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BQOM 2521 SEC1010

6.15.2021

Final Project Report

The laboratory I currently work at is a biomedical research lab which focuses on diffusion MRI. Part of the struggle with MRI imaging is that there is no current method of data standardization, meaning that a scan with one vender at one hospital will differ substantially from another hospital and vendor. Although imaging techniques like CT have already been implementing calibration techniques for over 25 years, MRI imaging is much more complex and its modality more numerous, making the problem substantially tougher to solve. Recently, the lab I work at has applied for and received grant money for the purpose of data harmonization. The goal is to design a method of calibration that could be spread nationwide and perform with relative ease in order for MRI calibration to approach the precision necessary for inter-hospital comparison.

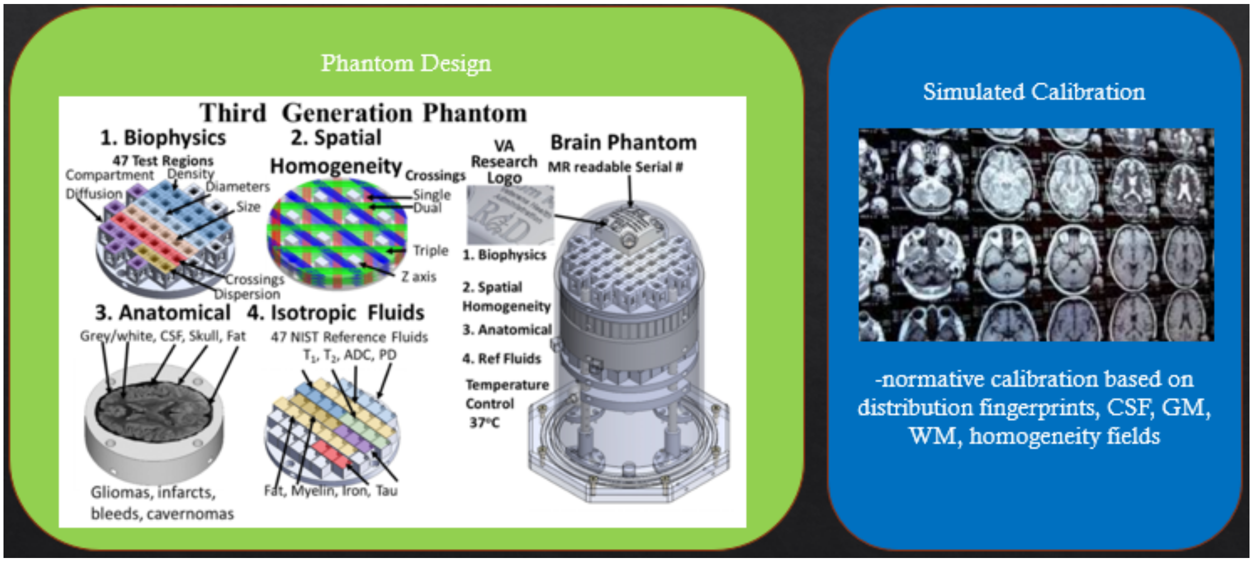
Decision: How should calibration occur for the data harmonization of MRI imaging in the US?

The decision maker in this scenario is a lab at the University of Pittsburgh funded by the VA to initiate work on MRI scanner calibration. It consists of a group of 7 individuals with talents varying from machine learning and software to imaging and medical expertise. The final decision will be made by the PI of the lab.

There would be several ways to approach a solution to this. The first method entails the creation of a phantom. The phantom is a head shaped container containing several slices consisting of various solid and liquid materials, as well as 3D printed axonal bundles mimicking the physical structure and responsivity of neuronal axons. This device, once perfected, would be manufacture in bulk, and sent to many hospitals nationally to be used in a calibration procedure similar to CT. The second solution is a strictly software one, where simulation and modelling would be used to calibrate the scanner, purely based on a series of initial images. This method is the least accurate of the two being that there is no ground truth, or certainty of the imaging's correctness. Both solutions require a backend database and processing pipeline. Given these solutions, the alternatives are the following:

Alternatives:

1) Collaborate with other groups to create phantom
2) Create the phantom internally within the lab with external manufacturing aid
3) Create simulated method of image calibration

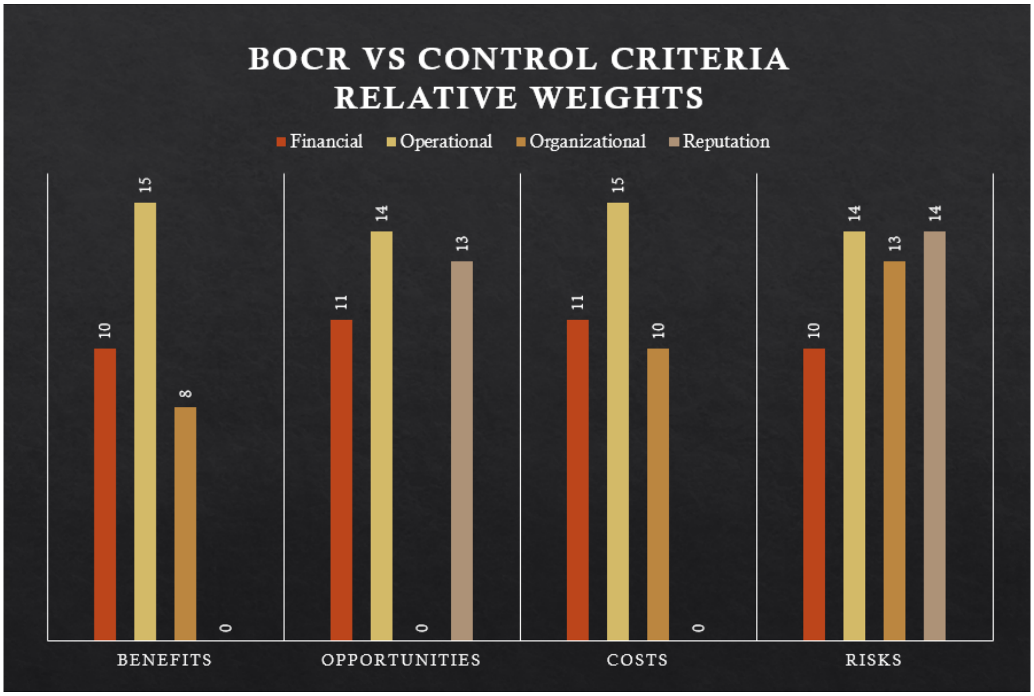


There are several aims that the lab strives for while performing its work. The first is integrity which includes the correct and careful observation, collection, storage, and presentation of data. This also pertains to reproducibility which implies that results are produced in a fashion that is repeatable by other labs with a high degree of precision. The second is the achievement of excellence, in other words creating a solution to the highest degree in terms of robustness, efficiency, and support. The next aim is innovation, the goal being to create something novel or to use an older approach to a novel problem in order to contribute to the community in a meaningful way. The final aim is collaboration, or the desire to connect with others and complimentarily benefit each other's goals and aspirations.

Strategic Criteria

Integrity | Excellence| Innovation | Collaboration

For each of the components in the BOCR model, several control criteria were selected to best differentiate between the three alternatives: financial, operational, organizational, and reputational. The importance ratings (out of 15) are given for each control criteria and benefits/ opportunities/ costs/ risks combination below. For both benefits and costs, the operational importance is elevated in comparison to the rest of the control criteria. This is due to the importance of creating a functioning pipeline from scanner hardware all the way to integrative analysis and cumulative metric checking in the backend. The system must be robust and contain enough quality control measures in order to minimize risk of misreporting of data or worse fates. As time progresses and benefits/ costs turn into opportunities/ risks, respectively, and the organizational and reputational factors begin to meet the operational ones in importance. These control criteria are crucial to weigh more heavily over time since these traits affect future events such as vendor/hospital trust, future funding, future contracts, etc.



Below is a breakdown of which sub factors within each control criteria were chosen to generate the bottom level ANP models.

Benefits

Financial

-short-term funding

-centralization

-fund allocation

Operational

-installation efficiencies

-external support

-task efficiency

-accuracy of results

Organizational

-vendor privacy

-sole proprietorship

-interconnectivity

Opportunities

Financial

-future grants

-scalability savings

-training savings

Operational

-long-term upkeep

-ease of upgradability

-transportability

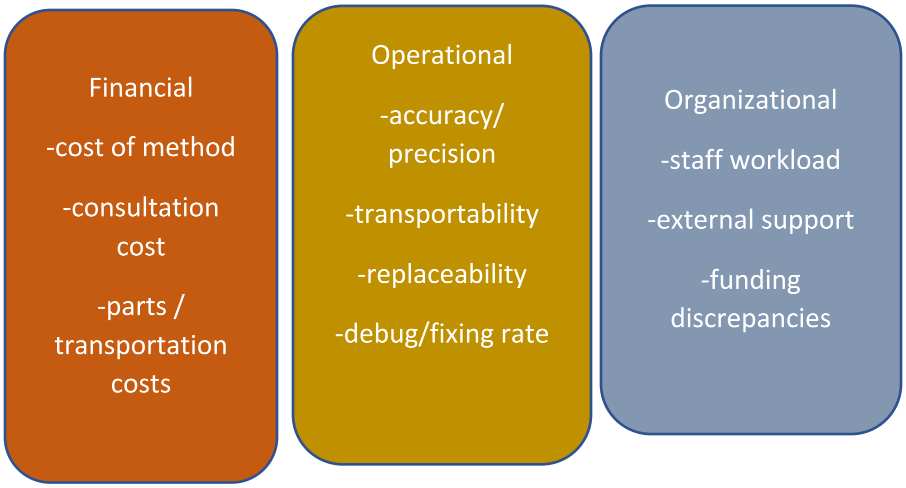
Reputation

-future collab

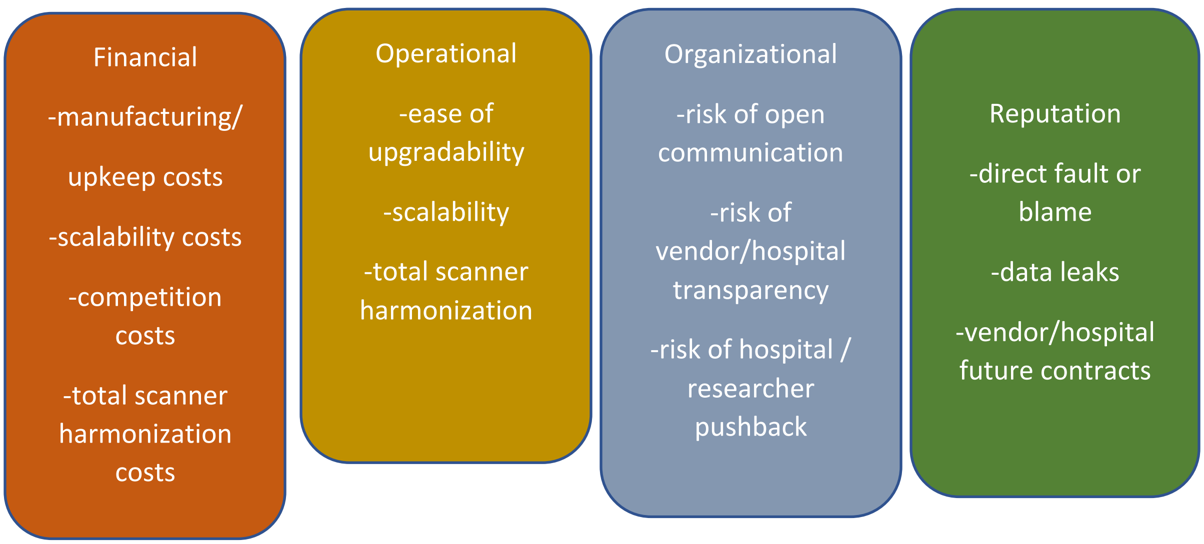
-trust in central data ownership

-vendor/hospital trust

Costs



Risks



The majority of the subfactors are self-explanatory. However, a short description of the more involved ones may be necessary to clear up confusion:

Short-term funding: Depending on how involved the project is, the funding agency will grant an additional short-term boost to the lab's resources.

Centralization: When a pipeline is created, it is beneficial for the output data to be sent to a single handler that will prepare, package, and possibly even analyze the data for future interpretation by outside parties.

Fund allocation: Funding money can be spread across many different groups and parties, or it can be funneled into a single lab.

Vendor Privacy: Due to the delicacies and competition of the vendors at play, it is critical to keep data private and to gain the trust of the vendor in order to accomplish the calibration scheme at a national level.

Hospital Trust: The vast majority of hospitals prefer older tech and hardware devices over fancy software. In addition, fear over patient privacy or scanner purchases is delicate information that must be handled with care.

Staff Workload: Depending on the complexity and type of project a lab may choose to partake in, the staff may feel over or under burdened as a result of their particular work ethic and skill set.

Each bottom level network was connected bidirectionally to the alternatives and the appropriate weights were chosen to describe the relationship that each alternative had with each subfactor for each control criteria/BOCR combination. For example, when comparing the alternatives to the financial benefits aspect, the thought process would proceed as such: the simulated calibration method has the best fund allocation since all of the funds would come directly to the lab, the worst short-term funding due to the fact that the funding agency would proportionately match the lightweight cost of the operation, and possess the best centralization both for frontend and backend modules.

Once all of the bottom and middle level networks were rated, the final ratings set was performed. To begin this process, the strategic criteria were set with the following priorities according with the lab aims and mission statement.

Strategic Criteria	Norm Weight
Integrity	31%
Excellence	26%
Innovation	23%
Collaboration	20%

The results of each individual alternative-BOCR model network were the following.

	B	O	C	R
PhantomCollab	28%	29%	35%	30%
PhantomInternal	36%	33%	33%	34%
SimCalib	36%	38%	32%	36%

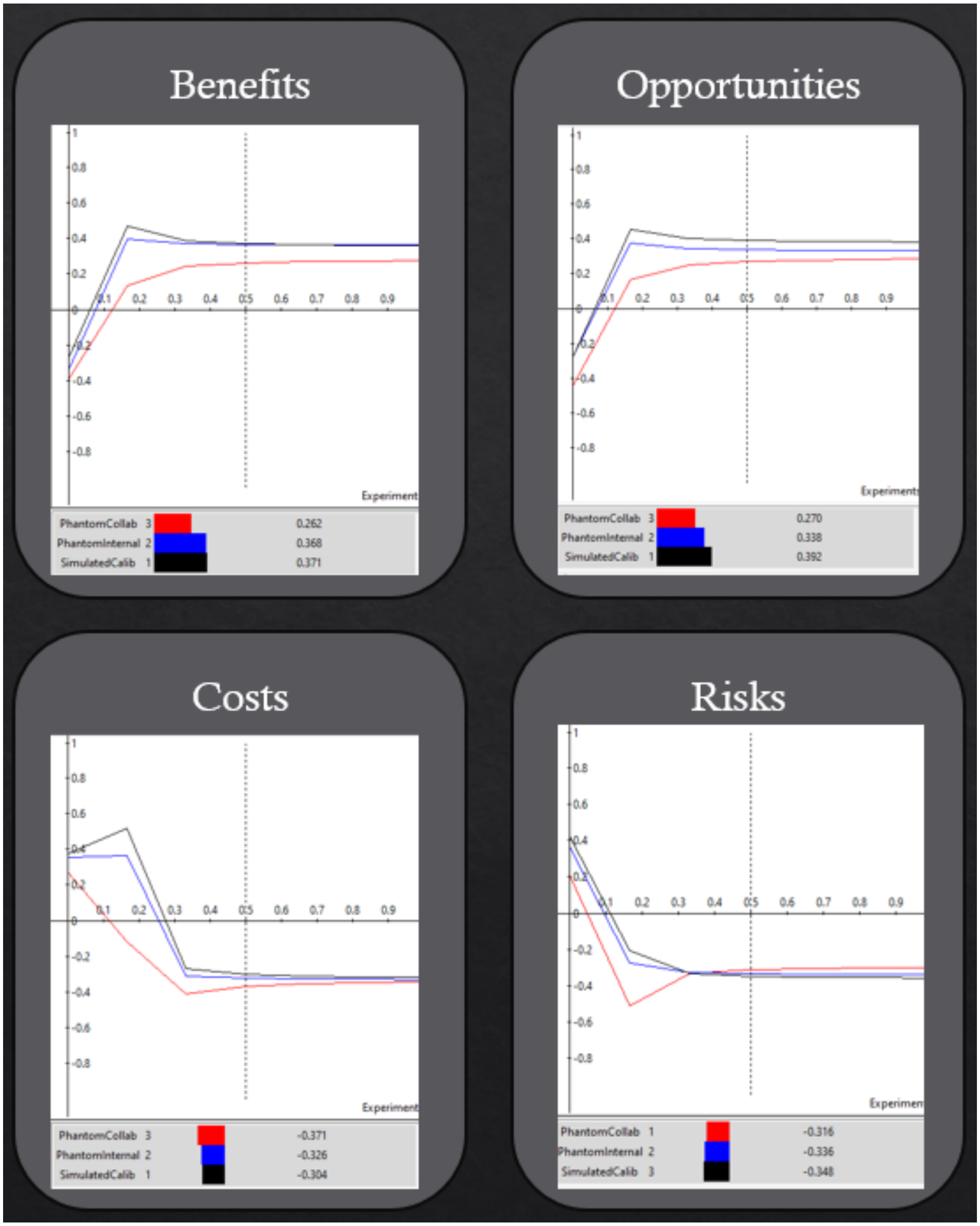
Using a ratings system from poor to average to best, each BOCR-based winning alternative was rated against the strategic criteria, i.e., how innovative or collaborative each winning alternative was. The results were calculated using both additive (long term) and multiplicative (short term) methods and the results are as shown.

Short Term		Long Term	
Phantom Collab	25%	**Phantom Collab**	7%
Phantom Internal	35%	Phantom Internal	41%
Simulated Calib	40%	Simulated Calib	52%

In both the short term and the long term, creating a simulated calibration method seems to be the alternative that most aligns with the priorities of the decision maker as well as the selection and importance of the strategic criteria. Despite this, the internal creation of the phantom was an extremely close runner-up. It is important to note however, that despite its clearly low percentage, phantom collaboration method is much more enticing in the short term than in the long run. Under further investigation, this can be attributed to the possibility of reputational/ organization loss due to data leaks, vender/hospital trust breaches or other damaging events caused by increase collaboration.

Sensitivity analysis was performed to better understand how weighted priority differences in the BOCR components would affect the alternatives. For the most part, the model results seem fairly robust with the exception of the risk factor. As seen below, the more heavily weighted risk is, the more enticing phantom collaboration is, due to any future blame in data leakage or instability being spread between the parties involved and not a singular one.

The BOCR model successfully gave insight into an important work issue that my lab is dealing with. If I were to recommend a route to my PI, I would explain that the best course of action would probably be to begin with the simulated calibration method, but implement it with future phantom hardware in mind. Meaning, that the backend is identical and able to receive both software input and phantom calibration input. Over time, the software can be replaced with the hardware and the technicians can be trained on how to run the phantom through the scanner similarly to how CT calibration is done with a phantom test tube. In the future, the simulated calibrations could even be improved by the phantom calibration process using AI in order to minimize the need to create physical phantoms for every facility.



Benefits
Experiment
PhantomCollab 3 0.262
PhantomInternal 2 0.368
SimulatedCalib 1 0.371
Opportunities
Experiments
PhantomCollab 3 0.270
PhantomInternal 2 0.338
SimulatedCalib 1 0.392
Costs
Experiment
PhantomCollab 3 -0.371
PhantomInternal 2 -0.326
SimulatedCalib 1 -0.304
Risks
Experimen
PhantomCollab 1 -0.316
PhantomInternal 2 -0.336
SimulatedCalib 3 -0.348