, the Project Management Team has ensured that external advisory meetings are held every six months. Through regular internal and external technical and general advisory, the

development of project components and broader conceptualisation has been reviewed and adapted to address unforeseen challenges and stakeholder feedback. Regular communication and formal review meetings have been complemented by the tracking of a project risk register and integration register, both of which have ensured a coordinated and organised approach to innovation management.

Table 1. Recent project meetings where partners have gathered to plan technology and testing developments.

Date	Title	Scope	Partners	Attendees
15 Sept 16	WP Leader Meeting	Technical meeting	BMT, SMD, DAM, INESC	6
03-04 Oct 16	Review Meeting	Technical and project progress meeting	BMT, BMT WBM, SMD, DAM, INESC, FEMU, ZFT, MUL, SAND, CF, EFG, TRE	21
05 Oct 16	AB Member Meeting	Technology advisory meeting	DAM, SMD, BMT, INESC, CF, (+AB Members)	14
05-06 Dec 16	WP6 KO Meeting	Economic, environmental and road-mapping methodology	BMT, SMD, CF, MUL, FEMU, LPRC, GeoZS	9
29-30 Mar 17	WP Partner Forum, AB Meeting	Technology and field test planning and external technological and planning advisory	BMT, SMD, DAM, INESC, FEMU, Zft, MUL MIN, MML, EDM SAND, GeoZS, CF EFG, TRE, FZG, FORRV, (+AB Members)	47
22 June 17	WP5 site visit and planning	Test planning	DAM, INESC PORTO, SAND, Fugro	

3.2 Innovative components

The following list and descriptions catalogue the identified innovative solutions within the ¡VAMOS! project. These components could be subject to further development and customisation because of the market-acceptance survey and further engagement with the end-user community.

1. The Prototype: a remotely operated underwater mining system for submerged inland applications, with associated launch and recovery equipment and with the following main components:
   - New application of cutting technology for submerged inland mining conditions.
   - New slurry circuitry and riser transportation system
   - Floating winch technology
2. Underwater multi-tool system and a reliable method of tool change.
3. The undercarriage system: designed to provide machine stability and manoeuvrability, based on known safe gauge-to-pitch ratios. Heavy-duty components will be integrated as opposed to lightweight track systems which are sometimes used for soft seabed excavation vehicles. This is due to the rugged nature of the mining environment at the test sites.
4. Surface vessel (LARV): a modular pontoon with key equipment securely fastened to it. The hoisting capacity needs to be matched to the machine weight, bullet and lift-wire weight for the deepest operating site with appropriate allowances for any unwanted settlement of ore on the prototype. The module with tools, containers and spares on board will weigh around 170 tonnes.

5. The size of the prototype equipment will be comparable to existing land-based cutting machines with consideration of ease of transportability across EU and local road networks.
6. The supporting technologies that have been developed to overcome the current limitations of underwater sensing, spatial awareness as well as navigation and positioning. These will enable safe and reliable operation of the equipment in the application environment. Fusion of a variety of proven and state-of-the-art sensing technologies provides a virtual-reality tool for pilot control whilst mining submerged orebodies. The main survey and sensing tools are mounted on the MV, HROV and the LARV:
   - Underwater positioning technology developed via the fusion of acoustic data with information from 3D Sonar, underwater laser scanning, EO images and from Simultaneous Localisation and Mapping (SLAM);
   - Augmented reality technology for the representation of the mining environment to enable a high level of pilot awareness;
   - AUV technology that allows the perception of mine areas and the observation and navigation of the mining machine, and the supervision of tool changing;
   - Real time grade control capability using Laser Induced Breakdown Spectroscopy equipment.

3.3 Innovative advantages

The main advantages of the system compared to *conventional opencut mining* can be summarised as:

- No dewatering costs and associated environmental impacts;
- Less waste and the cost of removing waste rocks is marginal compared to open-cut mining;
- No blasting noise/ground vibration or dust nuisance;
- Reduction of necessary groundworks and access routes;
- Cheaper capital cost than an underground mine and quicker set up;
- Access to barrier pillars, buffer zones etc.;
- No personnel in the mine;
- No discharge of mine water;
- Chance to re-address rehabilitation problems that have been left behind.

Further competitive/commercial advantages can be defined in relation to *offshore mining*:

- No need to deploy an expensive ocean-going vessel;
- The environment is already contaminated, usually acidic and unsuitable to sustain life, therefore, environmental concerns are marginal;
- Production is much closer to market;
- There is no need to transport waste or other unwanted material to the shore;
- Easier access enabled to smaller deposits of critical minerals onshore.

The ¡VAMOS! innovations have been communicated throughout the duration of the project and have been a central part of Task 1.4 dissemination planning. Key in promoting the project is focussing on the innovative advantages that differentiate ¡VAMOS! by its socioenvironmental and economic impact from other methods and products which are currently available such as strip mining and conventional dredging machines.

4 Market acceptance analysis

The objective of this task was to lay the groundwork for the development of a commercial exploitation and research strategy for the ¡VAMOS! Prototype and concept. Market research has been designed and carried out by means of a market acceptance survey. The findings from this research will allow the Consortium to develop innovations in products and services that are more customer-focused. Since the key components of ¡VAMOS! innovations are already established, the market survey focuses on evaluating market expectations for the solutions that can be developed in the future. The market research was also designed as a dissemination tool that can be used to begin communication with future customers, and has been promoted through various online media.

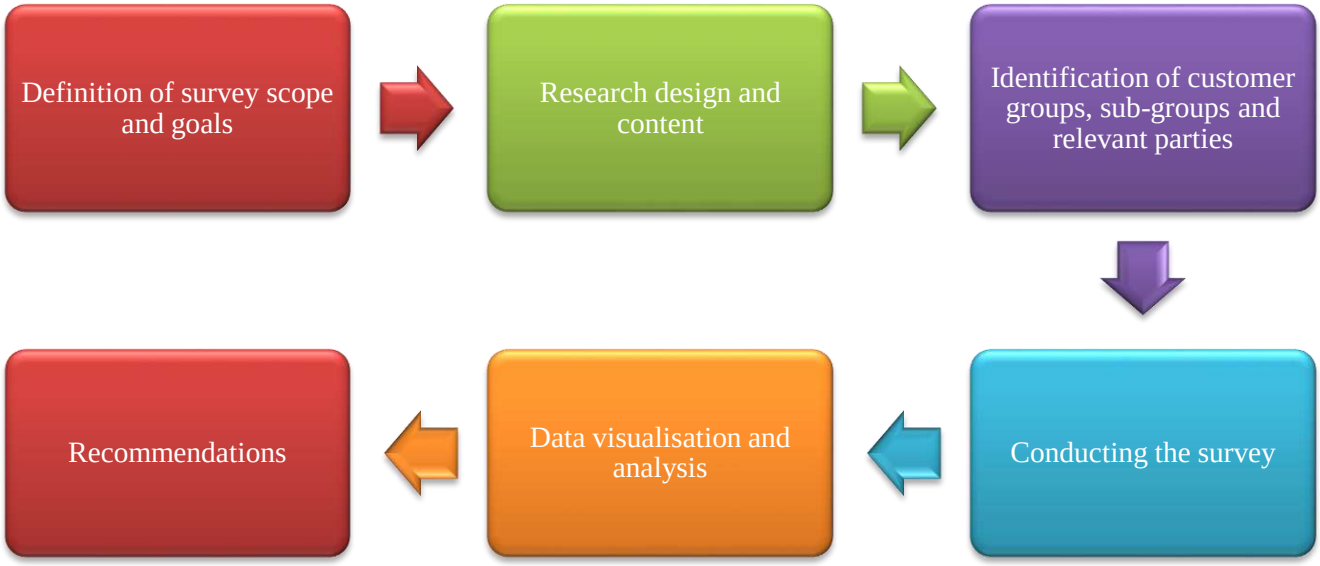

Figure 2. Flow chart of the survey process from conception to recommendations reporting

4.1 Scope and goals

The survey intended to showcase the best of the ¡VAMOS! technology whilst gathering meaningful feedback from relevant and interested stakeholders. The goal of the survey was to promote the project and gain data on how customers perceive the project, its technology and its market offering. Survey results were to be analysed to create recommendations for Consortium partners and the European Commission on how to improve the ¡VAMOS! solution and better define their innovation agendas and commercial strategies. The results from the survey will also provide a baseline for the future research roadmap in Work Package 6 and act as a report on interim stakeholder and customer perspectives.

4.2 Design

The design of the market research had to ensure the collection of data which would be most useful for the Consortium to plan the future commercial offering of the system and its various technologies. This process included deciding how to let the audience explore all aspects of the project whilst also limiting the survey in length to increase the response rate.

A first draft of the survey content was reviewed internally by CF prior to the March 2017 ¡VAMOS! Partners Forum meeting in Porto. On the first day of the Porto meeting, the 29th of March, the contents and format of the survey were discussed during the Work Package 1/6 workshop. Present at this workshop was the Project Coordinator, the Technical Manager and nine other contributors from Consortium organisations. After the meeting, the accepted format, content and phrasing suggestions were implemented to the survey design.

An online survey was created using Google Forms. This survey was divided into sections addressing technological, economic, and social and environmental factors. To keep the survey brief and response rates high, the survey was limited to seventeen questions. Questions included a combination of open and multiple-choice formats, making it possible to collect both qualitative and quantitative data.

'Dear Valued Respondent,

After reading our online brochure on the innovative ¡VAMOS! concept and additional information available on our website (www.vamos-project.eu), we'd be grateful if you would answer some very brief questions in this survey on your impression of the project and its goals for a more sustainable and economically viable inland mining solution.

We will collect the results from the survey in 2 weeks' time and would kindly ask you to send us your thoughts before then.

Kind regards,
The ¡VAMOS! Project Consortium'

Figure 3. The introductory text at the beginning of the Google Forms survey. This text is an abbreviation of the tailored introductory message sent directly to stakeholders whose email addresses were known.

A Microsoft Word version was also created. To the stakeholders that were contacted directly by email, the Word version was sent as an attachment alongside a link to the Google Forms survey, with the latter having the added function of anonymous submission.

The final version of the survey consisted of fourteen questions related to the technology and three supplementary questions on the respondents' backgrounds, their willingness to be kept informed of project developments, and their interest in a project open-day event. The fourteen technology questions were divided into seven sections covering different aspects of the system; these sections and their associated questions are listed in the next sub-chapter.

4.3 Content

The fourteen technology questions are described below, listed and described under their respective sections as defined in the market research design phase.

4.3.1 General impression

- How Innovative does the concept seem to you?
- How positive do you feel about the impact in 30 years' time?

In this section, respondents answered two questions based upon their impression of the novelty and the potential success of the project in the mining extraction market. These two questions were presented on a scale of 1 to 10, allowing quantitative analysis of the results.

4.3.2 Uncertainties

- What would be crucial for you to know before using VAMOS?
- Which ¡VAMOS! components must be developed further to make the system appealing?
- What additional functionalities would you like the system to provide?

Here, respondents were given the opportunity to express their uncertainties on ¡VAMOS! in open answers. The feedback received to these questions allows for an insight into what direction the system might need to move to make it more successful in the market once the testing is complete and commercialisation is approved. The answers will also help us within D6.6 Future Research Roadmap to gain an idea of which topics could be explored.

4.3.3 Purchase options

- Would you prefer to rent or purchase the entire system?

This open question was included to assist the consortium with its exploitation planning in D6.4 Technologies Exploitation Plan.

4.3.4 Commercial appeal

- What are the three most important economic variables influencing your impression of VAMOS?

This open question allowed respondents to rank their three prime concerns on the economic feasibility of ¡VAMOS!. This question was added despite no economic results available prior to field testing. The reason for this is that the question will still tell us what aspects of the project potential customers are most concerned about from a commercial perspective.

4.3.5 Social and environmental responsibility

- How socially and environmentally beneficial do you perceive ¡VAMOS! to be?
- What stands out as socially and/or environmentally responsible and/or irresponsible?

This section was included after receiving questions and feedback through the project Twitter page regarding the environmental integrity of the system.

4.3.6 Feasibility

- What is your impression on the feasibility of VAMOS?
- Do you perceive any bottlenecks to operation and implementation?
- How concerned are you about these aspects of the feasibility?
- What are your comments based on your response to the previous question?

These questions were included so that the respondents' perceived feasibility of the system and its various components could be discussed. This would enable the Consortium to gain access to knowledge and suggestions for various potential improvements which were not foreseen in the Grant Agreement. These questions also provide the dissemination team with data which could be used to tailor the dissemination programme to more accurately reflect potential end-users' concerns.

4.3.7 Further comments

- Do you have any further comments about the project?

A general question for any other issues which respondents could highlight which might not have been covered in the previous sections.

4.4 Audience

The target audience was identified based on who could be able to give the most insight into the market reaction from potential buyers and competitors. Over 200 individual contacts were compiled from mine operators, mining technology providers, non-governmental organisations and academics in related fields. In addition to this, the survey was disseminated to professionals from European projects including INTRAW, MINATURA2020 and UNEXMIN, and within the ¡VAMOS! Consortium, on the ¡VAMOS! website, Twitter account and Sustainable Mining Forum, various LinkedIn mining groups and in a monthly geoscience dissemination journal published by EFG. These outlets have a combined population of tens of thousands of professionals. The survey will remain on the ¡VAMOS! website.

4.5 Results

In this section, you will find graphs of the survey data as well as an interpretation of the results grouped, which are grouped under their respective subheadings, in the order they appeared in the survey. In the graphs and the response tables (*see:* appendices B and C), the open-answer responses have been grouped by topic; those which contain data on more than one topic have been duplicated and divided between the appropriate themes.

4.5.1 Background information

Q1 What is your background/area of work?

2/24 responses: This question was answered by only two respondents. Both had a background in raw materials technology. The remaining respondents may have chosen to remain anonymous.

4.5.2 General impression

Q2 How innovative does the ¡VAMOS! concept seem to you?

24/24 responses: Every respondent answered this question. As you can see from the bar chart below (figure 4), there is a skewed distribution of responses in favour of a more positive opinion of the novelty of the project.

Q3 How positive do you feel about the project in 30 years' time?

24/24 responses: All respondents answered this question. There is a more diverse opinion on the potential longevity or influence of VAMOS over the long-term. However, there is an identifiable clustering of the responses to the *more positive* side of the chart.

4.5.3 Uncertainties

Q4 What would be crucial for you to know to make an informed decision on advocating/using VAMOS?

22/24 responses: Responses to this question highlight multiple factors which might influence potential buyers of the technology. Respondents focussed on issues ranging from the practical operability in real conditions underwater, the economic viability of the system in hard rock environments, and the environmental hazards associated with full-scale operation.

Q5 Which components need to be developed further for ¡VAMOS! to be more appealing from your perspective?

22/24 responses: Responses mainly focus on the technology aspects of the project and the practicalities of operation in an underwater environment. Concerns include costs, scalability, locomotion of the MV, PNA functionality, environmental hazards and the recovery of damaged equipment underwater.

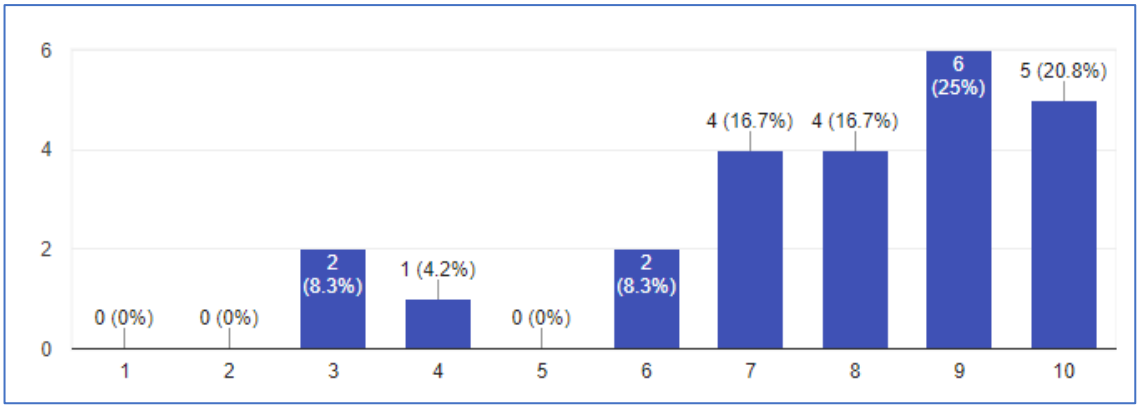

Figure 4. Q2 Responses. 'How innovative does the ¡VAMOS! concept seem to you?

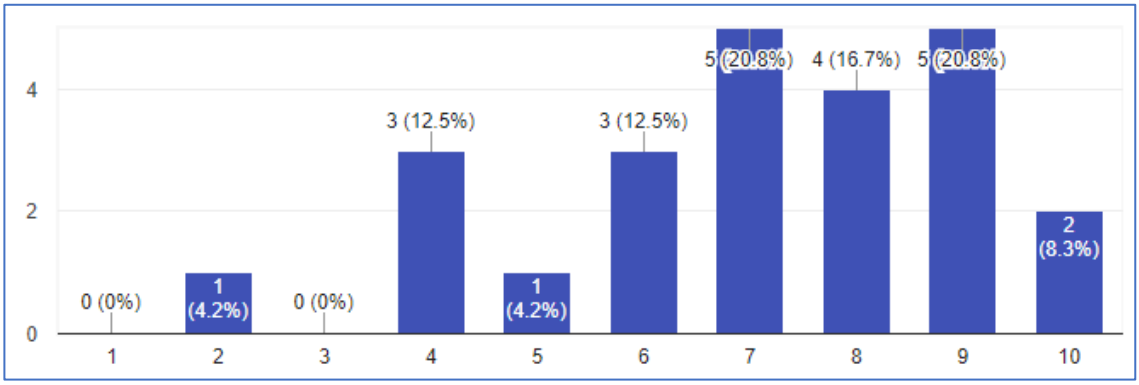

Figure 5. Q3 Responses. 'How positive do you feel about the project in 30 years' time?'

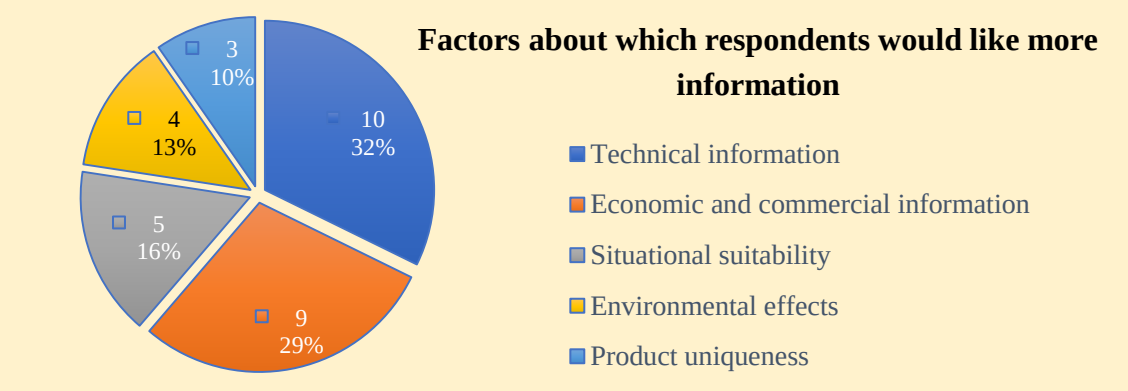

Figure 6. Q4 Reponses. 'What would be crucial for you to know to make an informed decision on advocating/using VAMOS?'

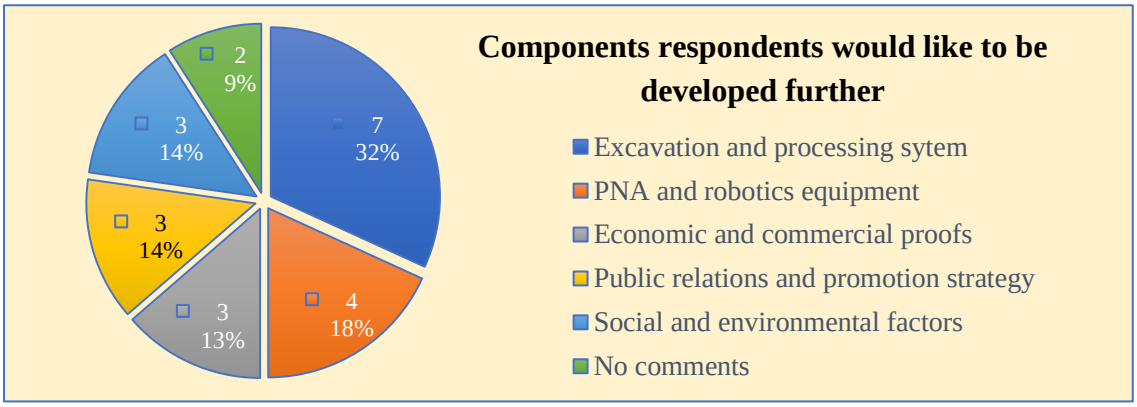

Figure 7. Q5 Responses. 'Which components need to be developed further for ¡VAMOS! to be more appealing from your perspective?'

4.5.3 Uncertainties *(continued)*

Q6 Are there any additional functions which you would like the system to provide?

17/24 responses: Responses include multiple requests for a proven real-time grade control system, *in situ* mineral detection methods and underwater drilling. In addition to this, respondents have requested a functional PNA system, underwater coring capabilities and other technologies to extend the range, environment and the productivity of the system.

4.5.4 Purchase options

Q7 If relevant, would you prefer a rental service or machine-purchase option?

18/24 responses: The largest percentage of respondents (50%) would prefer a rental service from the system owner. 33% of respondents opt for an outright purchase of the equipment. One respondent comments that there is a place for a hybrid solution, whilst another requests a deal wherein the operation and the hire of the system are included together.

4.5.5 Commercial appeal

Q8 In order of decreasing importance, what are the three most important economic variables influencing your impression of VAMOS?

19/24 responses: The most common primary concerns are the costs of the purchase (capex) and operation (opex) of the system. Other factors include excavation productivity, metals markets, environmental limitations, regulatory restrictions and the potential need for further processing of the final product produced by the ¡VAMOS! method. Further technical concerns include the cost of spares and replacement parts and the energy consumption of the system. Circumstantial suitability was also mentioned, as one respondent mentioned the possibility to use the system in underexploited flooded mines as well as conventionally depleted mines. One respondent suggested innovating a system capable of measuring the mineral content of material at the point of excavation i.e. the front of the Mining Vehicle.

4.5.6 Social and environmental responsibility

Q9 How socially and environmentally beneficial do you perceive ¡VAMOS! to be?

24/24 responses: All respondents answered this question. A majority of votes (14) score 8-10, indicating a majority of the respondents have a positive perception of the social and environmental aspects of ¡VAMOS!. There is a minority of five respondents who rate the system as five or less on this scale.

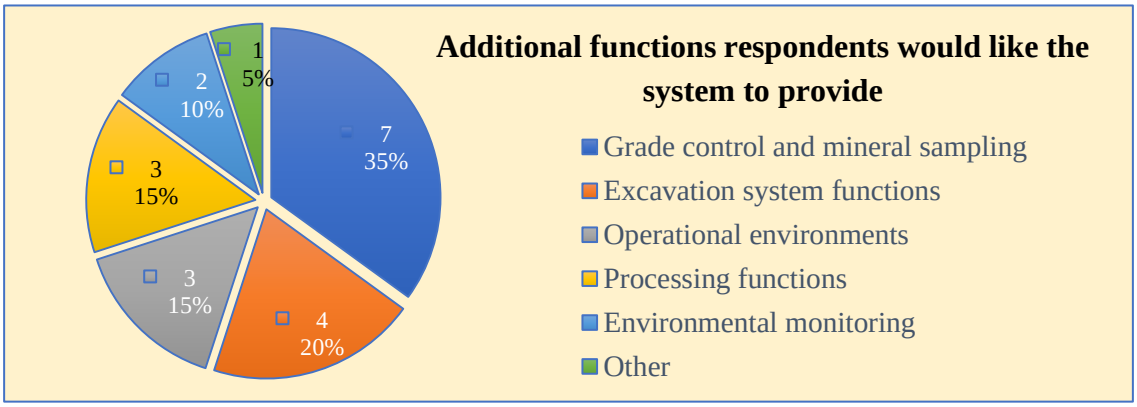

Figure 8. Q6 Responses. 'Are there any additional functions which you would like the system to provide?'

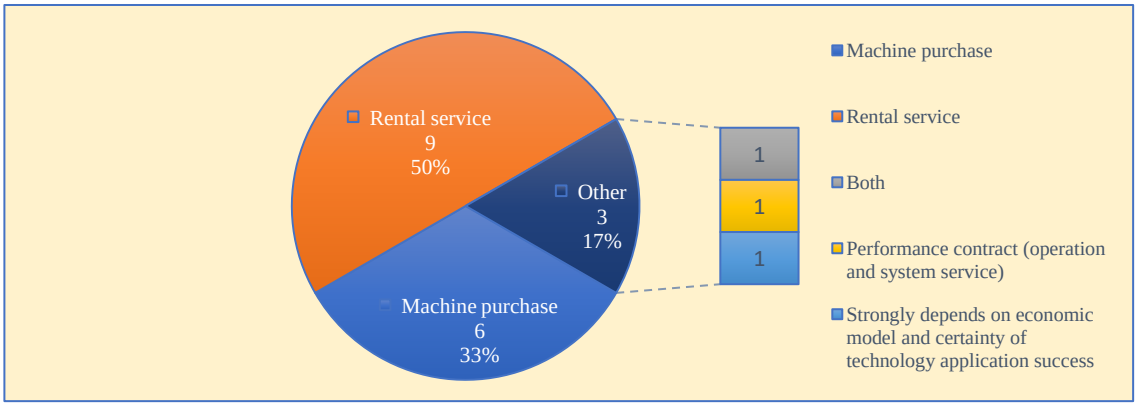

Figure 9. Q7 Responses. 'If relevant, would you prefer a rental service or machine-purchase option?'

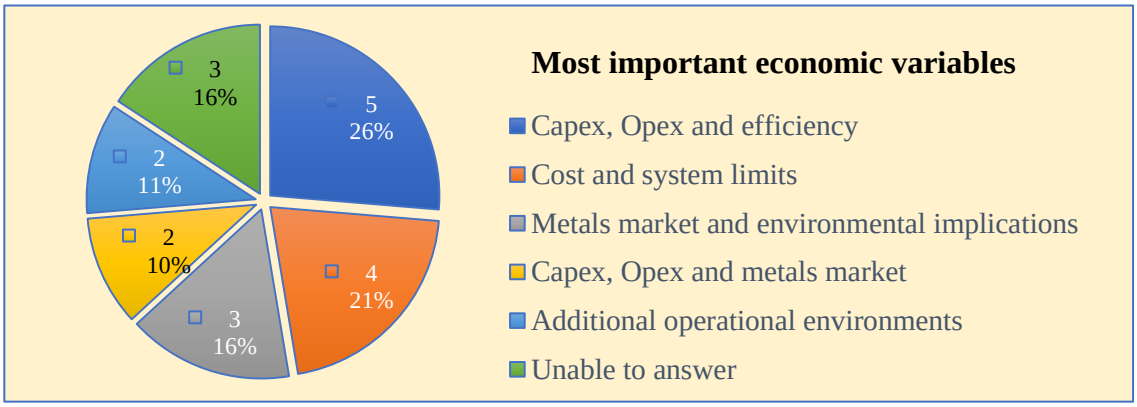

Figure 10. Q8 Responses. 'In order of decreasing importance, what are the three most important economic variables influencing your impression of VAMOS?' *(see Appendix B for full results table)*

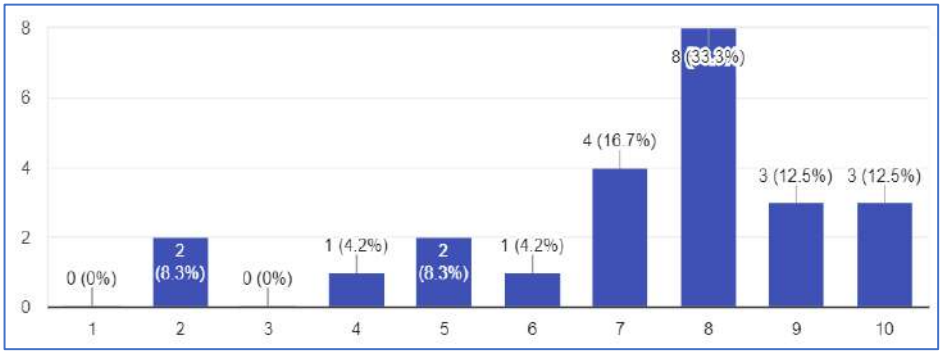

Figure 11. Q9 Reponses. 'How socially and environmentally beneficial do you perceive ¡VAMOS! to be?' (10 = most beneficial.)

4.5.6 Social and environmental responsibility *(continued)*

Q10 Are there any factors which stand out to you as being socially and/or environmentally responsible and/or irresponsible?

19/24 responses: Positive responses infer that these respondents view the technology as energy efficient, socially responsible and environmentally unobtrusive. Highlights include concerns over the prioritisation of the social and environmental aspects of the project rather than its economic feasibility, the unaccounted necessity for the construction of a tailings dam, the ability of the sensors to monitor the system in operation, the perceived potential for contamination of groundwater, the effectiveness of the design of the power supply and the size of the energy consumption.

4.5.7 Feasibility

Q11 What is your general impression of the feasibility of the ¡VAMOS! concept?

21/24 responses: From the twenty-one responses to this question, twelve exhibit an optimistic view of the feasibility of the concept, nine indicate some degree of scepticism, and two note that they are (1) unconvinced, and that (2) there isn't a market for the product.

Q12 Do you perceive any specific bottlenecks to the operation and implementation of VAMOS?

21/24 responses: Several respondents expressed uncertainty prior to the results from the field trials, indicating that they are unable to give an accurate answer. Five respondents highlighted their concern about the economics of the operation. Other responses include concerns about the suitability of the concept in 'highly variable' ground conditions, the likelihood of investment from mine owners and potential difficulties in environmental permitting. Practical concerns include the performance of the LARV as a launching mechanism, the effectiveness of the grade control system, the waste and ore separation procedure and difficulty in operating in old mines with complex and uncertain bathymetry.

Q13 Please number the following on a scale of 'most concerned' to 'least concerned.' With 1 being 'most concerned,' and 5 being 'least concerned.'

Categories: (1) Environmental concerns, (2) Social concerns, (3) Legislative feasibility, (4) Technological feasibility, (5) Economic feasibility.'

24/24 responses: All respondents answered these multiple-choice questions. Note that a lower score indicates a higher level of concern. Aggregating the scores of all 24 respondents, it is shown that there is the most concern about the economic feasibility of ¡VAMOS! followed by its technological feasibility, legislative feasibility, social effects and least of all, environmental impact.

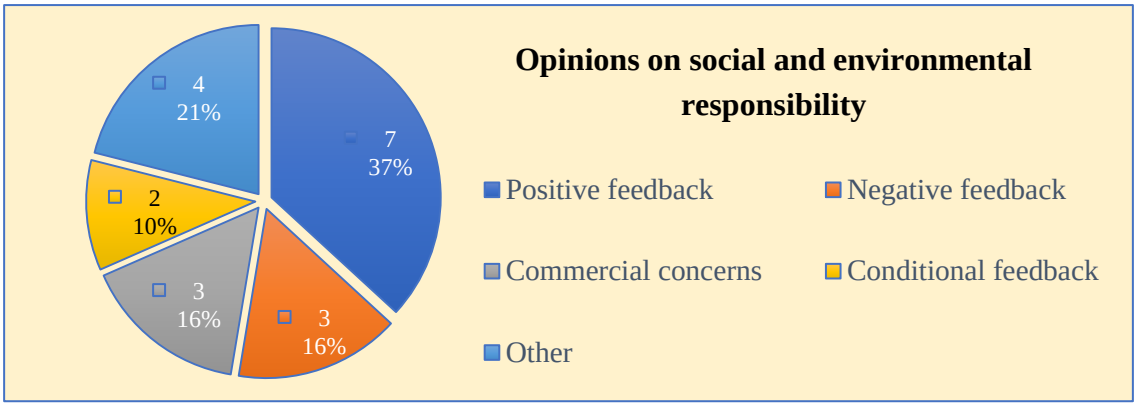

Figure 12. Q10 Responses. 'Are there any factors which stand out to you as being socially and/or environmentally responsible and/or irresponsible?'

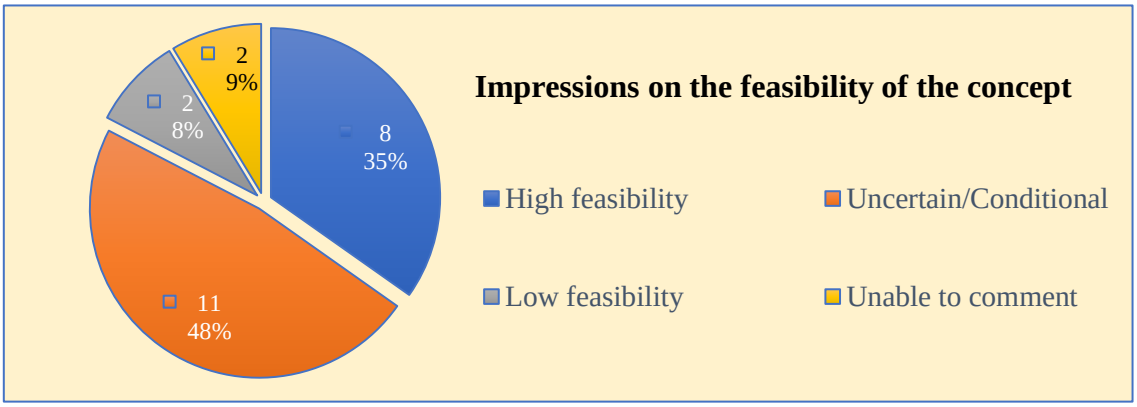

Figure 13. Q11 Responses. 'What is your impression of the feasibility of the ¡VAMOS! concept?'

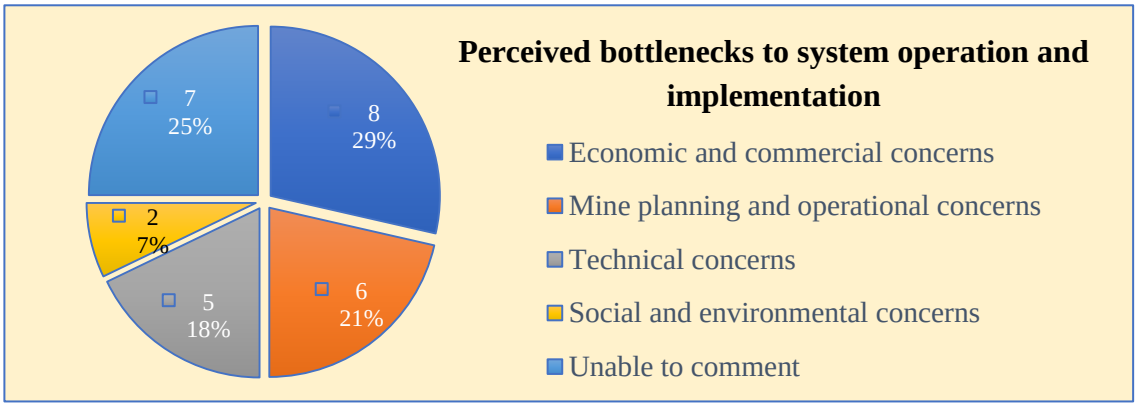

Figure 14. Q12 Responses. 'Do you perceive any bottlenecks to operation & implementation?'

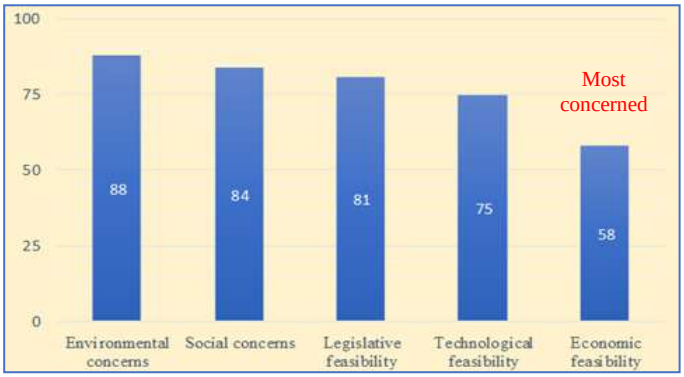

Figure 15. *Cumulative bar chart.* Q13 Responses. 'Please number the following on a scale of 'most concerned' to 'least concerned.' With 1 being 'most concerned,' and 5 being 'least concerned.''

4.5.7 Feasibility *(continued)*

Q14 Do you have any comments based upon your answers to the previous question?

13/24 responses: Eight respondents answered 'no' or 'n/a' to this question. Issues which respondents discussed further include commercial viability, environmental protection and the realistic effects of ¡VAMOS! implementation on the economy of local communities due to reduced personnel requirements compared to conventional mining methods.

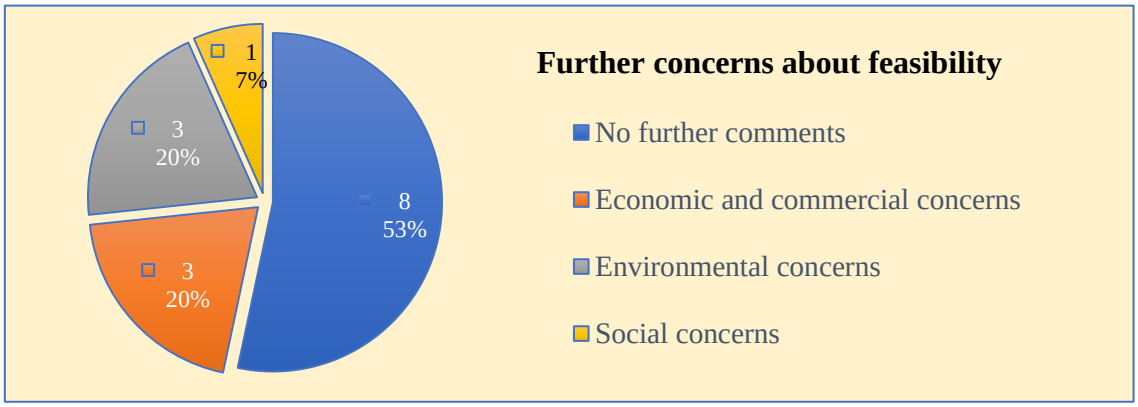

Figure 16. Q14 Responses. 'Do you have any comments based upon your answers to the previous question?'

4.5.8 Further comments

Q15 Do you have further comments about VAMOS?

13/24 responses: Seven respondents replied that they had no further comments to add, four express excitement about the project and the test results. One respondent suggests to begin considering a follow-up project and the development of a commercial strategy. Another respondent suggests involving larger mining companies to strengthen credibility.

4.5.9 Keeping in touch

There are no data presented in the next two questions. This is because of the agreement of confidentiality between the respondents and CF.

Q16 If you would like to receive updates on the progress of ¡VAMOS!, then please write your e-mail address below.

16/24 responses: 16 people have registered their interest in updates on the project. The ¡VAMOS! dissemination partners are now implementing this service in the form of email notifications/a newsletter.

Q17 If you would be interested in attending a ¡VAMOS! open day in 2018, then please write your email address below.

15/24 responses: Due to the high response rate to this question, the Consortium is now considering holding a marketing event to promote the technology.

4.6 Survey experience evaluation

A directly contacted audience of over 200 mining professionals was combined with promotional posts on LinkedIn, the ¡VAMOS! website and Twitter account. From those who were contacted and those who viewed the promotional posts on various media, 24 people have responded to the survey at the time of the writing of this report. All 24 responses were submitted through the open-access online Google Forms version rather than the Microsoft Word document which was sent to the 200 mining professionals. It was also found to be easier to entice a response from those closely related to the Consortium, and therefore this should be one of the main future target groups. To achieve a more statistically significant response, it is recommended that *all* project partners contact their close customers and partners. Future research may also benefit from being promoted at various upcoming events which partners may attend such as Mines and Technology, at which CF are presenting ¡VAMOS! in a keynote presentation on mining automation. Whilst the proportion of respondents is low, valuable data were retrieved. To gather more data and monitor the growing awareness of the project, the current survey will remain available and continue to feature on the ¡VAMOS! website.

4.7 Further research

Further to the results of this research, and as discussed at the work package meetings at INESC TEC in Porto in March 2017, it is proposed that a further market survey is conducted after the first test, in Devon in September 2017. This research will be conducted using the experience learned from this survey. The gathered data will then be analysed as part of the road-mapping exercise in D6.6.

5 Recommendations

5.1 SWOT analysis

The results from the market survey have provided data which the Consortium can use to identify areas to invest and promote innovation. Figure 17 presents a SWOT (strengths, weaknesses, opportunities, threats) analysis and recommendations aimed at project partners and the European Commission. The analysis is founded in the data from the market acceptance survey.

Figure 17. Strengths, weaknesses, opportunities and threats derived from market research.

5.2 Partner recommendations

Based on the assessment of the survey responses and the SWOT analysis results, several actions can be recommended to specific project parties. These recommendations aim to maximise the innovation potential of ¡VAMOS! even after the EC-funded period ends. It is emphasised that:

1. Recommendations are to be interpreted as non-binding suggestions only, noting that certain items refer to the period after the EC-funded period is over;
2. Recommendations leading to the development of the innovation potential of ¡VAMOS! are connected to the output of the research road-mapping exercise (D6.6.) This will define specific short, medium and long term R&D actions for ¡VAMOS! and its individual components.;
3. Exploitation planning (D6.4) and research road-mapping will consider further the actions related to enhancement of the components and sub-systems identified in this report;
4. Recommendations are intended to kick-start the discussions before the forthcoming technology exploitation and road-mapping workshops in January 2018.
5. As the project continues and pilot demonstration data becomes available after the first test in September 2017, further innovation items will likely be identified. New economic and technological data will be discussed in the exploitation plan and the research roadmap

Table 2. Party-specific recommendations to further innovation of the system and concept

Identifier	Category	Recommendation	Partners
1	Commercial	Form a market-based initiative (joint venture or similar) and continue to develop and improve innovative system features.	**BMT**, PMT
2	Commercial	Develop and offer innovative financing schemes for future buyers, such as system rental or system rental plus machine servicing solutions.	**BMT**, PMT
3	Dissemination	Create a sub-section on the website showcasing differences between the technological innovations of ¡VAMOS! and conventional dredging.	**Damen**, CF
4	Dissemination	Publish journal articles concerning productivity and economic viability using actual data from the field tests, highlighting the economic feasibility of the ¡VAMOS! solution.	**CF**, MUL
5	Dissemination	Step up social media and internet coverage of the primary field test results supported by multimedia recorded on site.	**Damen**, CF
6	Dissemination	Organise an international networking event in Brussels on the potential effects of ¡VAMOS! on the EU minerals trade balance and supply security brought by enabling access to mineral resources that cannot be exploited economically by any other technology.	**European Commission**, CF
7	Dissemination	Organise a dissemination activity directly targeting potential customers and collaboration with mining companies, showcasing the viability of the concept.	**Damen**
8	Dissemination	Conduct an extended follow-up market acceptance survey after the first field trial, engaging with new stakeholders and reflecting on previous concerns on economic/technical feasibility.	**CF**
9	Analysis	Account for the waste handling challenges in D6.1 economic calculations and predictions.	**MUL**, SMD
10	Technology	Design a range of renewable energy power solutions and schemes for off-the grid deployment of ¡VAMOS!. Develop corresponding marketing and communication strategies.	**TC**, PMT

11	Technology	Extend system scope and design to access mineral deposits in other flooded environments such as underground mines.	**SMD**, Damen, INESC TEC
12	Technology	Develop concepts for an underwater blast rig to the system.	**SMD**
13	Technology	Develop auxiliary drilling and coring capabilities.	**SMD**
14	Technology	Develop *in situ* mineral sampling apparatus for the MV.	**INESC TEC**
15	Technology	Create a system where multiple machines operate together.	**SMD**, INESC TEC
16	Technology	Design (with others) innovative mineral processing facilities onshore tailored to the deposits likely to be targeted by ¡VAMOS!.	**TC**, PMT
17	Technology	Further enhance system automation for deployment in regions where human supervision is difficult to accommodate.	**INESC TEC**, SMD, Damen
18	Technology	Include waste handling system in prototype design.	**SMD**, Damen
19	New project	Create an industry-scale pilot demonstration project with time and budget sufficient to conduct a detailed environmental impact assessment.	**European Commission**, PMT
20	New project	Create a project to capitalise on global commercial opportunities, possibly implemented as a networking initiative with overseas partners.	**European Commission**, PMT
21	New project	Create a follow-up project which implements technical innovations discovered during market acceptance and future research road-mapping.	**European Commission**, PMT

5.3 Consortium recommendations

The following strategic recommendations can be advised at a Consortium level:

1. Continue the management and enhancement of internal opportunities after the closure of this task and the submission of the deliverable. Maximising access to partner expertise and identifying unforeseen potentials for cooperation within the Consortium could be maintained by regular physical and online meetings;
2. Continue screening for external opportunities, such as the identification of stakeholder requirements for any desirable adaptation of the ¡VAMOS! technology and its individual components for new technology scenarios that were not foreseen in the original work programme. A follow-up market acceptance survey implemented after the first pilot should help facilitate this objective;
3. Continue increasing the visibility and networking around ¡VAMOS! innovations so that internal and external contributors with different skills and knowledge can help to further innovate the best ideas. This goal could be best supported by attending relevant networking events such as the EIT Raw Materials Week;
4. Monitor upcoming Calls for Proposals, financial instruments and EU funds suitable for continuation or co-financing of ¡VAMOS! and/or its individual components. This will result in the continued development of ¡VAMOS! either as a follow-up project or as sub-projects for individual components.

5.4 Recommendations summary

The project has now almost concluded its design and build phase and site testing is to commence in September 2017. Outcomes from the testing and evaluation can have substantial influence the subsequent implementation of the innovation agenda and could also have an impact on the scope and outcomes of the road-mapping activity. Accordingly, there is a need for the continued integration of the innovation process with other project tasks such as internal and external communication and formal dissemination and reporting. Through activities in other related deliverables such as D6.3 Environmental Impact Analysis and D6.6 Future Research Roadmap, the Consortium is working to create a plan to boost its output of innovative products, components and services, and to develop an innovative business model for subsequent commercial exploitation defined in D6.4 Technology Exploitation Plan. Altogether, these interactions are expected to lead to the appraisal of new methods, products and services that were not foreseen in the work plan. The outcome of these interactions will, in turn, provide a longer-term beneficial impact on research, development and innovation of ¡VAMOS! system components after the EC-funded period.

The project partners are asked to take the recommendations in this chapter under advisement during the elaboration of the project's commercialisation strategy. Stakeholders and end-users have made clear several technological enhancements and novel ideas which they would like to have implemented as part of a future commercial system. To implement these suggestions and likewise continue to develop the concept, new projects ought to be considered which focus on (1) *technological enhancement*, (2) *thorough environmental performance analysis* (which requires a longer timeframe than the project allows), and (3) *European dissemination, promotion and implementation*. In addition to this, the dissemination plan should be updated to address concerns which were given by respondents and a follow-up market survey ought to be conducted after the first field trial has concluded and there are results to present to the target audience.

6 Conclusion

D1.2 Innovation Agenda identified the innovation targets for ¡VAMOS! and formulated an overall strategy for maximising value creation until the end of the project and after the EC-funded period. This sub-task has interacted with several horizontal and thematic tasks and has required a WP1 presence at all project-wide meetings and workshops. The market research and stakeholder workshops generated valuable additional insights and suggestions from within the project's stakeholder community that include future clients and buyers. The aim has been to create a baseline understanding of the project's novelty and innovation potential which can be used as input for the subsequent road-mapping exercise in WP6.

These targets were based on the initial concept of an innovative system for inland underwater mining that could reduce the environmental, economic and social constraints that hinder mining operations in Europe. To create innovative solutions to the challenges outlined in the Grant Agreement, partners have cooperated internally and with other partner organisations. As well as regular informal collaboration between co-working partners, this approach has been made possible by routinely scheduled interaction at Technical Meetings, Advisory Board reviews, and Partners' Forum meetings. The consortium intends to fine-tune the initial approach and consider a longer-term innovation strategy in terms of hardware, software and other features as the first test results become available towards the end of 2017. This collaboration will continue until the end of the project, and partners will continue to work together and meet at scheduled intervals to discuss solutions to technical and commercial challenges.

7 References

[1] European Commission. *Research & Innovation Glossary*. [Online]. page I. 'Innovation'. Available at: http://ec.europa.eu/research/participants/portal/desktop/en/support/reference_terms.html. Accessed 18 July 2017.

[2] British Library. *Defining a new product development process*. [Online]. Available at https://www.bl.uk/business-and-ip-centre/articles/how-to-define-a-new-product-development-process. Accessed 18 July 2017.

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[4] Appio, F.P., Achiche, S., McAloone, T.C. & Di Minin, A.. 2011. Understanding Managers Decision Making Process for Tools Selection in the Core Front End of Innovation. Proceedings of the 18th International Conference on Engineering Design: Impacting Society through Engineering Design. **10** Design Methods and Tools. Design Society. pp. 102-113.

[5] Hauser, J.R., Dahan, E.. 2008. *New Product Development in Marketing Management: Essential Marketing Knowledge and Practice*. McGraw Hill, Inc.. Columbus, Ohio.

8 Appendices

Appendix A

Full survey data is found in Appendix B, and is found also in its original format on the ¡VAMOS! Sharepoint. Access to respondents' personal details, including those on the mining professionals database, is unavailable due to an agreement of confidentiality. Responses to the other survey questions were agreed to be shared under the survey disclaimer.

'Disclaimer: By completing the online or Word document survey, you agree to the following: The responses to the questions within this survey will help to direct the development of the ¡VAMOS! project and better plan its future strategy to bring the best possible solution to market. Your responses to the questions within this document will likely be anonymously (unless mutually agreed) disseminated to the ¡VAMOS! consortium, used within our official reports to the European Commission, and perhaps published in our press releases.'

Figure 18. Survey disclaimer

Appendix B

The following tables display the responses to all the open-answer survey responses. These are grouped per their subject. Individual responses which address more than one subject are shown in all their relevant subject categories, with the irrelevant information coloured light grey.

Table 3. Categorised responses to Q4, 'What would be crucial for you to know to make an informed decision on advocating/using VAMOS?'

Technical information
• The effectiveness of the machine in hard rock. • Economic viability in hard rock environment • The elevation of the water table. The possibility of silt building up. Hardness of the rock. • How is the stability of the excavated pit ensured under water? The cutting machine is only part of the problem. Slope/wall stability will be crucial. How deep could be the excavation? Could the system work under overhangs? • How [will it work] in muddy water • Price, cost-efficiency, transportability, volatility • Economic and technical feasibility based on real examples. • Results of the performance test and plume impact measurements • Production rates, operating costs. • Involvement of ground water protection authorities, how will you prevent / minimize contamination of aquifers, how will you reduce size of mineral orebodies rocks and particles to produce slurries, what sizes of operations will be candidates
Economic and commercial information
• Scalability and economic viability • Economic viability in hard rock environment • Price, cost-efficiency, transportability, volatility • [Economic feasibility] • Economic and technical feasibility based on real examples. • Production rates, operating costs. • Clear demarcation for the client of who is supplying what part of the system? Or there has to be a one stop shop interface for the user. i.e. Set up a startup company. • Involvement of ground water protection authorities, how will you prevent / minimize contamination of aquifers, how will you reduce size of mineral orebodies rocks and particles to produce slurries, what sizes of operations will be candidates • More detail about how it works, what differentiates VAMOS with a conventional dredge? What are the expected mining rates? small scale? medium scale? large scale. Generally insufficient information contained in the brochure to spark much interest
Situational suitability
• A survey of sites that this solution suits. At present, the VAMOS system will not work in a marine environment and most old mining pits that have been checked have got serious geometric and resource problems and I don't think the whole set up is fit for purpose. • Overall mining attractiveness of the site where I am considering to use it, efficiency and rentability • A rigorous life cycle analysis • Involvement of ground water protection authorities, how will you prevent / minimize contamination of aquifers, how will you reduce size of mineral orebodies rocks and particles to produce slurries, what sizes of operations will be candidates • How is the stability of the excavated pit ensured under water? The cutting machine is only part of the problem. Slope/wall stability will be crucial. How deep could be the excavation? Could the system work under overhangs?

Product uniqueness
• More detail about how it works, what differentiates VAMOS with a conventional dredge? What are the expected mining rates? small scale? medium scale? large scale. Generally insufficient information contained in the brochure to spark much interest • What are the differences between VAMOS and the other existent systems for underwater exploitation of minerals • Examples [are] lacking. [They do not need] to be a real [ones] either. Make up [something] which is close to reality.
Environmental effects
• [The results from an environmental impact] assessment • Involvement of ground water protection authorities, how will you prevent / minimize contamination of aquifers, how will you reduce size of mineral orebodies rocks and particles to produce slurries, what sizes of operations will be candidates • What risk / What difference would that make for social - environmental impact compared to previous mines that are now flooded? • The elevation of the water table. The possibility of silt building up. Hardness of the rock.

Table 4. Categorised responses to Q5, 'Which components need to be developed further for ¡VAMOS! to be more appealing from your perspective?'

Excavation and processing system
• The cutting system has limitations in terms of rock strength and ease and effectiveness of operation, material gathering system may prove not to be effective enough (spillage, handling of larger size material,) limitations in mining selectivity. • An underwater blast hole rig • Mixture handling/preprocessing on shore • Fleet operation of several units, large-scale operation scenarios • Further transition to machines fueled by renewable energies • Subsea imaging; Excavating to depth (2 meters say) in a trench, with side restraint to the excavation. Concerned about the delays that will be caused when the machine throws a track - lots of time will be spent rescuing it, unless it can be made to repair itself! • Locomotion in non-flat ground; cutting tools
PNA and robotics equipment
• Real-time grade [control] • Camera technology • Autonomy and robotic systems • Subsea imaging; Excavating to depth (2 meters say) in a trench, with side restraint to the excavation. Concerned about the delays that will be caused when the machine throws a track - lots of time will be spent rescuing it, unless it can be made to repair itself!
Economic and commercial proof
• Production rates and operating costs. • Environmental protection, cost analysis compared to conventional mining • At the moment, it is not clear what production rate can be achieved and whether a number of extraction units can be deployed at one pit.
Public relations and promotion strategy
• Technology development and who is doing it. • Public relations - website updates are too infrequent. • Solid test case to show proof of concept
Social and environmental factors
• How is the possible contamination of the open-pit water and any groundwater flowing through the pit controlled? • Environmental protection, cost analysis compared to conventional mining • Social [and environmental] acceptance

No comments
• None for now • Unable to answer • Not able to answer

Table 5. Categorised responses to Q6, 'Are there any additional functions which you would like the system to provide?'

Grade control and mineral sampling functions
• A fully developed real-time grade control system • Sampling system to determine metal grades • Real-time mineral analysis to allow for selective exploitation • How are the mineable areas detected under water? • Perfect navigation and positioning system, possibilities for geological exploration (e.g. sampling, geophysical methods, core drilling?) • Not sure, but if ongoing exploration option (core drilling and recovery) is not a part of the machine, this could be introduced. • Drilling
Excavation system functions
• Downstream processing, relocation of the dredge • [...] a range of [cutter-heads] and tools for different rock conditions • An underwater blast hole rig • Perfect navigation and positioning system, possibilities for geological exploration (e.g. sampling, geophysical methods, core drilling?)
Additional operational environments
• Extended umbilical systems so that the excavator can be controlled from shore. If the system could be made seaworthy, then it would be exciting. • Urban mining • How does VAMOS work for abandoned underground mines?
Processing functions
• Extended umbilical systems so that the excavator can be controlled from shore. If the system could be made seaworthy, then it would be exciting. • Downstream processing, relocation of the dredge • Mixture handling/preprocessing onshore
Environmental monitoring functions
• [Monitoring] the environment while extracting minerals. • Water quality data [and] monitoring the operation [in] real-time
Other
• We will [see] after the first [tests]

Table 6. Responses to Q8, 'In order of decreasing importance, what are the three most important economic variables influencing your impression of VAMOS?'

CAPEX, OPEX and efficiency
• Cost efficiency • Cost of operation, productivity, renting cost • [Breakeven] point of operation, net amount of product recovered, projected financial advantage over reopening mine using traditional methods • Productivity, CAPEX, OPEX • Cost competitiveness, can all aspects of mining operation be covered by VAMOS, environmental impact

Cost and system operational limits
• Process automation; [RoI]; Easy to operate • Proven technique, cost, final processing scheme • Energy consumption, spares, availability • Scale of operation (tonnage), [OPEX] and [CAPEX].
Metals markets and environmental implications
• Raw material prices, access of raw materials in populated areas, less waste production • Market value of currently unrecoverable reserves, environmental issues concerning expansion of existing mines, safety • Metal market, environmental impact and regulations
CAPEX, OPEX and metals markets
• Ore price, OPEX of mine, remaining reserves • Ownership and OPEX costs, the price of the ore, restoration costs.
Additional operational environments
• Making the product seaworthy. Being able to measure the content of the excavated material using some sort of sensing device that works in front of the line of digging. i.e. How much % of gold or tin or whatever is in the resource. This could do away with the need to carry out an extensive and expensive pre-drilling programme. • Possibility of exploit old underexploited submerged deposits
Unable to answer
• [Too] early to say • N/a • Not able to answer

Table 7. Responses to Q10, 'Are there any factors which stand out to you as being socially and/or environmentally responsible and/or irresponsible?'

Positive social and environmental feedback
• Not as noisy as shovel and dump truck. • Social - potentially assisting economy of areas below poverty line that once relied on mines for income • The surface foot-print is likely to be relatively small and unobtrusive. • Focus on old (abandoned) mine site means mostly isolated areas, less populated and often polluted. New activities can generate work and clean-up of the area. • Energy efficient, no dust, remote controlled: safe • Environmental - the ability to mine without the upheaval of water pumping and removing non-essential materials to maintain stripping ratio. • There will be no dust.
Negative social and environmental feedback
• There is a possibility that the water will become contaminated with oil. It could contaminate the local drinking water. • [Effect] on quality of waters, mining waste management. • I only see a shift in environmental concerns compare to actual open-pit mining.
Economics concerns
• Exponential growth in mining exploitation is impossible • At present, it doesn't seem to adequately serve a purpose that will be economic. • [At present], the entire idea [seems] to be based on social and environmental advantages rather that economics.
Conditional feedback
• The quantity of sensor to monitor the process; Don't take harsh water out and use remote vehicles • There will be tailings dams.

Other
• Electric-powered system • Energy consumption • No • No

Table 8. Responses to Q11, 'What is your general impression of the feasibility of the ¡VAMOS! concept?'

High feasibility
• Reasonable good chance to work in ore bodies with soft to medium hard ground, concerns for hard rock in terms of productivity and excavation cost. (target market?), handling of waste - high energy levels to crush it down for hydraulic transport • I cannot think of any reason why it will not work. • Feasible • It is feasible • An exciting concept with huge potential. • Very good. It seems a little crazy, [however] it [could] be a great tool for the future • It´s [a] very innovative project with a good perspective for the future • Good initiative, in general terms
Conditional feasibility
• I gather it depends on the deployment depth and how in-pit repairs/maintenance can be organised. • OK for clear water • Worth investigating further • I'm bit sceptical[.] [It would] be good to see the evaluation of field demos • Not sure, before real testing is done. • Knowing the mining world, it will be hard to compete with conventional methods on a large scale. • Might be interesting to deploy the technology for seabed mining at certain attractive deposits, if applicable. • Medium feasibility as it depends on the existence of underwater underexploited economic deposits • Technically: yes, economically: maybe, commercially: depending on the perseverance of the seller. • If the technology will be accepted and spread in mining, [then] it can be economic. • Seems relatively [feasible at a] small scale, unclear how VAMOS will differentiate itself from a dredge
Low feasibility
• At present, there is not a market for the product. • Not convinced
Unable to comment
• Need more info • Difficult to say

Table 9. Categorised responses to Q12, 'Do you perceive any specific bottlenecks to the operation and implementation of VAMOS?'

Economics and commercial concerns
• Cost • Cost efficiency • Commercial. • The above mentioned *(this refers to 'the existence of underwater unexploited mineral deposits')* and the economic performance of the method. • Costs and available operating hours • [Primarily] productivity • Willingness of active miners to look at new opportunities • Will there be a supplier that can mobilize a sales force to work the market?

Mine planning and operational concerns
• If tailings dams must be built, then that could become an issue. • Deposits with highly variable ground conditions may not be suitable. • [Is there] enough geotechnical information available to do mine planning? • [There needs to be a] plan B for material which cannot be economically mined with VAMOS plus attached auxiliary breaking system. • Difficult operations in old mines [:] machinery [could get] stuck, tangled in obstacles [or trapped underneath] underwater rockfalls etc. • Costs and available operating hours
Technical concerns
• The LARV is an inadequate method of launching the vehicle in terms of the fact that the market is just not there for it. • If the LARV could be seaworthy then that would [open] possibilities. • [Grade control] • The effective separation of waste and ore • [Waste] dumping procedure.
Social and environmental concerns
• Social and environmental • Environmental permitting may remain an issue, particularly as this is a novel technique with little precedence. Successful demonstrations will be important. Regulators may be also unsure of how to handle this.
Unable to comment at this stage
• Unsure • [Unable] to answer • Stated above • Not yet • In need of pilot examples • All eyes [are on] the outcome of the trials • [It] is very case [dependent]

Table 10. Responses to Q14, 'Do you have any comments based upon your answers to the previous question?'

No comments
• No *(7 responses)* • N/a
Economics and commercial concerns
• The problem is that economic growth based in exponential consumption is impossible • All aspects should work perfectly, the only question mark for me is whether the operation can be run economically. • Commercial feasibility
Environmental concerns
• Must be environmental safe. • Dust and noise are the main issues with open pit mining, these will be considerably reduced. • Tailings dam could be the main issue.
Social concerns
• There probably will not be as many people employed on the mine so it will not be a great a benefit to the local economy.

Table 11. Responses to Q15, 'Do you have further comments about VAMOS?'

No comments
• No *(6 responses)* • N/a
Positive response
• Could be a great project. • Anyway, it's an interesting project. • [I'd] like to see it work • It's another tool for the mining engineer.
What comes next...
• It is time to think about a follow up project and strategy. • Involvement of large mining companies would strengthen credibility.

Appendix C

Table 12. Breakdown of responses into categories for questions on which categorisation was used in the analysis. Integers represent the number of times an issue was raised and do not sum to give the total number of responses.

Question 4 'What would be crucial for you to know before making a decision on using/advocating VAMOS?'				
Technical information	*Economic and commercial information*	*Situational suitability*	*Product uniqueness*	*Environmental effects*
10	9	5	3	4

Question 5 'Which components need to be developed further for ¡VAMOS! to be more appealing from your perspective?					
Excavation and processing system	*PNA and robotics equipment*	*Economic and commercial proof*	*PR and promotional information*	*Social and environmental factors*	*No comments*
7	4	3	3	3	3

Question 6 'Are there any additional functions you would like the system to provide?'					
Grade control and mineral sampling functions	*Excavation system functions*	*Additional operational environments*	*Processing functions*	*Environmental monitoring functions*	*Other*
7	4	3	3	2	1

Question 8 'In order of decreasing importance, what are the three most important economic variables influencing your impression of VAMOS?'					
CAPEX, OPEX and efficiency	*Cost and system operational limits*	*Metals markets and environmental implications*	*CAPEX, OPEX and metals markets*	*Additional operational environments*	*Unable to answer*
5	4	3	2	2	3

Question 10 'Are there any factors which stand out to you as being socially and/or environmentally responsible and/or irresponsible?'				
Positive social and environmental feedback	*Negative social and environmental feedback*	*Economics concerns*	*Conditional feedback*	*Other*
7	3	3	2	4

Question 11 'What is your general impression of the feasibility of the VAMOS concept?'			
High feasibility	*Conditional feasibility*	*Low feasibility*	*Unable to comment*
8	11	2	2

Question 12 'Do you perceive any specific bottlenecks to the operation and implementation of VAMOS?'				
Economics and commercial concerns	*Mine planning and operational concerns*	*Technical concerns*	*Social and environmental concerns*	*Unable to comment*
8	6	5	2	7

Question 14 'Do you have any comments based upon your answers in the previous question?'			
No comments	*Economics and commercial concerns*	*Environmental concerns*	*Social concerns*
8	3	3	1

Question 15 'Do you have further comments?'		
No comments	*Positive response*	*What comes next...*
7	4	2

Appendix D

Table 13. Recommendations reference data

Identifier	Recommendation	*Primary* Reference Question
1	Form a market-based initiative (joint venture or similar) and continue to develop and improve innovative system features.	Q3
2	Develop and offer innovative financing schemes for future buyers, such as system rental or system rental plus machine servicing solutions.	Q7
3	Create a sub-section on the website showcasing differences between the technological innovations of ¡VAMOS! and conventional dredging.	Q4
4	Publish journal articles concerning productivity and economic viability using actual data from the field tests, highlighting the economic feasibility of the ¡VAMOS! solution.	Q4
5	Step up social media and internet coverage of the primary field test results supported by multimedia recorded on site.	Q9
6	Organise an international networking event in Brussels on the potential effects of ¡VAMOS! on the EU minerals trade balance and supply security brought by enabling access to mineral resources that cannot be exploited economically by any other technology.	Q17
7	Organise a dissemination activity directly targeting potential customers and collaboration with mining companies, showcasing the viability of the concept.	Q17
8	Conduct an extended follow-up market acceptance survey after the first field trial, engaging with new stakeholders and reflecting on previous concerns on economic/technical feasibility.	Non-specific
9	Account for the waste handling challenges in D6.1 economic calculations and predictions.	Q11
10	Design a range of renewable energy power solutions and schemes for off-the grid deployment of ¡VAMOS!. Develop corresponding marketing and communication strategies.	Q5
11	Extend system scope and design to access mineral deposits in other flooded environments such as underground mines.	Q6
12	Develop concepts for an underwater blast rig to the system.	Q5
13	Develop auxiliary drilling and coring capabilities.	Q6
14	Develop *in situ* mineral sampling apparatus for the MV.	Q6
15	Create a system where multiple machines operate together.	Q5
16	Design innovative mineral processing facilities onshore tailored to the deposits likely to be targeted by ¡VAMOS!.	Q5
17	Further enhance system automation for deployment in regions where human supervision is difficult to accommodate.	Q8
18	Include waste handling system in prototype design.	Q11
19	Create an industry-scale pilot demonstration project with time and budget sufficient to conduct a detailed environmental impact assessment.	Q4
20	Create a project to capitalise on global commercial opportunities, possibly implemented as a networking initiative with overseas partners.	Q13
21	Create a follow-up project which implements technical innovations discovered during market acceptance and future research road-mapping.	Non-specific

Appendix E

Figure 19. The Google Forms survey as viewed by potential respondents

¡VAMOS! Market Survey

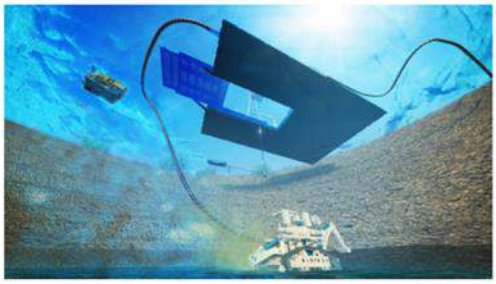
Dear Valued Respondent,

After reading our online brochure on the innovative ¡VAMOS! concept and additional information available on our website (www.vamos-project.eu), we'd be grateful if you would answer some very brief questions in this survey on your impression of the project and its goals for a more sustainable and economically viable inland mining solution.

We will collect the results from the survey in 2 weeks time and would kindly ask you to send us your thoughts before then.

Kind regards,
The ¡VAMOS! Project Consortium

The ¡VAMOS! Set-up



What is your background/area of work?

Your answer

How innovative does the ¡VAMOS! concept seem to you?

	1	2	3	4	5	6	7	8	9	10	
Less innovative	○	○	○	○	○	○	○	○	○	○	More innovative

How positive do you feel about the potential impact of the project in 30 years' time?

	1	2	3	4	5	6	7	8	9	10	
Less positive	○	○	○	○	○	○	○	○	○	○	More positive

What would be crucial for you to know to make an informed decision on advocating/using VAMOS?

Your answer

Which components need to be developed further for ¡VAMOS! to be more appealing from your perspective?

Your answer

Are there any additional functionalities which you would like the system to provide?

Your answer

If relevant, would you prefer a service + operation or machine-purchase option?

- ○ Rental service
- ○ Machine purchase
- ○ Other:

In order of decreasing importance, what are the 3 most important economic variables influencing your impression of VAMOS?

Your answer

How socially and environmentally beneficial do you perceive ¡VAMOS! to be?

	1	2	3	4	5	6	7	8	9	10	
Less beneficial	○	○	○	○	○	○	○	○	○	○	More beneficial

Are there any factors which stand out to you as being socially and/or environmentally responsible and/or irresponsible?

Your answer

What is your general impression on the feasibility of the ¡VAMOS! concept?

Your answer

Do you perceive any specific bottlenecks to the operation and implementation of VAMOS?

Your answer

Please number the following on a scale of 'most concerned' to 'least concerned'. With 1 being 'most concerned'.

	1	2	3	4	5
Economic feasibility	○	○	○	○	○
Technological feasibility	○	○	○	○	○
Legislative feasibility	○	○	○	○	○
Environmental concerns	○	○	○	○	○
Social concerns	○	○	○	○	○

Do you have any comments based upon your answers in the previous question?

Your answer

Do you have any further comments about VAMOS?

Your answer

If you would like to receive updates on the progress of ¡VAMOS!, then please write your email address below.

Your answer

If you would be interested in attending a ¡VAMOS! open-day event in 2018, then please write your email address below.

Your answer

SUBMIT

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Never submit passwords through Google Forms.