Ref. Ares(2022)7505904 - 28/10/2022

esteem3

Enabling Science through European Electron Microscopy

Deliverable D1.5 – version 1

Estimated delivery date:	31th October 2022
Actual delivery date:	31th October 2022
Lead beneficiary:	UA
Person responsible:	Jo Verbeeck
Deliverable type:	☒ R ☐ DEM ☐ DEC ☐ OTHER ☐ ETHICS ☐ ORDP
Dissemination level:	☐ PU ☐ CO ☐ EU-RES ☐ EU-CON ☐ EU-SEC

THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT NO **823717**

Grant Agreement No:	823802
Funding Instrument:	Research and Innovation Actions (RIA)
Funded under:	H2020-INFRAIA-2018-1: Integrating Activities for Advanced Communities
Starting date:	01.01.2019
Duration:	54 months

Table of contents

Revision history log

Version number	Date of release	Author	Summary of changes
V1	14/10/2022	Jo Verbeeck, Mathieu Kociak Rafal Dunin-Borkowksi	Final report
V1.01	17/10/2022	Peter van Aken	Approval
V1.02	17/10/2022	Aude Garsès	Review
V1.03	24/10/2022	Jo Verbeeck	Corrections

Introduction

A series of 10 interviews were conducted with a selection of current ESTEEM3 labs as well as a selection of similar national organizations, which offer transnational access (TA) in the period May-July 2022[1]. The results of these interviews are used as ballpark estimates of the current economics of TA provision and to evaluate future scenarios for service provision to a wide base of European researchers requiring nanoscale characterization of materials over a broad range of research directions, providing a foundation for nearly all of the grand challenge innovations that will emerge.

Estimate of the cost to provide EM services

Transmission electron microscopes are expensive both in capital cost (1-10 Mio. Eur per instrument). On average, the interviewed labs spent approximately 170kEur/y capital cost per instrument over the last 15 years but certainly also in running cost. The running costs involve:

- infrastructure (typically highly customized building with very precise air conditioning systems and chillers for cooling, electromagnetic shielding and high ceilings and entry doors). If we assume that only the adaptation costs of existing buildings is taken into account, we can estimate this to be 10% of the instrument cost at 17kEur/y per instrument.
- energy consumption. We estimate this to be 100MWh per instrument per year including the cooling infrastructure. This approximates to 10kEur/y for energy when assuming 10ct/kWh. This cost is likely going to increase significantly in the coming years.
- service costs. From the interviews, we estimate this figure to be approximately 75kEur/instrument/y.
- personnel costs: TEM equipment requires highly trained personnel (PhD level with multiple years of experience) that is relatively hard to find. From the interviews, we estimate that per instrument, established labs hire approximately 4.4 specialists to operate and interpret the data. At an approximate yearly cost of 100k€, this boils down to 440kEur/y/instrument to make efficient use of the instrument.

This brings us to approximately 712 kEur/y/instrument. If we assume the instrument to be effectively used 220 days we obtain a ballpark figure for the full cost of 1 TEM day as:

~ 3300 Eur

We note that these estimates are significantly higher than the average unit cost that is currently charged to the ESTEEM3 project for reasons they do not contain depreciation, infrastructure etc. Note that this cost does not include the building or any other overhead costs (administration, HR dept, legal dept etc.) that the institute would charge to the research groups.

This sets the scene to evaluate different models on how this cost can be covered in order to provide access to the very best TEM material characterization that is available in Europe to the European scientists that will depend on it for their developments. In the following, we will discuss a series of

[1] EMAT Antwerp Belgium (University lab), ERC Juelich Germany (National lab), MPI Stuttgart Germany (National lab), ELECMI Spain (Consortium national lab), Diamond UK (National lab), Daresburry UK (National lab), Nortem Norway (Consortium national lab), METSA France (Consortium national lab), ESTEEM3 Europe (European consortium), TU Graz Austria (University lab), Microscopy Australia (Consortium national lab).

alternative scenarios for a TEM Research Infrastructure (RI) on how this cost can be covered and we will discuss some benefits and disadvantages on a qualitative level.

Scenario 1: Service provision is entirely outsourced to commercial actors

A number of commercial players offer TEM services to industry. The best known to date is Eurofinns. They provide standardized measurement services that could potentially serve a subset of TA requests. From interactions with industry, we know that these services are considered valuable in terms of guaranteed time to result, but in terms of in-depth research into e.g. root causes of failure they lack many of the state-of-the-art techniques that are being developed, e.g. in ESTEEM3. These high-end methods give the edge in scientific research, where a deeper look into the nanoscale reality of samples gives a clear strategic benefit. These high-end investigations come, however, at the cost of being very time consuming and require continuous efforts into improving and developing novel methods while keeping a vibrant innovating workforce.

It is important to note here that TEM RIs should never be to compete with these industrial service providers, but rather to focus on the cutting edge, where new developments will drive scientific innovations, which will eventually become common and standardized methods, which can be integrated in the commercial workflow at a (much) later stage.

We see that some form of value creation takes place as well in parallel with the scientific service provision. This value could potentially cover some of the service provision costs if successful transfer to industry can be done and is correctly valued by that industry.

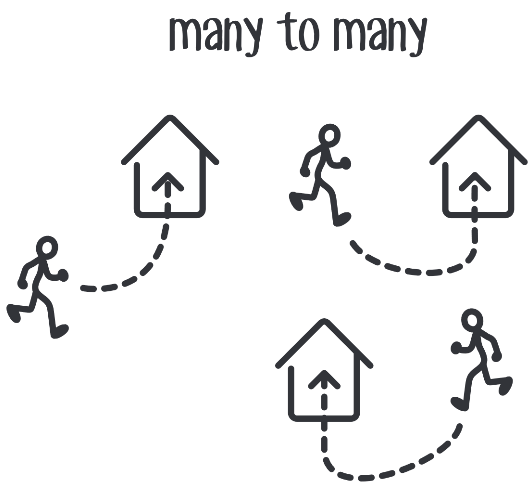
Note also that all companies that thrive in electron microscopy (and some thrive really well) are entirely dependent on universities and research groups to deliver the highly-trained personnel, which takes with them a significant amount of know-how and innovation ideas that will flourish in later commercial products. This does not have to be a problem and may even be seen as the main raison d'être of Universities, but in terms of sustainability this puts all the burden with the national funded institutes, while the commercial benefits are all obtained with the commercial actors. As long as member states see the benefit of job creation and economic growth and they correctly link this growth to the innovation driver that science driven research is, there is no problem. The current situation throughout Europe is, however, shifting towards saving on scientific budgets, especially those for structural and long running investments in favor of ever shorter project cycles with ever more administrative burden.

Scenario 2: National funding needs to cover all expenses

In this scenario, all costs are covered by national funding and the national funding agencies or the research labs could decide to organize an open access policy for national/European or international researchers. This could work (and this is how it always worked until the EU came into existence) but leaves huge differences between willingness to spend on science between countries. As an example, Germany has a long tradition of actively funding national research institutes (2 of which are ESTEEM3 members).

The downside of this funding scenario could be that quality of the service provision (hand in hand with investments and quality of the equipment and availability of support staff) can vary wildly and that access to this infrastructure could depend on personal networks and preferences. The danger exists that power games and little empires come into existence, which are in our opinion not in the benefit of serving the wider European research community towards excellence.

Another risk is that funds get used in places where there is already a lot of equipment and the added value is sub-optimal, or that for political reasons, money gets invested in subcritical research groups, which cannot provide the required scale and pool of know-how to create sufficient return on investment.



Scenario 3: The TA user pays from project funding

A totally different scenario could be that the TA users will pay the actual costs from their funded scientific projects. This would mean they need to set aside a part of their budget for characterization of the materials. Typically it is hard to know upfront how much of such characterization will be needed and how difficult and time consuming it will turn out to be.

The benefit of this scenario that is not uncommon e.g. in the US is that users of the service will have a good feeling of the actual cost of such measurements and will avoid squandering the resources on less well thought out experiments.

The downside is that projects, which are in a very early pre-funding stage, would have to miss out completely on the ability to characterize their materials. One could argue that it is exactly these early-stage innovations that the EU should try to capture and nourish, as one of them could lead to the urgently needed breakthroughs in the different grand challenges that Europe and the world are facing.

Another downside of this scenario is the complicated billing procedure. Each applicant will then have to send out purchase orders and get billed by the different institutes (or a centralized institute) significantly increasing the administrative burden and likely adding VAT and several overhead layers, which will eat away the budget.

Scenario 4: A joint centralized European service provision is funded by EU

An entirely different sustainable plan would be to build a centralized European RI for transmission electron microscopy, e.g. located in one of the member states, comparable to e.g. some of the synchrotron facilities.

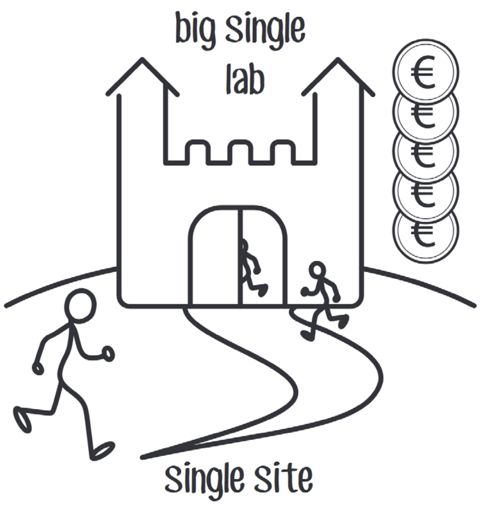
This has the benefit that all instrumentation is maintained in one place and some economy of scale could occur. Also, the know-how and knowledge transfer could be optimized with a very large body of highly-trained specialists on-site that can all learn from each other.

For TA visitors this could have the benefit of centralized travel (on many synchrotron sites there is even dedicated accommodation) and centralized and unified administration and reporting. It could even be considered to place such an institute near existing synchrotron facilities to further increase the scale of organization.

One could argue that although economy of scale is certainly beneficial up to a certain level, it can also create a very large and slow corporate culture, with many layers of decision-making. In terms of costs, it would create a European science institution that will likely cost several orders of magnitude more than what the EU is currently investing in TEM.

It is also unlikely that member states will be enthusiastic when the chosen site is geographically distant from the member state and they miss all the (indirect) job creation such a large site could bring.

This scenario would definitely go against the current trend of 'lean' and 'agile' businesses and we could argue that this is a key strength of current TEM operation (multiple reasonably affordable instruments serving many scientists in parallel with a non-centralized decision center) allowing it to much more rapidly respond to new demands and innovations. In this respect, the time to accept and execute experiments in TEM can be much shorter than is possible in larger infrastructures.



Scenario 5: A joint distributed European service provision is funded by EU

In this scenario, the labs remain decentralized but the service provision is arranged and distributed by a single portal. This portal has the benefit that a unified TA request and evaluation process is in place, that all interactions, including the reporting, which is unified resulting in better overall quality of service. This is also how ESTEEM3 is currently working.

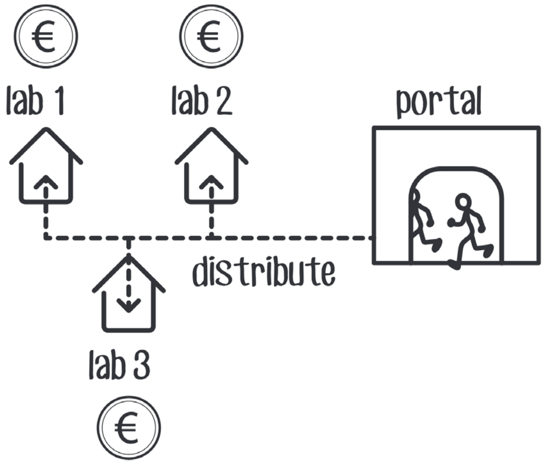
The consortium profits from interacting on method development, staff training, staff exchange and exchange of best practices, all of which result in better TA provision for the users.

A challenge in this scenario is the funding and the distribution of this funding to the different labs forming the infrastructure.

First of all, sustained funding is needed to create continuity in the TA offering. The labs providing TA access should ideally be allowed to organically change over time as new instrumentation or methods may become available in new sites. In this sense, an allocation plan that is revised every say 2 or 3 years could allow for this flexibility and would allow to fund TA providers based on a proven track record. The TA portal organization would then have the duty to evaluate the performance of the different joint TA providers and to decide on a new budget allocation for the next period.

This portal could be a legal entity on its own, representing the total EU TEM community as a whole with each TEM lab being a member. It is likely that this portal vehicle could remain light in terms of employed staff as many of the functions could be taken up by volunteering scientists that are on the payroll of individual institutes (which is a common setup in all scientific society activities and peer reviewing).

A challenge is, however, the redistribution of budgets and the potential risk that in the internal billing process, overhead is added.



Alternative funding

In all discussed scenarios, funding comes from the EU (or national) either directly or indirectly (if e.g. the TA users pay from their projects). There seems to be an understandable concern within the EU with respect to perpetual funding, but it is important to remember that the services the TEM RI offers here are essential for any kind of innovation that relies on creating or understanding new materials at the nanoscale. The capabilities of TEM RI are not easily replicated and a form of pooling is natural to share the high capital and personal investments that are needed. Pooling implies that someone should take care that the pool is kept sufficiently funded to get access to the state-of-the-art capabilities TEM can offer and to make sure that the pool of available characterization techniques keeps innovating and expanding.

Doing this on the national level has worked but leads to heavily fluctuating quality of service throughout Europe and many sub-optimal investments in equipment, which is not used to its fullest capacity.

We contemplated different methods of paying for the costs, such as membership fees, pay per service, paid training and accreditation programs, lucrative conference organization, but all of these eventually are still based on EU or national funded science programs, but now through a very indirect and inefficient route.

Obtaining part of the funding through service for industry is another possibility and this is actively being tried at the moment. We observe, however, that partners are very reluctant to route these requests through a common portal. The reasons for this are primarily the wish of industrial partners to work under strict confidentiality schemes and preferably with as few people involved as possible.

Creating value through innovation is another possibility, and many efforts are taking place. The values of doing this through a portal are less clear as a specific innovation typically involves only one or a few partners directly and contracts, patents and general IP agreements would become overly complicated and slow if they involve multiple legal entities and the company interested in the innovation. One way out of this would be to agree that all funded innovation is put in the open source, giving equal rights to all companies in the world to include it in their products. This would probably increase the innovation rate, but could have unwanted international side effects with business shifting out of Europe because of cost. Even if this would work, this system would still rely on sustained funding to fuel the innovation-driven industry in Europe.

Conclusion

From the above discussion, it is clear that TEM is an enabling technology that is at the base of many future innovations. As such, it requires sustained funding much in the same way that roads are needed for driving even though reluctance exists to pay for making or maintaining them. In this sense, we believe there should be structural sustained infrastructure[2] funding for TEM and we argue that the investment cost will be lowest if we opt for a distributed and open facility. Compared to other large Research Infrastructures, we are confident that the output per invested euro is extremely favorable and the distributed structure would allow for a very agile and adaptive offering, which can closely and rapidly follow the needs that arise in new materials characterization.

Within ESTEEM3, we are currently progressing on setting up an AISBL legal entity within a new consortium under the name of eDREAM [https://e-dream-eu.org/]. This endeavour is however more challenging than expected because of the legal and financial consequences this could have for the parties involved. The goal of this effort is that this entity will become the portal organization and that it is open for all EU TEM labs to become members and can offer their capabilities as TA to all users that require this in Europe (scenario 5). Provided adequate funding is secured, this would organize the sustainable pool of expertise and instrumentation, and make sure the best possible sharing of good practices and skills is obtained. It would form a fertile innovation ground for growth, both in characterization technology as well as in its application to novel materials. From the above discussion, it is however clear that this organization could not hope to operate without this adequate funding unless we bill the TA clients for the actual cost (scenario 3), which eventually also boils down to government funding, but would put an aspect of friction on the very important first steps of blue sky research.

The arguments presented here, resonate with the impressions obtained during the ICRI 2022 event where a side event session on "sustainability of distributed RI's-funding models and operational

[2] Structural in the sense that it identifies the need for these services and provides a means to apply for funding to build and maintain the infrastructure. Sustained is referring to long term investment that would allow to set out a future direction and allow to maintain knowledgeable experts on a time scale that reflects this. This means project durations counted in decades rather than reapplications and uncertainty on e.g. few year timescale which allows only short term commitments and decisions that lack long term directions and vision.

solutions" was organised. Multiple participants representing RI's at different maturity levels of legal organisation (consortium, AISBL, ERIC) commented all on similar struggles, but none had a viable plan for sustainability without substantial structural and long term funding by EU. All aspects presented in this deliverable are generically applicable to other RI's as well as they all suffer to keep a highly skilled research workforce without being able to give any long term prospects and with specialist and expensive instrumentation base that needs to be kept at the state of the art.

One participant in the event even phrased it as such "If a believable business model could be created around an RI, a company would already exist and would be doing this". And here we see the real divide between processes that are amenable to business plans (predictable, monetizable) and processes that are not (blue sky research, shifting boundaries of what can be done, providing measurement capabilities that are several stages before routine workflows, creating new workflows to answer to measurement challenges encountered by clients). This point of view may seem pessimistic, but it simply expresses the gap between innovation and the payback coming from these innovations. This gap is a time gap – from initial innovation to product can take a very long time, but also a gap between who invests in the innovation and who profits from it. This is also at the heart of why so many larger companies have reduced their RnD efforts and are looking to universities to fill some of these gaps, assuming that this is community funded. This point of view clearly shows a role for public funding of such research as eventually the public will enjoy the benefits of innovation to solve its many challenges.