

FENET

PRODUCT and SYSTEM OPTIMIZATION (PSO) Technology Area

Executive Summary on the Survey of FENET Members on Uses, Issues and Requirements in PSO Technology Area

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At the Wiesbaden meeting of FENET a survey of the membership present was undertaken in relation to the role that the Technology Area of Product and System Optimisation could play in the engineering design process for network members. This is a summary of the conclusions from the survey. For full details on the questionnaire and the specifics of the membership responses search the FENET WWW site under the topic of Product and System Optimisation (PSO). What follows is a dot-point summary of the survey outcomes and my interpretation of them.

- Engineers and analysts are very dependant on computational methods. FEA is the most preferred one to carry out such analyses, with geometric and material non-linear analysis becoming much more common in usage as is non-linear transient dynamic.
- A significant percentage of analysts wish also to pursue PSO. Those that already do PSO use mostly software, either commercial or in-house for this.
- Product and System Optimisation (PSO) was regarded as a highly important task by nearly all the respondents, with many industrial benefits and opportunities. At this point of time Product Optimisation is more clearly defined and understood than System Optimisation.
- Most engineers still see optimisation in the traditional calculus form whereby some function of the structural behaviour is made to maximize or minimize. Having many constraints upon such behaviour is not clearly understood
- Experience remains as the main decision tool, this would appear to place more importance on education and training rather than commercial software. There is a strong impression gained from the responses to the questionnaire that the respondents did not feel that the important design decisions in relation to optimisation objectives could be delivered by a computer programme.
- Giving a emphasis placed on training/education and software development there was a feeling in the responses that there was a lacking in this area.
- The software developers who specifically responded appear to be aware of the users needs in the area of Product and System Optimisation.
- All the optimisation methodologies presented are known. Sensitivity analysis and mathematical programming are the more popular and widely used. The newer heuristic methods are not so well known, understood and appreciated.
- Recent developments involving the inclusion of probabilistic effects, which have gained the title of Stochastic FEM, do not have a high profile as yet.

- **Robust Design Optimisation (RDO) and Reliability Based Design Optimisation (RBDO) are not widely known about.**
- **The main issues and requirements in the PSO arena, can be summarised in industrial applicability, training and appropriate software.**
- **Finally an overarching impression from the responses in relation to the role of FENET is its role of promoting optimisation in the various industry sectors and making it affordable and understandable for anyone.**





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Commentary on the Survey of FENET Members on Uses, Issues and Requirements in PSO Technology Area

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Preamble

FENET has been running for 14 months now and a crucial ingredient of the activity is to establish issues and requirements in each Tech Area. From these can come definitions of research and guidance to members on current and best-practice. In joining FENET we have acknowledged that our contributions are pre-competitive in our industry areas and that as far as possible we will share our wisdom. A very early activity in the PSO RTD has been to conduct a survey of members' activity and interests and requirements in the Product and System Optimization technology area of FENET. This manuscript is the final presentation on that survey. The draft of the survey outcomes was presented to the PSO meeting at the Zurich June 2002. There was also a brief presentation to the plenary wrap-up session at the Zurich meeting.

What follows is a listing of the questionnaire and the write up of the results. Where relevant I have added my comments and also paraphrased such feedback as I have received informally.

The Survey Questions

Note:: Since the sample group are all FEA and computational mechanics aware the use of jargon is allowed and the questionnaire does not set out to follow high end sampling techniques. The intention has been to get somewhat of a snapshot of what is going on in this area

- Name _____
 - Organization _____
 - Response Nature (circle which applies) Personal Organization
 - Nature of FEA Technologies used (FEA, BEM, CFD others)? _____
 - How dependant are you/your organization on FEA _____
 - What analysis type do you use Lin Static/Non Lin Dynamic etc. _____
-
- What engineering software do you/org use _____
-
- Do you/org actively pursue PSO _____
 - How do you do this (analysis/trial and error/laboratory/software) _____





- What software if any do you/org use for PSO _____

- How important is PSO to you/org _____
- Can you/org identify financial benefits from PSO _____
- Which is more important to you/org Product Opt System Opt
- What tools do you have for your decisions in PSO
 - Experience _____
 - Consultants _____
 - Commercial Software _____
 - In-House Software _____
 - Others(name) _____

- If you had endless money to spend in this area what would you spend it on _____

- If you were able to direct research and development in this area what would you do. _____

- Circle any of the following areas do you feel lacking in the area of PSO
 - Education _____
 - Training _____
 - Software that is appropriate _____
 - Software yet to be developed _____
 - Access to technical resources _____
 - Some organization that you can go to for support _____
- Do you feel the Software developers in this Technical Area are aware of your needs _____

- If you could get software to do one (or more) thing in this area what would it be(Extra line for more things) _____

- Are you/org aware of the following optimization methodologies(put Y or N) or use any of them (put Y or N)

Genetic Algorithms _____	Aware _____	Use _____
Genetic Programming _____	Aware _____	Use _____
Design of Experiments _____	Aware _____	Use _____
Response Surface Analysis _____	Aware _____	Use _____
Simulated Annealing _____	Aware _____	Use _____
Mathematical Programming _____	Aware _____	Use _____
Sensitivity Analysis _____	Aware _____	Use _____
Evolutionary Structural/Design Optimization _____	Aware _____	Use _____
Linear or Quadratic Programming _____	Aware _____	Use _____
- Are there PSO methods you use that are not mentioned above _____
- What are ISSUES in the Tech Area of PSO that you/org feel are important
 1. _____
 2. _____
 - More ?? _____
- Are there are REQUIREMENTS in the TECH AREA of PSO that you/org feel are important
 1. _____
 2. _____
 - More ?? _____
- Are there things you/org feel that FENET could do to help you/org in the area of Product and System Optimization _____



The responses to the survey

Note::: The facts of the responses are in bold Times Roman below, my commentary is in Ariel font.

1. Population: 31 surveys fill in

There were 65 potential responses so 45% is not an unreasonable number considering the very busy meeting schedules.

2. Organization

Industry	University/ Research	N/A
21	10	0

This split between industry and academic/research is in proportion to the FENET composition of members.

3. Response Nature: Personal Organization

Personal	Organization	Both	N/A
9	17	2	3

4. Nature of FEA Technologies used (FEA, BEM, CFD, others)?

FEA	BEM	CFD	Others	N/A
31	4	11	Discrete elements 2	0

All of them are FEA users. The proportion also using Boundary Elements is 12%, this is an interesting figure and indicates the validity of the argument that for mostly 3D linear statics BE has advantages. That 34% also use CFD is a very interesting proportion and again strongly indicates that analysts are taking a holistic approach to the design process for their technical or manufacturing areas. Finally that people/organizations use discrete element analysis in addition to FEA indicates the nature of their technical areas, either mining/mineral processing or defence.

5. How dependent are you and/or your organization on FEA?

Main design tool	1	Highly
Developing FE algorithms and software	1	Highly
Very	5	Highly
Highly dependant	2	Highly
Medium-High level	2	Medium
Low dependant	1	Low
100%	8	Highly
75-80%	2	Highly
50%	2	Medium
30%	1	Low
Some (industrial projects)/ somewhat	3	Low
Important to R&D	1	Medium
N/A	2	N/A



This is a very interesting set of responses. Considering these and the response to the question 4 above it has to be said that the question should have read not "dependant of FEA" but Computational Mechanics in general. Still room for improvement in the follow up questionnaire. The question was not a fixed multiple choice so what is recorded above is the number that responded with various levels or descriptions of their dependency. The response that FEA is the main 100% or >80% *design* tool shows just how important the method is to these companies. If the respondent is an academic or vendor than one would expect different responses and possibly this question should have had a breakdown by type of respondent.

6. What analysis type USED::Linear Static/Nonlinear/ Dynamic/Others

Linear Static	Nonlinear Static	Dynamic	Acoustics/electromagnetic
15	22	19	1+1
Multiphysics	Crash/Impact	Thermal	Contact
1	5 +1	7	2
Fatigue/Creep	Metal forming simulation	Seismic	N/A
3+1	2	1	2

This response shows that there has been a significant shift in the maturity and sophistication of the applications in FEA and CM over the years. This is evidenced by the dominant usage being in non linear static and dynamic analyses with a scattering of usage across the board of other physical situations.

It would be good to see what the changes have been in these various application type over the last ten years. Also to have had a bigger sample group would have helped software developers direct some of their R&D effort.

7. What engineering software do you/org use?

ABAQUS	10	NISA	1
ANSYS	13	FEAP	1
FLUENT	2	VOLSOL	1
PAM-STAMP	4	ADAMS	1
PAM-CRASH	4	PROCAST	1
PAM-SYSWELD	2	FEMSYS	1
MSC FATIGUE	1	OPTISTRUCT	1
NASTRAN	8	POWERFLOW	1
MARC	5	ST-ORM	1
FORGE	2	CFX	1
AUTOFORGE	1	STRAND	2
SUPERFORGE	1	LMS GATEWAY	1
IDEAS	4	DADS	1
SYSNOISE	1	STAR	1
PATRAN	4	FALANCS	1
UNIGRAPHICS	1	MEDINA	1
PROENGINEER	3	CADA-X	1
SOLIDEDGE	1	HYPERMESH	1
LS-DYNA	5	FEMGV	2
DYNA3D	2	ELFEN	2
STAR-CD	2	CADMOULD	1
MECHANICA	1	BEASY	1
MATLAB	1	FRANC	1
LUSAS	3	DIANA	3



CATIA	1	SOFISTIK AG	2
BETSY	1	MODLFLOW	1

Who said the choice in engineering software was narrowing. Clearly a very large range of products are in use, many with single sites in this survey. Some of the above are only post-processing activities like fatigue, others are specialized moulding software. However the range is very large and we can clearly identify the major FEA software packages.

8. Do you/org actively pursue PSO?

Yes	No	N/A
19+4 Just starting /just a few	5	3

This is a very encouraging response. The question was not broken down sufficiently to identify who is just becoming aware or who is fully engaged in using software and other techniques to optimise their products and systems for making them. From the list of software in Q7 there are not many of the optimisation programmes listed with lots of users. It was hoped in subsequent questions that more could be teased out about what people are actually doing.

9. How do you do this? Analysis/trial & error/laboratory /software

Analysis	Trial and error	Laboratory	Software	N/A
12	6	5	12	8

There are many ways to achieve a good result. This question was a curiosity one and also designed to make the respondents think about the processes they used. The first option has to do with simply using the analysis to check for problem areas or areas that can be changed and then doing so. The final choice is the use of some form of search engine.

10. What software if any do you/org use for PSO

HYPEROPT (Altair)	2	C	PERMAS	1	C
OPTISTRUCT (Altair)	2	C	GATEWAY (??)	1	C
SLANG	1	C	DADS (Dynamic)	1	C
ANSYS	3	C	FEMGV	1	C
LS-OPT	1	C	MECHANICA	1	C
OWN ALGORITHMS (In-house software)	8	N	FRONTIER	1	C
ABAQUS	1	C	NASTRAN	1	C
DOT (Vanderplaats Research & Development)	1	C	AYDI	1	C
ST-ORM (Stochastic optimisation)	1	C	N/A	14	NA

Not such a big list as the analysis software packages but still a significant number. The greatest usage is for in-house algorithms demonstrating that no commercial software yet is sufficiently flexible or capable of investigating all types of problems. This is different to a general purpose FEA package that is fully capable. Most of these programmes undertake a particular type of optimisation. For instance the Frontier software is in general a Genetic Algorithm environment whereby various analysis engines can be called up

11. How important is PSO to you/org?

Very	Normal/medium	Not much	N/A
13 (2 future market and opportunity) 1 (research)	1 1 (reasonable)	4 (want to improve/ being introduce) 1 2(not at all)	10



This response shows that at least 50% have a view on the relevance and importance or lack of importance PSO can have for them or their organization. This is a good sign but also shows that whilst all respondents are dependant on FEA only a proportion recognize the potential of PSO methods sufficiently to have begun to implement and realize the benefits.

12. Can you/org identify financial benefits from PSO?

Yes	N/A
15 Better engineering, better service, customers get interested, reducing prototype, weight reduction, lifecycles, reduce number of numerical models...	16 (No and blank answers)

As with the response to Q11 above about 50% of the respondents can see that the implementation of PSO methodologies in addition to undertaking PSO can produce easily identifiable bottom line financial benefits. It is to be hoped that if a clear success story with a clear financial benefit could be articulated then this would encourage other organizations to invest more in the necessary software and training in the various PSO technologies and intellectual concepts.

13. Which is more important to you/org? Product Opt or System Opt

Product Opt	System Opt	Both	N/A
12 (39%)	5 (16%)	4 (13%)	10 (32%)

This response indicates that more people can see what the term Product Optimisation means. I feel it is taken to mean that whatever the engineer or the company is doing there is a desire/requirement to ensure that the product operates as well as possible for all the environments the design has to live/survive in. If this is coupled to the potential of financial benefits as was indicated in Q12 above then provided there is the knowledge and the training and the software to do this at an appropriate cost then the barriers are removed. Fewer respondents identified System Optimisation as being of importance. Possible here there is a lack of clarity about what it means. We have taken it to mean not the product itself but the system whereby it is manufactured. For example an aircraft part could be welded up from steel but could be cast, sintered, forged form aluminium or it could be a composite made by RTM. Clearly the system whereby the product is produced has to be optimised to the maximum benefit of the product and to its producer. They two are linked in so much as changing the material for a product can change the design given manufacturing and material constraints.

14. What tools do you have for your decisions in PSO?

- Experience
- Consultants
- Commercial Software
- In-House Software
- Others

Experience	Consultants	Commercial	In-House Software	N/A
18 (58%)	2 (6%)	8 (26%)	9 +1 Develop algo (32%)	7 (22%)

Always good to know that even in these modern times with all our computers and *always getting smarter* software we still identify experience as our major decision making tool. The number using In-House Software was not sufficiently fine grained to tell whether this is commercially developed software or In-House developed. Putting this uncertainty aside we can infer from this answer that currently a combination of experience plus software is the practice. In the future it may be that some of this experience will be embodied in the software.

15. If you had endless money to spend in this area what would you spend it on

Physical test with good instrumentation/Test correlation/ Material data	2
Optimisation modelling tool	1



Education/ Training staff + more staff/ People to expertise/ improve computing resources	4
Biological Optimisation	1
Put in more influential factors in in-house software	1
Purchase SO software (he doubts if the software is mature enough)/ Develop their own one	3
Graphical user interface	1
Parametric FEM modelling	1
N/A	16

This shows that we mostly have not thought about what needs to be done. Possible message to software developers and researchers to get stuff on the market and then see what is used and what is not. Another possible message to academic members of FENET which is that we have to put more generic teaching material into our undergraduate programmes that will make the engineers of the future more demanding for quality products in this area.

16. If you were able to direct research and development in this area what would you do?

Optimisation of creep (time dependant problems)	2
Optimisation algorithms using sensitivities	2
Fracture mechanics	1
Integration of processes optimisation towards to performance	1
Implement optimisation for manufacturing process simulation	1
Graphical user interface	1
Improve test/analysis working together with correlation	1
Speak to an expert/ get more knowledge	2
Exploit FEA into industry	1
Improve software making it modular	1
N/A	19

In line with the sort of number of respondents who are giving some thought to the replies this again tells us that more than 50% of those who replied have not given much thought to the area of PSO. The rest of the replies I feel reflect the individual situation of each respondent. There is clearly someone worrying about design for creep minimization.

17. Circle any of the following areas do you feel lacking in the area of PSO

- Education**
- Training**
- Software that is appropriate**
- Software yet to be developed**
- Access to technical support**
- Support organizations**

Education	9
Training	8
Software that is appropriate	9
Software yet to be developed	5
Access to technical resources	4
Some organization that you can go to for support	3 (not lack of but imp to be there)
Others...	Acceptance by industry 1
N/A	11



Again it is possible to say that these are all predictable responses, however that fact that 66% of respondents filled in something means that they have given this some thoughts and that the majority of the ticks were do with training and education is very important. The number of responses that mention software both current and future indicated that many of us and not aware of what is there, and education and training issue, and/or feel it is still either too inaccessible or expensive and have not yet investigated the software area yet. The next question tried to draw out this aspect.

18. Do you feel the Software developers in this Technical Area are aware of your needs?

YES	NO	TO SOME EXTENT (Probably)	N/A
8*	2**	5 (yes, but not totally + Affordable, real prob.) +1 Not applicable	15

* 1 of the Yes responses was answered by a software developer

** 2 of the Yes responses were answered by university members

This is an interesting response. 25% think software developers are aware of what is needed. Given that there are quite a number of such people who are members of FENET it could be that they are the ones to say yes to this question and the problem with the lack of technology diffusion and awareness and the need for education and training is that the bulk of the community are still not fully aware of what the current and forthcoming software products in this area can do.

Another interpretation is that many of the YES votes are from academics, who have been informing the vendors and developers about what is needed. For this question there needs to be a finer distinction on the sort of person who is saying YES or No and who is abstaining and possibly why.

19. If you could get software to do one (or more) thing in this area what would it be?

To optimize heavily non linear production processes	1
Make it easier to link	1
Easy to use, good GUI, usable with different solvers	1
Open for further implementation, well documented and training	1
Topology optimization for fatigue life	1
In the construction industry there are many practical aspects of design that make adoption of structural optimization very difficult. (Seems not very convinced about PSO)	1
Optimization algorithms using sensitivities	1
Parametric modeling	1
Probabilistic computations	1
Conveniently define + Mesh Complex geometries	1
Specific purpose optimization design modules. Integrate experimental, analytical and numerical information	1
Optimizer in the sense of trying out various alternatives	1
Combination of FE & Optimisation tools	1
N/A	20

Each item got one vote because these are the written down replies to the question. It could be of interest to developers to see if the points raised are covered as they at least reflect the view of one practitioner. That 66% of people did not respond to this question is possibly interpreted to mean that they are not sufficiently involved to have encountered problems or deficiencies.

20. Are you/org aware of the following optimization methodologies?

Optimization methodologies	Aware	Use	N/A
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	YES		NO		YES		NO		19%
Genetic algorithms	19	61%	6	19%	4	21%	15	79%	6
Genetic Programming	15	48%	10	32%	2	13%	13	87%	6
Design of Experiments	20	64%	5	16%	12	60%	8	40%	6
Response Surface Analysis	15	48%	10	32%	7	47%	8	53%	6
Simulated Annealing	7	22%	18	58%	1	14%	6	86%	6
Mathematical Programming	20	65%	5	16%	9	45%	11	55%	6
Sensitivity Analysis	24	77%	1	3%	15	62%	9	38%	6
ESO	18	58%	7	23%	11	61%	7	39%	6
Linear/Quadratic Program	18	58%	7	23%	6	33%	12	67%	6

Percentage over 31 Percentage over Aware YES

This is one of the most interesting questions and it may take a bit of thought to see what the responses indicate. If a respondent was not aware or use and PSO methodologies then I have assumed they are in the N/A category, which is about 33% of replies. Of the other 66% some are aware of at least one of the methods that are currently in use in PSO. Sensitivity analysis and Design of Experiments are amongst the most aware groups but the others are not far behind.

Of the people who said they were aware of a method, some would have said they actually use the methods. So it is the % of the aware people who have used or use the method that are in the Use columns. Here again the biggest %ages are against sensitivity analysis and DOE methods. The newer heuristic methods of Genetic Algorithms and Evolutionary methods do not have such a heightened awareness.

It could be argued that this is the purpose of the FENET organization to produce material for the whole CM community that will help make them more aware and provide more information on training for such methodologies.

21. Are there PSO methods you use that are not mentioned above?

YES	1
	Stochastic analysis 1
	SKO/CAO/CATO 1
	Biological growth 1
NO	7
N/A	20

This question was included because I was aware that I may have forgotten some important methodology or that a member of FENET could be researching/developing new methods. To mention briefly what has been put down, stochastic analysis is a way of looking at robustness of a design on the basis that the data, material and environmental for the analysis may not be precise. The imprecision is quantified in a probabilistic way and FEA undertaken to explore the range of responses with the uncertainty present. Clearly if all the results cluster about a single solution the design is robust but if there are outlying responses then these indicate a sensitivity to a particular data combination.

SKO/CAO/CATO. I think these anagrams are meant to stand for a class of methods developed over a series of years by researchers such as Rozvany, Bendsoe, Sigmund, Kikuchi and others whereby energy based sensitivity analysis is conducted at the element level in an FEA analysis rather than at the geometry level. There have been some significant advances with these methods and indeed they are at the core of some of the commercial codes mentioned in Q10.

Biological growth is a special shape optimisation process whereby highly stressed regions of a surface of a body can be added to and lowly stressed regions can be removed. It has been championed by the work of Mathahek in Germany.

22. What are ISSUES in the Tech Area of PSO that your/org feel are important

Applications	1
Easy handling of PRE&POST processing	1
Interfaces for Opt. Data	

Heterogeneous analysis tool. Integrated use of information from analytical, experimental and numerical models	1
Knowledge based PSO's	
Promoting the use of optimisation in the design process	1
Best method for specific problems	1
Simplified method in the context of optimisation	
Training	1
Sharing experience and knowledge	1
Interface with FEA	1
User friendliness	
Structural Optimisation	1
Metal forming process optimisation	
Ease of use/ Integration into CAD	2
External software for optimisation	1
Flow of analysis, compatibility of software	1
Flexibility	
N/A	18

Again it is clear that this question has attracted a series of individual requirements. However looking at each separate issue it seems to me that they all have somewhat of a common thread. This is that the benefits of making products and systems more optimum are clear to us all. The current state of affairs as indicated through these responses is that we are not quite there yet. Also for the information of developers in the area of design of robust and optimum performance are some tips on the areas of concern and how users would like to interact with their software.

23. Are there any REQUIREMENTS in the TECH AREA of PSO that you/org feel are important?

Industrial applicability	1
To focus on well spread commercially available software	1
Education	1
Guidelines for optimisation	1
N/A	25

Some good ideas for FENET here. I interpret "guidelines" in two ways. Firstly as a need for benchmarking so that new users can get good well documented examples to try before they launch into a full scale production optimisation where there is no indication of the fidelity of the results. Secondly there is a need for an exhaustive "How to ----" book in the spirit of many NAFEMS publications. Finally there is the need to textbook type material so that the methods we are coming to appreciate and use are presented in undergraduate curriculum. To me, as an academic this final point seems the most important as my experience tells em that many engineers seem to stop learning when they leave university and feel that there is no more to come.

24. Are there things you/org feel that FENET could do to help you/org in the area of Product and System Optimization?

Prescription role orienting developments in the way of increasing industrial use of technology and focus on the industrial benefit rather than on technological excellence	1
Education/Training	1
Held appropriate workshops	1
Publish case studies	
Dissemination (Spread ideas ?) and best practice	1
Benchmarking, organize meetings	1

N/A	25
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Not much response to this question but the clearly the same indicators for NAFEMS and FENET activity as for Q23.

CONCLUSIONS

- Engineers and analysts are very dependant on computational methods. FEA is the most preferred one to carry out such analyses, with geometric and material non linear analysis becoming much more common in usage as is non-linear transient dynamic.
- A significant percentage of analysts wish also to pursue PSO. Mostly they use software, either commercial or in-house for this.
- Product and System Optimisation (PSO) was regarded as a highly important task by nearly all the respondents, with many industrial benefits and opportunities. At this point of time Product Optimisation is more clearly defined and understood than System Optimisation.
- Most engineers still see optimisation in the traditional calculus form whereby some function of the structural behaviour is made to maximize or minimize. Having many constraints upon such behaviour is not clearly understood
- Recent developments involving the inclusion of probabilistic effects which have gained the title of Stochastic FEM do not have a high profile as yet.
- Robust Design Optimisation (RDO) and Reliability Based Design Optimisation (RBDO) are not widely known about.
- Experience remains as the main decision tool, this would appear to place more importance on education and training rather than commercial software. There is a strong impression in the responses to the questionnaire that the respondents did not feel that the important design decisions in relation to optimisation objectives could be delivered by a computer programme.
- Giving a emphasis placed on training/education and software development there was a feeling in the responses that there was a lacking in this area.
- The software developers who specifically responded appear to be aware of the users needs in the area of Product and System Optimisation.
- All the optimisation methodologies presented are known. Sensitivity analysis and mathematical programming are the more popular and widely used. The newer heuristic methods are not so well known, understood and appreciated.
- The main issues and requirements in the PSO arena, can be summarised in industrial applicability, training and appropriate software.
- Finally an overarching impression from the responses in relation to the role of FENET is its role of promoting optimisation in the various industry sectors and making it affordable and understandable for anyone.

