MANAGING LOGISTIC CONSTRAINTS IN 3D SEISMIC DATA ACQUISITION FOR OPTIMAL OUTPUT IN 3D SPACE OF FOLD, OFFSET AND AZIMUTH

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Summary

3D Seismic Data acquisition in land is suffering from data gaps and fold loss as time is progressing due to growing urbanization and severe logistic constraints. To start with, source locations are getting irregular, which is increasing day by day and getting random. The same case is with the receivers. Then the question arises that how to address this issue of disorder where the departure in source and receiver locations is high from the regular geometry. The question also arises can we acquire a reasonable meaningful 3D data. The answer is yes, provided we take recourse to real time dynamic modelling through an algorithm. This will not replace the regular geometry data but help in minimizing the irregularity in attributes of the acquired 3D data, which will be more meaningful than the highly random data that we acquire today. This requires a real time monitoring of 3D data in 3-dimensional attribute space namely fold, offset and azimuth. This will definitely lead to increase in source locations and receiver locations than that arrived with regular geometry but at the same time provides advantage for regularization at processing level. This paper deals with the change in approach towards tackling logistic constraint in 3D data acquisition in land areas, with the help of an algorithm, developed to aid the decision-making process. This approach will provide optimal source locations, receiver locations and spread for each source location thereby optimizing the overall acquisition and provide the best 3D data. Such 3D seismic data acquisition will be closer to the planned acquisition.

Keywords: fold, offset, azimuth, algorithm

Introduction

These days 3D Seismic data acquisition is facing lot of problem due to various obstacles like tube wells, houses, roads etc. present in the acquisition area which is growing day by day due to increase in urbanization.

On the other side the demand for 3D data acquisition with full azimuth and regular offset is growing due to requirement of better data to cater to the requirement of new software at processing level for better processed output. Thus, there is always a call for a better seismic data acquisition in particular when surface logistics is affecting the quality of 3D data acquisition.

The question then arises how to handle this increase where randomness of source and receiver locations is increasing. In order to compensate the irregularity due to the inherent obstacles present in the area of acquisition and provide meaningful 3D seismic data acquisition, which meets the given objective. This real time planning tool will cater to the growing demand of acquiring reasonably regular data in terms of fold, offset and azimuth with the existing logistics constraints, which will continue to increase.

The popular forward modelling tools available in the industry are like MESA, GEOLAND, OMNI etc. These tools do not provide the inverse predictions for optimum placement of shots and receiver locations given the target offsets, azimuths and logistics and other constraints. Hence the requirement was felt in the absence of any tool how to regularize these parameters, thereby leading to development of this tool.

This paper deals with the methodology of the data acquisition planning tool, the data requirement, results obtained and the implementation feasibility in the field and the final output obtained. This planning tool will help in optimizing the shots and the associated spreads with the given inherent irregularities present in the area and provide the most optimum 3D seismic data acquisition, which caters to 3-D space of fold, offset and azimuth.

Objective: To optimize the shot and associated receiver spreads for 3D seismic data acquisition in land area with given inherent logistic constraints of no shot zone, no receiver zone, present in the area and provide the most optimum regularized 3D seismic data survey which caters to 3-D space of fold, offset and azimuth requirement with the given objective.

Methodology:

To start with initial parameters of the geometry are to be provided to this tool as shown in figure 1.

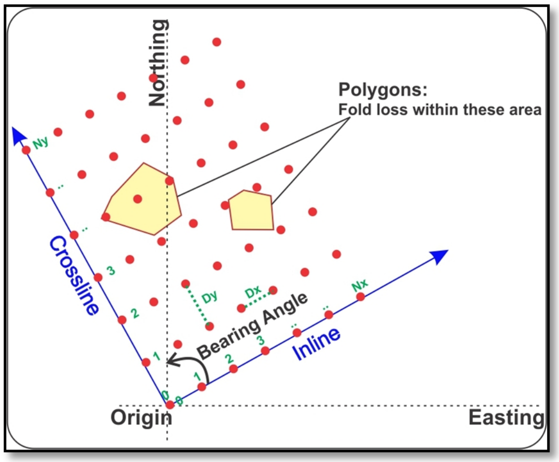


Figure-1 Outlines of the parameters

a) Analysis of the planned geometry

The first step would be to set the goal by analyzing the planned geometry. Then visualize/analyze the likely output data with the given Geometry with the given Objective of the area in the absence of any logistic constraints i.e. under ideal circumstances.

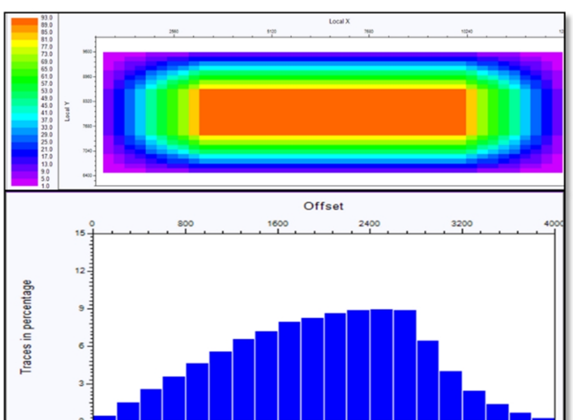
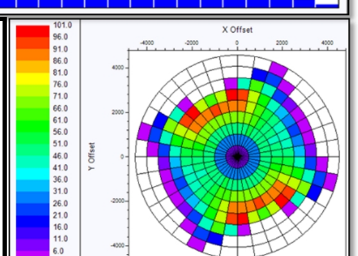


Figure-2

Fold, offset histogram & Azimuth plot of theoretical data



The attributes in terms of the likely fold, offsets and azimuths distribution under ideal condition is shown in Fig. 2.

In the Fig. 2, the fold of planned 3D seismic data acquisition is seen along with Offset distribution in the increment of 200m and the rose diagram in the bottom displays fold with 10° increment clockwise.

This will be the ultimate goal of the data acquisition of the project undertaken. If achieved that would be the best data and this planning tool will be redundant and not required.

b) Analysis of the surface logistics observed during surveying:

After the surveying work in the area and mapping of logistic constraints leading to arriving at the likely placement of the source and receiver locations. The same is incorporated in this planning tool and deviations from standard planned locations is observed in both the domains of Shot and receivers.

Subsequently obstacles and other logistic constraints is also incorporated resulting in departure from planned stage in terms of shot and receiver locations resulting in the variation of fold, offset and azimuth. The new fold, offset and azimuth plot is shown in Fig. 3. This figure provides the exact locations of the likely shots, receiver spreads overlaid with the associated fold map. From this Fig. one can easily visualize the randomness in the shot locations thereby leading to loss in fold. The same will be the case with receivers if one incorporates the dead receiver and the deviation in the location of the receivers.

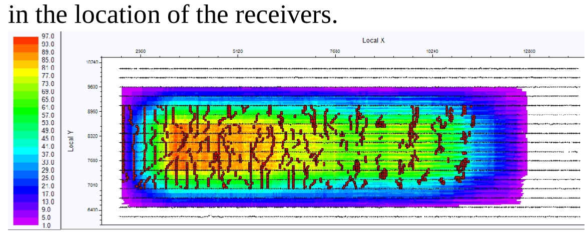


Figure-3 Actual Fold Map with shots and receivers

Subsequently this Fold Map, Offset histogram and azimuth is visualized & analyzed in this planning tool. (Figure 3-5)

Next step of this process is to the analyze the likely fold map and pick the fold loss polygon in the fold plot, where fold needs to be enhanced. The associated other plots like offset and azimuth distribution are also analyzed for the loss.

This variation is seen in a better way by obtaining the difference between the plots of that arrived under the ideal condition fig. 2 and under the actual condition as seen in fig. 4. This difference is shown in the fig 5. This difference plot is the key to further analysis of the data and provide clues as to how to handle the problems i.e the deviations. So one can see the loss of data due to incorporation of logistic hindrances in the 3D space of fold, offset and azimuth. After this visualization the next step would be at arriving at the optimum geometry different from the ideal geometry which will minimize this loss in 3D analysis space.

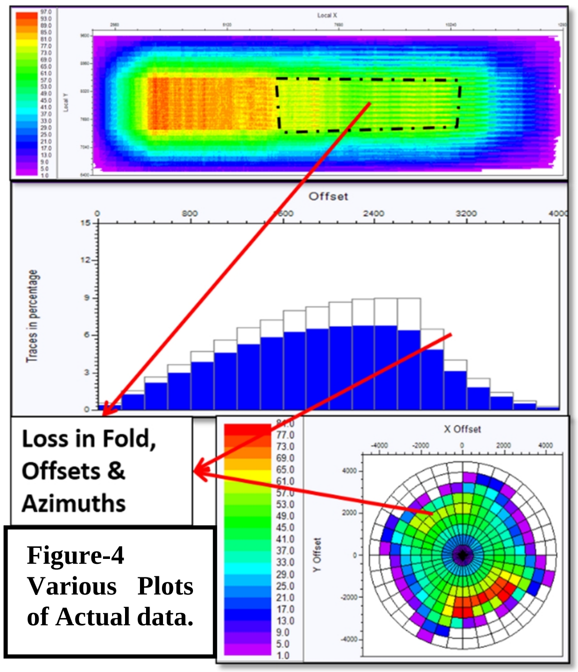


Figure-4 Various Plots of Actual data.

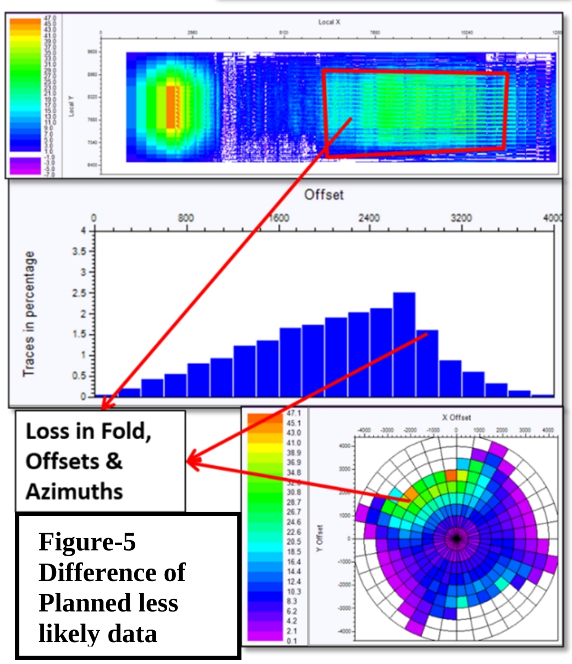


Figure-5 Difference of Planned less likely data

c) Optimization of shot locations.

Based on the fold loss polygon, target offsets and azimuths, shot favorable map is generated. Shot favorable map are plotted as values indicating the percentage of bins it contributes to the fold loss region within the target offsets and azimuths (Figure-6). This map is a guidance for choosing the shots for enhancing the attributes of the data so as to meet the required objectives (fig. 7) and thereby minimize the difference between the ideal and the actual attributes.

Using both the shot favorable probability map and the likely shot position juxtaposed, required shots can be selected or generated which will address the issue of fold loss. Tools exists to select the shots interactively within the polygon. Color map shows the percentage of contribution in the bins.

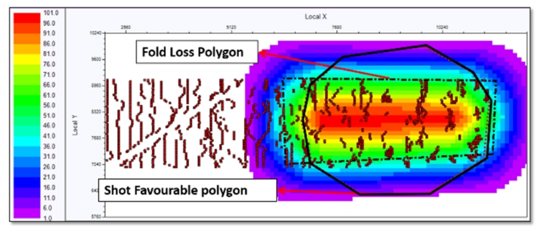


Figure-6 Shot favorable map on which the existing shots are plotted.

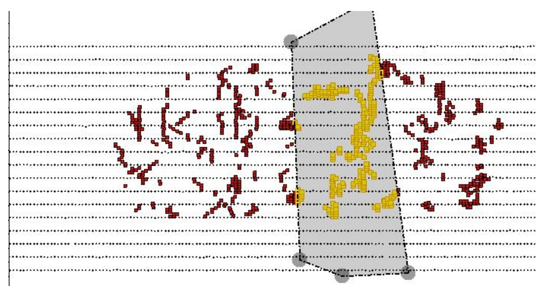


Figure 7– Selecting of shots for Optimization

d) Optimization of Spread

Based on the offsets requirement, fold loss polygon, azimuths, along with the selected shots (using shot favorable map), receiver favorable map is generated. Receiver favorable map color depicts the percentage of bins it contributes to the fold loss region with the given target offsets and azimuths for the shots selected previously (Figure-8). It has to be noted that receiver favorable map depends on the shots that were selected earlier. So each time the shot changes, the receiver favorable map will also change and hence needs to be visualized and optimized iteratively. Receivers needs to be placed in the highly favorable zones to get the desired offsets, azimuths and coverage in fold loss so as to minimize cost. Color shows the probability of contribution.

Hence this mechanism minimizes the time in optimizing the spread related to each shot so as to minimize the net difference between the planned output and the output incorporating all the logistic constraints.

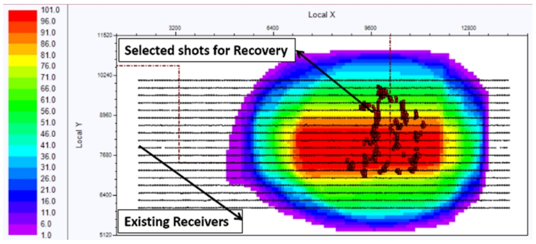


Figure 8-Receiver favorable map for selected shots.

Additional receivers other than that in the regular spread needs to be located in the highly favorable probability zones to get the maximum desired offsets, azimuths and fold. This will lead to arriving at optimal shot locations with optimal spreads to meet the Objective of the 3D seismic data acquisition such as fold, offset and azimuth and will minimize the difference between the desired and the actual.

The next step would be to analyze the restriction imposed on the receivers especially in the no receiver zones using all shots of the probability map interactively in real time based on offset and azimuthal distribution output in real time leading to optimization of spreads and if need be make more shot intensive instead of receiver intensive zone depending on the logistic constraints.

In the Figure-9 all the five windows are linked interactively and hence optimizing the receiver template in the first window (Figure 9A) will provide likely final results in the three space of fold, offset and azimuth along with the difference compensation. (Figure 9 B-E).

e) Optimizing the offset and azimuth requirement

In order to meet the required offset criterion additional shots as well as receivers will be required to be placed which will cater only to the requirement of the offset and azimuth requirement and would naturally lead to over fold. Thus one will have to tradeoff between the requirement of fold, offsets and azimuths and if need be prioritize them as per the necessity. All these exercises can be done interactively and iteratively in this planning tool where the fold, offset histogram and rose plots is updated in real time dynamically. This leads to better optimization of shots and receiver locations in lesser time.

Often meeting the offset and azimuth criteria is a difficult task. For this one must keep in mind the four quadrants i.e. Ist Yes Shot, Yes Receiver IInd No. Shot, Yes Receiver IIIrd Yes Shot, No Receiver, and IVth No Shot, No, Receiver. The effort is always to be made in the case of IInd and IIIrd Quadrant which also decides whether planning is to be shot intensive or receiver intensive depending on which quadrant the logistic constrains falls into.

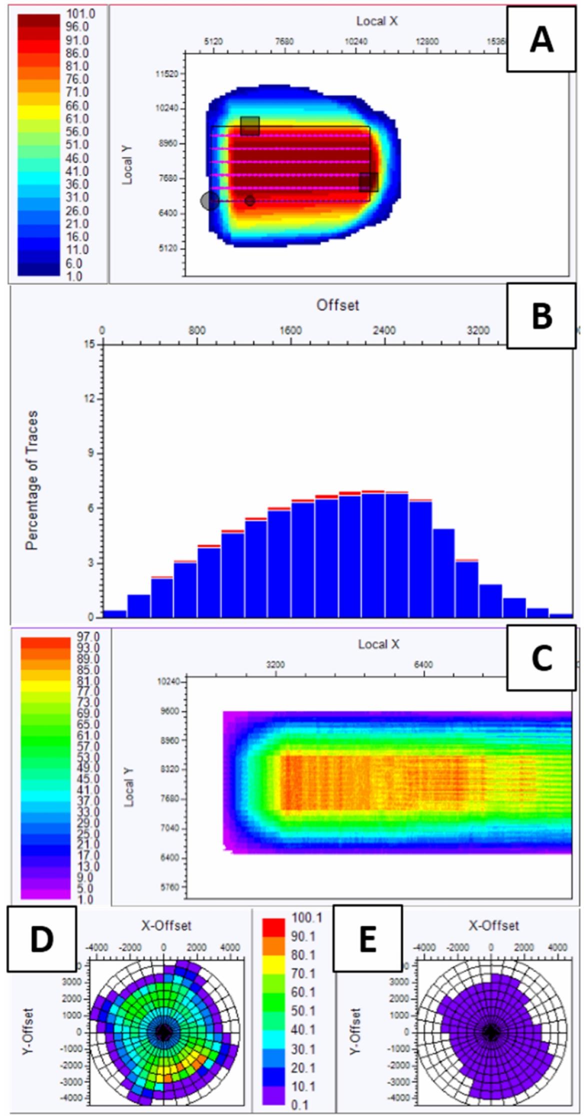


Figure 9A-Receiver favorable map, 9B Blue- Initial offset histogram, Red histogram due to recovery, 9C- Interactive Fold Map, 9D- Recovery plus regular survey azimuth distribution. 9E- Azimuth distribution difference.

Planning Tool Insight:

Fold Loss Analysis: Fold loss analysis is carried out in real time by optimization shots and receivers based on offset and azimuthal distribution results.

Shot Analysis: Depending on the maximum offset required, CDP circles can be drawn as shown as shown in Figures 10 & 11. Computing the overlapping area of the CDP circle and fold loss area for every shot, will generate the shot favorable map, shown in Fig. 12. Hence the color scale basically represents the contribution to a bin fold wise. Same would be the case for a receiver favorable map.

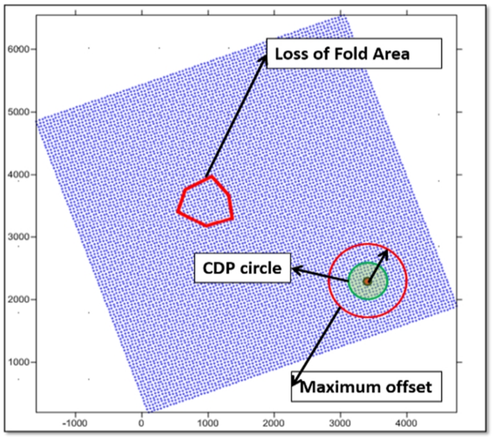


Figure-10: CDP circle of single shot

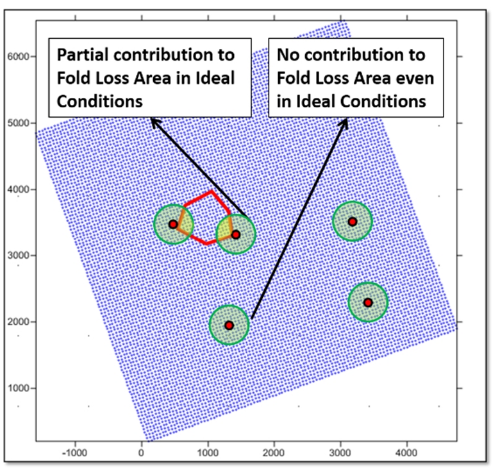


Figure-11: CDP circles of several shots

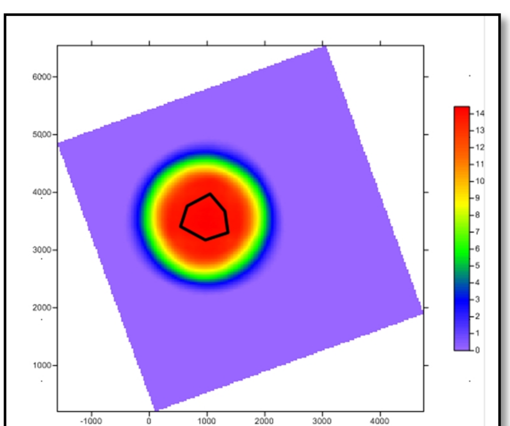


Figure-12: Shot favorable map.

Receiver Analysis: For every receiver location and the N number of shots selected using shot analysis, N CDP's (Common Depth Points) will be generated. Computing the percentage of these points contributes to the fold loss region which will generate the receiver favorable map.

Figure 13 is a Receiver favorable map for a single shot, indicated by blue dot. In this if one keeps receivers in the red patch, then it will contribute to fold inside fold loss area specified by polygon.

Now this shot and receiver favorable map have to be utilized in a conjugate manner so as to derive the maximum benefit in Offset and azimuth distribution map. This process will then ultimately need to be iterated so as minimize the difference between the desired and that which is achievable under the given circumstances.

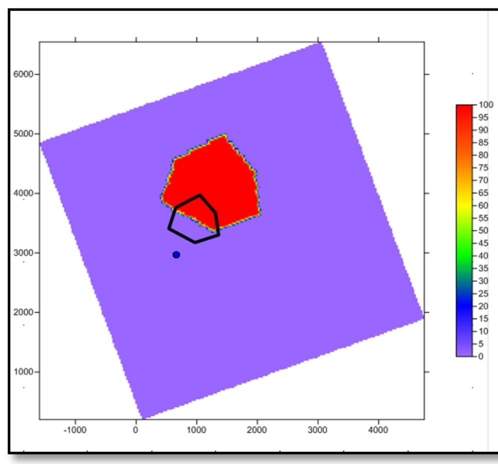


Figure 13 Receiver favorable map for a single shot

Practical Example

In one of the practical case the target offset was 1500 meters and the shots within the shot favorable region are selected. Totally 90 shots are selected. (Figure 14 & 15). The entire process has been demonstrated in fig. 15

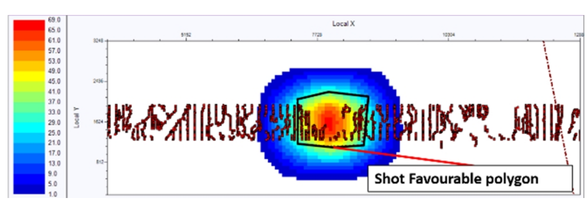


Figure 14 shot favorable polygon.

Figure 15A is the fold map before the recovery planning. Figure 15B is the receiver probable map over which the receiver template plotted. Figure 15C is the fold map obtained after adding the receiver template shown in Figure 15D is Offset histograms. Figure 15E shows the azimuth plot due to Regular plus recovery geometry. Figure 15F shows the azimuth plot due to only recovery geometry.

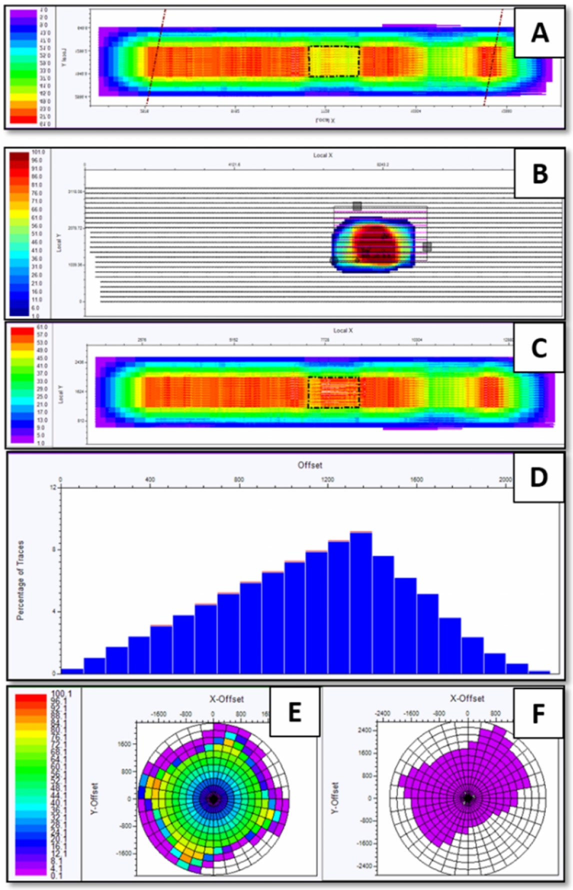


Figure 15 Receiver analysis map

Special Features of this Recovery planning tool:

i. Provides Favorable shots and receiver locations in terms of shot and receiver favorable maps if fold loss polygon, target offsets and azimuths are defined.
ii. As you edit shots and receivers over favorable maps, fold, offset histogram and Azimuth plots are updated interactively.
iii. Data can be exported in SPS format either for recovery shots and receivers or recovery shot-receiver templates can be appended to the regular planned template with the Obstacles present for optimized one time shooting.

Conclusion:

This study has led to an understanding that the planned output results in 3D Seismic land data acquisition is not feasible in general if logistic constraints are present. Then the next option remains in the seismic industry is to minimize the loss and thereby optimize and regulate the acquisition in a scientific manner. In order to regulate the acquisition in a scientific way we need a tool which resulted in this study and the output in form of Acquisition planning tool.

This tool fully addresses the two quadrant a) IInd which is No. Shot, Yes Receiver and the IIIrd which is Yes Shot, No Receiver and suggests for opting the receiver intensive or shot intensive acquisition.

It is expected that this is a beginning in this direction and many more thoughts will come up and the tool will get refined in the coming days resulting in better 3D land seismic data acquisition.

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