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Relationship between Nominal Group Techniques and Concurrent Engineering: A Review

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Abstract: Recent emphasis on concurrent engineering illustrates the need to integrate all aspects of design, marketing, finance, and production simultaneously into engineering decision-making processes. Most concurrent engineering efforts focus on improving communication by collocating and dedicating development teams. One such way of achieving team spirit is to use nominal group technique as one of the best decision-making techniques to facilitate the joint work among team members in order to reach consensus, assigning importance that reflects each individual member's preferences. To resolve the need for effective group decision-making techniques in dealing with team-oriented characteristics, there is need to take a look at the relationship between the nominal group technique and concurrent engineering in achieving group consensus without creating conflicts.
Keywords: Concurrent engineering, Group decision-making, Nominal group technique, Consensus, Design team, Product development process

1.0 Introduction

Nominal Group Technique (NGT) is a structured brainstorming technique that is used to produce a large number of ideas pertaining to an issue while ensuring that all the group members have equal participation in the development of ideas. Nominal group technique can also be regarded as an interview technique where participants work in the presence of each other but write ideas independently rather than stating them verbally (Macphail 2001). Nominal Group Technique, or NGT, is a weighted ranking method that enables a group to generate and prioritize a large number of issues within a structure that gives everyone an equal voice. The tool is called nominal because there is limited interaction between members of the group during the NGT process (Clark & Stein 2004; Recreation and Tourism Research Institute 2007; WBI Evaluation Group 2007). The nominal group technique is a narrowing and decision-making method that allows the input of all group members while it minimizes group debate. This is an especially useful tool when there might be people who will dominate the group or others who have a hard time expressing their opinions (EducationWorld, 2013).

Nominal group technique is usually applied to identify problems and generate solutions to these problems. This technique in which individuals work in the presence of others without significant interaction, has been used to cure many of the problems that formal group discussion encounter; they include ineffective idea generation, unequal participation in discussion, groupthink, domination by more powerful participants, and ineffective conflict resolution (Evan et al. 2004).

A team can use nominal group technique when it needs to create a list of options and rank them, using nominal group technique effectively, neutralizes the domination of the loudest person, or the person with the most authority, over the decision making process (Rafikul 2010). The nominal group technique is based on social-psychological studies of decision sciences, management science studies of aggregating group judgments, and social work studies of problems surrounding citizen participation in program planning. The nominal group technique (NGT) was first developed and conceptualized by Andre Delbecq and Andrew Van de Ven in 1968, which was evolved from organizational planning research and evaluation in education and health organizations as a means to make committee decision-making more effective as part of creative problem solving. Actually, the nominal group technique, as discussed by Delbecq et al. (1975), has been applied primarily to group decision making (problem-identification, problem-solving processes) in two general types of situations – intra-organizational group decision making and soliciting expert or citizen views as input for public policy formulation due to the fact that there are no available data that will help in the decision making.

Many researchers have equally applied the technique in education, and the common focus centered on group decision making. The technique has been extensively applied in health, but the core factor is also in group decision making. Even in market research, and social and governmental organization, it was also applied to group decision making and used for primary data collection. However, in design, the issue of nominal group technique has not been reported in the literature. This is due to the fact that designing is a dependent factor in concurrent engineering.

With concurrent engineering concept design, it reduces the need to re-design and re-work, thus reducing development time, increases the chances for smoother production thereby helping to minimize cost and improve quality. In the context of manufacturing industries, concurrent engineering helps companies shorten the product development cycle and quickly bring products to market. It embodies team values of cooperation, trust and sharing in such a manner that decision making is by consensus, involving all perspectives in parallel, from the beginning of the product life-cycle. Also, by executing the design in parallel, improvements occur in many areas such as communication, quality, production processes, cash flows and profitability. Concurrent engineering approach therefore tries to clarify and resolve any problems within the relationship between product design and manufacturing processes. New products will thus potentially arrive faster to the market, because the product has been designed to be effectively produced by the resources and technologies available in the company.

1.2 The Nominal Group Technique Process

The NGT procedure is normally implemented in six stages. First of all, the facilitator starts the session with an opening speech by introducing the issue, usually in the form of question for which the session has been convened and a brief background of the issue to be discussed, and the rules of a nominal group session which are to be followed. Thereafter, each member is given about 15 minutes, would silently and independently writes down ideas pertaining to the issue on how to solve the problem. Quality of ideas will be taken care of at a later step. This step of ideas generation needs to be completed in total silence. After the generation of ideas, each member takes turns to verbally present one idea at a time to the group and the facilitator will record all ideas on a marker board sequentially until the round robin presentation is completed.

Immediately the round robin is completed, the facilitator starts the serial discussion of the ideas generated from the beginning of the master list (i.e. the list on the marker board) and asks the participants if any clarification is needed. If any idea is not clear, then it needs to be clarified by the person who provided it or by someone else. Finally, voting to select the most important ideas is carried out. Each group member will be asked to identify the most important 5 to 8 ideas from the master list and ranked them. For instance, if 5 ideas are identified as the most important, the rating of 1 to 5 scales is used according to their importance. The most important idea is to be assigned a rating of 5 and the least among these 5 ideas will receive the rating of 1. The facilitator would then tabulate the results in which the votes are written against the ideas on the board. When all the votes are aggregated, the facilitator then picks 5 to 8 ideas which are most highly rated by the group as a whole, which reflects true group preferences. The voting can be done several times until the best option has emerged.

1.3 Rules of conducting a Nominal group session.

For a successful nominal group session, the following rules must be strictly followed.

Rule 1: There should be no criticism on anybody's idea.

All ideas generated are regarded as important.

Rule 2: No evaluation about anybody's idea

The participants are not allowed to evaluate others' idea. If someone thinks that someone's idea is not good enough, he/she has the choice of not selecting that in the voting stage. Actually, all the inferior ideas will be eliminated when voting exercise is completed.

Rule 3: Generate as many ideas as possible

Participants are strongly encouraged to generate as many ideas as possible. One of the advantage of NGT as earlier stated is that the larger the number of ideas produced, the greater the possibility of achieving an effective solution for an issue.

Rule 4: Modifying and Combining ideas

Participants are allowed to modify and combined two ideas that are already articulated. This is referred to as "hitchhiking".

Rule 5: Anonymity of input

In the nominal group session, status of the participants is not important. This means that all the inputs including the votes have to be kept anonymous.

It is obvious that in decision making, data are needed, but most times, hard data are not available due to incomplete information to do so, therefore, people are given the autonomy of finding a way of generating data that will enable them take decision. The problem now is the difficulty in reducing the subjectivity in their decision due to human factor. One approach that is capable of resolving this problem is nominal group technique. This is due to the fact that nominal group technique is a structured group approach that gives room for criticism, where individuals are implicitly criticizing by selectively ranking those ideas they think are better. This process can be repeated several times and re-ranking analyzed to ascertain the degree of consensus (Van Teijlingen 2006), so that once a consensus is reached, it can reduce the element of subjectivity. For many studies, this ranking of ideas may represent sufficient analysis, as it provides the researchers with a quantitative measure of the importance of the various ideas expressed during the NGT sessions (Claxton et al 1980). Secondly, the technique is a fact finding approach, and results are validated as seen in the following examples.

Case 1: Kuo-Hung et al. (2006) presented an online nominal group technique platform for implementing knowledge transfer to record the experimental experiences of thirteen Information technology experts from academia and industry in providing formal activities for promoting knowledge transfer in pursuit of consensus at a distance. Based on the analyzed data that were collected during the NGT process from ranking results. It was concluded that there was significant agreement on the priority of knowledge sources, and the efficiency of knowledge transfer was found to be significant due to the increasing value of Kendall's W coefficient of concordance test used. Their result from the study indicates that knowledge transfer can be initiated through an online NGT process as claimed.

Case 2: Charles-Owaba (2004) applied the NGT in diagnosing industrial ailment and remedy, as a means of knowing what is responsible for poor performance in a manufacturing company. Through the nominal group technique, it was clear from the results that the cause of the problem was as a result of bad materials that were supplied. Actually, when this was traced back, it was discovered that the materials they bought were sub-standard. The performance was really going down due to bad materials. Eventually, the company decided to buy the right material and put it into use, and found out that productivity has tremendously increased, validating the earlier result.

Case 3: Abdullah and Islam (2011) applied the nominal group technique in managing quality in higher education to generate large number of ideas to solve quality related problems specifically in Malaysian higher education setting. A total of forty four ideas that require attention were generated. The number were brought down to seven most important factors that constitute quality administration after due voting. In their findings, among the selected factor, it becomes clear that the University authority has to deal with motivation of staff to make them friendly who can assume high responsibilities, providing sufficient amount of training and management must expedite action in processing student's application forms. In order to validate their results, a survey was conducted in which 93 students took part. It was clear that all the seven crucial factors identified in nominal group session are also present among the 7 most crucial factors found in the survey. The author also pointed out that research in group dynamics has shown that more ideas are generated by individuals working alone but in a group environment than the individuals engaged in a formal group discussion.

Case 4: Charles-Owaba (2002) carried out research on civil service efficiency and effectiveness where NGT was applied to efficiency improvement issues when there was a report that shows that claims that the result of one of the quarter efficiency measurement had shown a tremendous increase with respect to outputs thereby resulting in a decline in efficiency. After a careful study was carried out, it was discovered that waste paper constituted 35% of the total material costs. These results were validated when nominal group session was conducted. The finding shows that out of the 13 generated and ranked ideas, only 8 ideas were proposed by the group for necessary action and others were discarded. The group recommended that they should work on to improve the efficiency by reducing wastage.

Case 5: Gresham (1986) used nominal group technique to determine whether or not policymakers and change agents with differing professional backgrounds and responsibilities, who participated in the structured process of a nominal group in the setting of diverse decision-making and problem solving conferences, would express satisfaction with the nominal group technique used. The study carried out uses four conferences at Texas A & M University involving training and decision making. His findings were based on the primary analyses of the data concerned with the independent variables: conference in which people participated; previous use of NGT; understanding of the purpose of the NGT; background and profession of participants; and participation on other group activities. The result shows that respondents expressed agreement with the usefulness of NGT, with a positive comparison of NGT with other group activities, and with a positive view of their personal involvement in the NGT at the conference that they attended.

Case 6: Also, the application of the nominal group technique to select the most appropriate topics for postgraduate research students' seminars was presented by Jones (2004). Her study was based on a mixed reaction received by the Faculty of Health & Behavioural Sciences at the University in 2003 that some seminars attracted a large proportion of the students whereas others were poorly attended. In her work two nominal groups were conducted: one with students at their beginning of their degree (early-stage students), and the other with recently completed students (late-stage students). The results shows that a total of 16 seminar topics were nominated by the early-stage students group while a total of 22 seminar topics were nominated by the second group. It was obvious from the results of the study that the students' preferences for seminar content are quite dissimilar to those anticipated by the development team. Only three of the students' top ten topics had been offered in the 2003 seminar series and a number of the preferred topics were outside the content areas that were under consideration for the 2004 series.

Case 7: Burrows et al. (2011) describes the development of a peer review of teaching model for the Faculty of Health at the University of Newcastle, Australia. The process involved using the nominal group technique to engage Faculty academic staff to consider seven key decision points that informed the development of the peer review of teaching model. The findings indicates that there was high levels of consensus on the structure and process of the developed peer review of teaching model due to the fact that participants from the Burrow et al. (2011) suggested that reviewers involved in providing feedback on an individual's teaching needs to be trained in the peer-review process. The paper also suggested that participants should consider peer review of teaching at all levels of teaching experience.

Since the choice of relative importance has always been subjective, I strongly believe that with some of the characteristics of nominal group technique mentioned above and the examples sited form the literature that has worked in other circumstances will reduce the subjectivity. The NGT makes it possible for a design team or group to quickly come to a consensus on the relative importance of issues, problems, or solutions by aggregating individual importance rankings into a team's final priorities.

Though, the origin of this technique was developed by Delbecq and Van de Ven and applied in committee decision-making as part of creative problem solving but the application has been found in many areas of interest such as health, education, marketing, civil service organization, policy making, etc. as a means of identifying various strategies and generating information that can be used in decision making. However, the nominal group technique has not been reported in the area of design.

In team work, the team is always used to do the ranking adopting the NGT. However, in using a team, conflicts do arise because every member of the team wants to make an input in concurrent engineering. The truth is that it is not the issue of concurrent engineering that matter but team approach to design is what is invoke in recent times. Team will be used to determine the design parameters in terms of choice of selecting materials. The design team is composed of experts in different field of engineering discipline such as production engineer, design engineer, manufacturing engineer, safety engineer, accountant, quality personnel, mechanical engineer, electrical engineer, maintenance engineer, and other functional area which form the decision making process working together for a common purpose, gaining a better understanding of project priorities and process discipline, making risks and compromises visible for better control. This design team is expected to work on a product right from the conceptual design stage to the finished stage concurrently. This implies that the design team which makes up the nominal group session in taking group decision forms the concurrent engineering team in developing a product right from the design stage and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirement.

In concurrent engineering, teamwork is allowed, and many stages and tasks as possible are done in parallel and every aspect of the product's development is given early consideration. A fundamental part of the concurrent engineering approach is to create a highly motivated, multidisciplinary team that performs the design work in real time. Human resources are by far most important element. To work effectively, the team members must accept to: adopt a new method of working; cooperate; perform design work and provide answers in real time; and contribute to the team spirit (Bandecchi et al. (1999). Reporting relationships are crucial, because to make fast cross-functional business decisions, the team must regard itself as an empowered business team, not just a group of functional representatives or a band of engineers (Preston 1998). Concurrent engineering uses the principles of product design methods such as Design for manufacturing, Design for assembly, Design for quality, Design for cost, Design for reliability, Design for safety, Design for produceability, etc., for improving the efficiency and effectiveness in product development process and manufacturing.

2 Literature Review

The nominal group technique originated by Andre Delbecq and Andrew Van de Ven in 1968 (Delbecq et al. 1975) for conducting potentially problematic group meetings involving a set of procedures for conducting group sessions. It is a popular technique and one of the most successful processes for structuring group meetings (Duggan et al. 2004; Dowling et al. 2000). The technique has been extensively applied in education, business, health, social and governmental organizations (Moore, 1987). In addition, Clark and Stein (2004) demonstrated the value of the nominal group technique as a means to effectively and efficiently incorporate stakeholders into a public land management agency's recreation planning process. The technique is especially useful for idea generation and also helps guide future recreation management decisions and program development. The technique not only allowed meeting participants to brainstorm ideas and generate a comprehensive list of possible recreation opportunities, but also led them through a process of reaching a consensus on what the most desirable opportunities might be.

Similar in format to a focus group, the nominal group technique is essentially an organized discussion with a small group of participants between 9 and 12 designed to generate and prioritize ideas about a particular topic (Siemer et al. 2001; Odu and Okereke 2012). Evaluation Briefs (2006) gave a brief discussion and definition of nominal group technique, how to prepare for it, process to conduct it, when to use it, and the advantages and disadvantages of its use. Claxton et al. (1980) illustrates the adaptation and modification of the NGT from the field of organizational planning for use in the study of consumer behavior. The proposed method was compared to traditional group interviews and structured survey methods. Their findings show that NGT provides structured output that can be analyzed at an individual level with opportunity to hear the views of others. Thus, the data output is more structured than is usual with group methods.

The nominal group technique is used to engage in consensus planning for the purpose of prioritizing issues (WBI Evaluation Group 2007). Clive (2012) presented a paper on NGT discussing the possible use in the types of market research or management research where it is desirable to generate as many ideas as possible. NGT is found to be particularly helpful for facilitating group discussions to identify and prioritize patient's needs (CHESS 2006). Potter et al. (2004) also discusses and describes the NGT protocol so that physiotherapists might consider it for use in future physiotherapy research. The authors described the application of the technique in health care research in providing an effective means of addressing a number of clinical practice issues such as developing or reviewing practice guidelines, addressing quality assurance matters, as well as identifying both practitioner and consumer needs and concerns, while also increasing awareness among physiotherapists of the potential application of the NGT in physiotherapy research. Ritchie (1999) has also described the current era of physiotherapy research to be that of expert evaluation, where researchers seek to accumulate objective proof that forms the basis of evidence-based practice. This method is utilized to evaluate the effectiveness of physiotherapy interventions, but does not consider individual patient's experiences in clinical practice. Vella et al. (2000) adopted nominal group technique as a feasible and reliable method for determining research priorities among clinicians. The results suggest that clinicians perceive research into the best ways of delivering and organizing services as a high priority, ensuring the likelihood of the results influencing clinical practice and policy. Borysowich (2006) adopted the NGT method to drive a team decision as a formal procedure for identifying, discussing, and ranking issues, problems or ideas in a group setting. Van Teijlingen et al. (2006), and CTU Course Assignment (2011) outlined the differences between Dephi method and Nominal group technique and were applied in family planning and reproductive health research. According to the authors, both methods are the two of the most common so-called "Consensus Methods", commonly used to synthesize information from conflicting evidence. In the work of Rupert (2008), consensus techniques comprising of Dephi technique and nominal group technique were illustrated, to elaborate and agree on recognition criteria and quality standards for self-assessment in the areas of capacity, expertise in the therapeutic area, established quality assurance systems of the network, potential conflicts of interest and ability to share in relation to competencies and experience.

Qualitative methods are increasingly recognized as valuable, yet practitioners face difficult decisions in their choice of method and the process of analysis. The nominal group technique combines quantitative and qualitative data collection in a group setting, and avoids problems of group dynamics associated with other group methods such as brainstorming, Delphi and focus groups (Gallegher et al. 1993). Delbeg and Van de Ven, (1972) presented a paper on a group process for conducting an exploration of the qualitative and quantitative elements, patterns and total structure of a health care problem under preliminary investigation. This group process is described as pilot research instrument for exploratory investigations prior to the use of more traditional measurement techniques such as questionnaires and field interviews. McCawley (2009) carried out a work on methods for conducting an educational needs assessment in which nominal group technique is one of the methods that was highlighted for work groups to set goals, identify problems (a component of a needs assessment), create ideas and suggestions to solve problems, or plan programs for an organization. Duggan et al.

(2004) proposed a joint application development (JAD) as a facilitated group technique that can be used in systems requirements determination (SRD). This was designed to encourage team rapport and achieve synergy by leveraging the combined knowledge of participants. In this study, we integrated JAD and nominal group technique (NGT), a popular group structure that has been used to reduce the effects of negative group dynamics on task-oriented objectives. The integrated structure was used to examine in a laboratory experiment to determine whether it could alleviate the problems that JAD has experienced during SRD. The results suggest that the integrated approach outperformed JAD in our test environment; it was as efficient as JAD alone and it appeared to contribute to the reduction of the need for great facilitation skills in group decision-making.

Concurrent engineering is a production management philosophy that has received much attention in manufacturing, and to a lesser extent construction over the past several decades (Bogus et al. 2005). The authors proposed a methodology in reducing design delivery time. In order to achieve desired time-saving goals, concurrent engineering was adopted, to advocate concurrent, overlapped processes instead of sequential product and process design. The extent to which two activities can be effectively overlapped depends on the relationship between those activities (Prasad 1996; Yassine et al. 1999). Pullan et al. (2010) applied concurrent engineering in manufacturing industry where an analysis of existing solutions to the problem of concurrent optimization of the design, and the process planning stages when a new product is developed was addressed. Yassine and Braha (2003) focus on four critical problems that challenge management while implementing CE in complex product development (PD) project. He described these problems by proposing a unified modeling and solution approach based on the design structure matrix (DSM) method, which is an information exchange model that allows managers to represent complex task relationships better plan and manage CE initiatives. Mitra and Sinha (1999) applied concurrent engineering in design of new automobile and demonstrated it with an example. A clustering algorithm, called Bond Energy Algorithm (BEA) was applied to identify design activities, which can be performed simultaneously. Bandecchi et al. (1999) adopted the concurrent engineering and applied it to space mission assessment and design. Kim et al. (2000) discusses the development of a concurrent engineering system for the design of composite structures, to compose the architecture of concurrent engineering system, the commercial and non-commercial programs related to design and analysis of composite structures are surveyed and classified. Sweitzer (2002) proposed simulation-based process for assembly cell design and used it for the initial design of a work cell. Also the thesis explores the value of implementing process concurrently with product design. Minis et al. (1999) describes the general approach for performing manufacturability evaluation and subcontractor selection concurrently. Also, Abdalla (1998) demonstrates the use of constraint networks for modeling the knowledge which is necessary for concurrent product and process design. Edward (2002) investigates the strategic application of materials and manufacturing process information during the design process. Methods were described for effective integration of quantitative and qualitative materials, manufacturing and assembly process information during product design. Dowlatshahi (2001) explores the role of product safety and liability in the early stages of product design in a concurrent engineering environment. The paper presents a system approach to product safety, a conceptual framework for design for safety and liability, and a product safety program, which covers the three safety techniques of preliminary hazard analysis, fault tree analysis, and failure mode and effect analysis.

Shehab and Abdalla (2001) developed an intelligent knowledge-based system that accomplishes an environment to assist inexperienced users to estimate the manufacturing cost modeling of a product at the conceptual design stage of the product life cycle. Myint and Tabucanon (1998) presented a paper on the framework and development of an expert system to generate alternative products based on the information of customers' need and existing products derived from the product realization model. Vasile (2004) discussed the evolution of the concurrent design process under uncertainties through the whole design process as a function of the co-evolutionary rules. Makinen (2010) also applied concurrent engineering approach to plastic optics design. Ismail et al. (2009) applied concurrent engineering approach in designing pressure vessel. The case study shows how the effect of implementation of the Design for Manufacture and Assembly (DFMA) in product development process. McKee (1992) suggests that cross-functional teams are conducive in a high change environment because they enhance communication and organizational learning. Communication is a vital and basic element in organizational activity. Communication for a complex process such as the new product development process is extremely important.

2.1 Why use Nominal group technique?

It makes it possible for a team or group to quickly come to a consensus on the relative importance of issues, problems, or solutions by aggregating individual importance rankings into a team's final priorities.

2.2 Benefits of Nominal group technique

- ✓ Helps eliminate biases and peer-pressure

- ✓ Encourages participation from all team members
- ✓ All opinions are heard and weighted equally
- ✓ When a team needs to create a list of options and rank them
- ✓ For a team or group to quickly come to a consensus on the relative importance of issues, problems or solution
- ✓ Reduce the number of ideas for easier handling
- ✓ Provide focused effort on topics of importance

2.3 Advantages and Disadvantages of NGT Advantages

- ✓ The NGT is more structured than the traditional focus group approach
- ✓ Through a NGT everyone in the group is given an opportunity to contribute to the discussion, while avoiding the likelihood of one person dominating the group process
- ✓ The nominal group technique can be used with small groups as well as with a larger number of participants
- ✓ With nominal group technique, issue can be prioritized, well represented among the members of the group.
- ✓ Usually, the quality of the ideas selected at the end of the session is very high. In fact, there have been numerous studies which prove that the quality of NGT ideas are better than compared to other group discussion making techniques, namely, interacting group, Delphi technique, etc. (Delbecq et al. 1975; Abdullah and Islam 2011).
- ✓ The NGT takes advantage of pooled judgments. This implies that the judgments of a variety of people with various talents, knowledge, experiences, and skill will be used altogether, and as a result, ideas are likely to be better than those that might be obtained by other methods.
- ✓ People do not look stupid in front of others. The essence of NGT is that it avoids that fear by seeking anonymous inputs from everyone.
- ✓ The NGT helps a group of people who fail to take a unanimous decision to arrive at a decision on the basis of group majority

Disadvantages

- ✓ The technique cannot deal with more than one issue at a time. Nominal group technique is limited to a single purpose, single-topic meeting.
- ✓ Nominal group technique requires considerable amount of time (about 90 minutes) to arrive at a decision.
- ✓ Nominal group technique requires a trained facilitator who is expected to have prior experience in conducting or at least attending nominal group session. In addition, NGT requires a meeting room equipped with a proper seating arrangement, and other materials
- ✓ The combined effort of individual members being experienced in more open-ended focus groups may not develop as easily in the nominal group approach.
- ✓ While there is a range of group sizes with which the NGT can be used, it is hard to implement it effectively with large audiences unless very carefully planned beforehand.
- ✓ The nominal group technique may feel somewhat mechanical to some participants. This can be avoided to some extent by ensuring that the facilitator shows flexibility in process and implementation.

2.4 Requirements for conducting a nominal group session

There are a number of requirements for a successful application of nominal group technique. First of all, a group should be formed comprising 9 to 12 persons who are expected to be knowledgeable about the issue for which the session is convened. It is preferable if the participants are of diverse background. For instance, in an engineering organization, group members may come from various departments like structural engineers, mechanical engineers, electrical engineers, project engineers, safety engineers, chemical engineers, cost engineers, quality control, production engineers, etc. The reason for having diverse experience among these people is the fact that people can visualize the issue from different perspectives in order to provide different types of ideas on the issue.

Secondly, a room should be prepared with a U-shaped table preferably. Other working materials that should be needed include a marker board, marker pen and some papers.

A facilitator should be chosen who is expected to have prior experience in conducting or at least attending a nominal group session. The facilitator is also expected to be an unbiased person and he/she is not supposed to direct the group at reaching a particular decision. Much of the success of a nominal group session depends upon the ability of the facilitator (Abdullah and Islam 2011).

3. Other Applications of NGT

The nominal group technique is applicable to a wide range of company decision situation with a good chance of success. Some of the areas it can be applied are:

- Setting of company policies
- Resolution of controversial issue
- Identifying and defining company problems in a manner that can be solved
- Implement policies or solution techniques
- Identify root causes of company problems
- Suggest solution technique.

3.1 The Basis for Concurrent Engineering

The concurrent engineering evolved as a result of problems of the conventional approach to product development process. This is due to isolated efforts to improve the efficiency and effectiveness in product development process and manufacturing. . In the following sections, some of the problems associated with the conventional product development process and the progressive improvements which finally metamorphosed into concurrent engineering are outlined.

3.2 The problems of the conventional approach

There are five categories of problems associated with conventional approach to product development process that have been identified. This includes: product definition related problems, product design related problems, factory design related problems, manufacturing related problems and general problems.

(i) Product Definition Problems:

- ✓ Too little time spent on
- ✓ Articulating the product vision
- ✓ Understanding customer needs
- ✓ Stating product design specification
- ✓ Product development success not well understood.

(ii) Product Design related Problems

- ✓ Too long a time spent on product design because CAD were not predominant;
- ✓ Long time spent on redesign
- ✓ Component design treated independently taking no advantage of similar designs.
- ✓ Concept optimization not a part of the design process
- ✓ Over-design was common
- ✓ Total design concept (team work) not applied.
- ✓ Prototyping machines unavailable
- ✓ No communication between the design and manufacturing engineers in the design process (commonly called "over-the-wall" design approach)
- ✓ Product quality not considered at the design stage.

(iii) Factory Design Problems

Because the functional layout was the type of factory design, it introduced very unproductive manufacturing environment. The functional was characterized by functional departments: e.g. lathe, milling, drilling, sawing departments and parts with independently planned routes that shuttle long distances between departments for processing.

The associated problems are:

- ✓ Complex in-process flow pattern which made production planning and control difficult,
- ✓ Numerous machine set-ups or changeovers which increase production cost,
- ✓ Lots of material handling problems caused by interdepartmental parts' travels,
- ✓ Unpredictable products' assembly time,
- ✓ Long product make span
- ✓ Many due-date disappointments.

(iv) Manufacturing and Management Problems

- ✓ Poorly defined manufacturing Engineering functions
- ✓ Difficulty in meeting ever changing customer demands because of long innovation periods,
- ✓ Mostly manual fabrication and assembly of components
- ✓ Quality control problems because of TQM concepts were not known,
- ✓ Production control problems arising from the complex in-process work flow pattern,
- ✓ Feuds between quality control, production control and maintenance departments.

(v) General problems

The following are general problems associated with the conventional approach:

- ✓ Too many product development process stages—15 of them as presented in figure 2
- ✓ All the stages were serial --- a stage commences only when its predecessor is completed
- ✓ Long product development process lead times caused by the many serial stages
- ✓ Lack of team work culture
- ✓ Product Failures were common because the customer needs were not considered during design
- ✓ Product design errors and redesigns were many,
- ✓ No strategy for maximum customer satisfaction
- ✓ Longer product life cycle
- ✓ Poor economies of scale therefore high product unit cost
- ✓ No strategies for systematic product innovation.

3.3 The Modern Approach to Product Development Process

Product and process technology is rapidly evolving. Competition is becoming more and more globally based and customers are placing an increased emphasis on quality and reliability, but at the same time looking for good value. Time to market, or speed to market is becoming a paradigm of world class manufacturing. To respond to this challenging environment, and to improve the efficiency and effectiveness in product development process and manufacturing, manufacturers are implementing concurrent engineering, a modern approach to product development process.

3.4 Structure of concurrent engineering

Before concurrent engineering can be well implemented, there are important factors that need to be considered, which form the framework or structure for the discussion of concurrent engineering as presented in Figure 1.

1. Organizational factor: This comprises of three aspect – cross-functional teams, liaison personnel and job rotation

(a) Cross-function teams:- Project team members gain a better understanding of project priorities and process discipline, making risks and compromises visible for better control. The design team is composed of experts from engineering, production, marketing, design engineer, manufacturing engineer, safety engineer, accountant, and any other functional area which has a vested interest in the development project, and the customer too are all deeply involved at the product design specifications and the conceptual design using optimization principles, then the customer will be fully satisfied through high quality and reliable products at low prices. The team is formed to work on a specific project, and stays together throughout the development of the product. This approach seems more recent, as it has been discussed throughout the forties, fifties, and sixties as a viable mode of accomplishing complex development work. A group of engineering specialists working together in one room, using sophisticated tools, are all essential elements but they are not sufficient to create a collaborative environment. On the contrary, it might become the place where conflicts are amplified. Above all else, the group of specialists must work as a team.

(b) Liaison personnel:- Liaison personnel are not members of any functional piece of an organization, but rather people who are capable and prepared to address issues which span functional organizational boundaries. Liaison Personnel have as their full-time job the coordination of the disparate functions. Under this approach, they become the primary modes of accomplishing information transfer between functional areas.

(c) Job rotation: - Job Rotation means to rotate personnel between functional categories. These personnel are assigned temporarily or permanently outside of their accustomed functional specialty, for instance, manufacturing engineer will work with design engineers or vice versa. Thus it is possible to integrate the various knowledge bases without making significant structural changes to the organization. Job rotation does seem to have useful integration benefits.

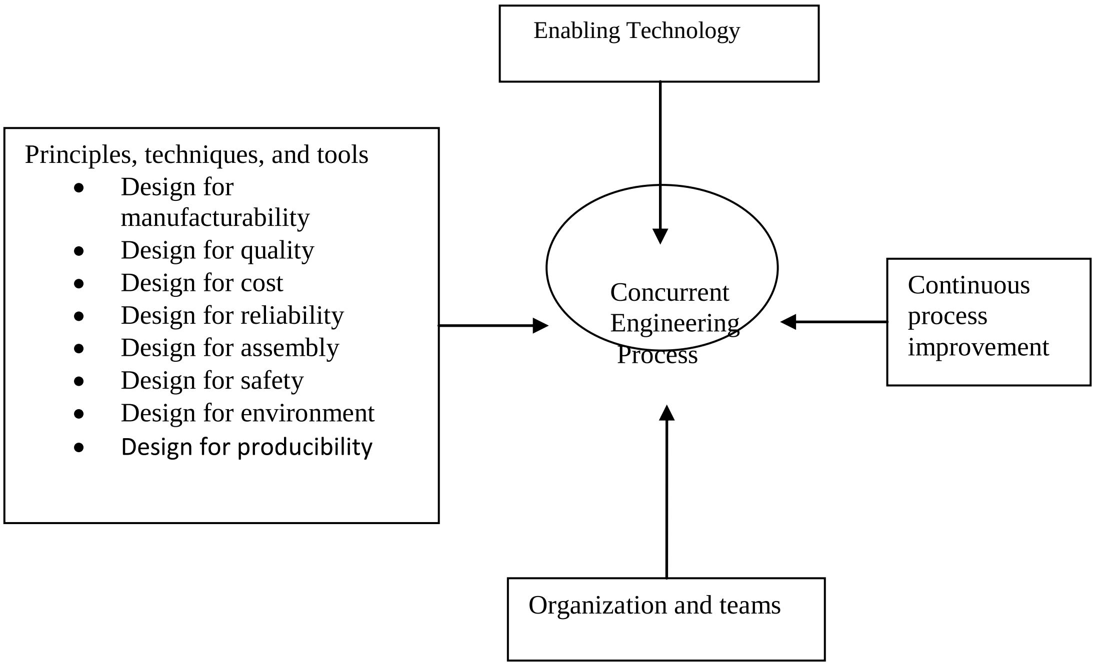

Fig. 1. A framework of concurrent engineering

2. Principles, Techniques, and Tools

(a) Product Design Methods

✓ ***Design for Manufacturing (DFM) -*** DFM seeks to minimize manufacturing information content of a product design to the fullest extent possible within constraints imposed by functionality and performance.

1. Minimize the total number of parts
2. Simplify the design to ensure that the remaining parts are easy to fabricate, assemble, handle and service
3. Standardize where possible to facilitate desirable produceability characteristics such as interchangeability, interoperability, simplified interfaces, effective consolidation of parts and function, availability of components and so forth.

✓ ***Design for Quality -*** can be implemented in the system design step by intentionally designing the product and process to be tolerant of variation

✓ ***Design for Cost -*** It is essential that industrial organizations have viable and responsive cost analysis and control systems. Effective analysis of product or project costs and the ability to implement cost control management includes management of the product or project cost, and this requires a knowledge and understanding of the cost elements and their sensitivity to various control parameters. Cost analysis forms the basis for cost control, and without accurate and timely cost data, effective cost control is impossible. The most accurate and timely cost data are useless unless coupled with an effective cost control mechanism.

✓ ***Design for Assembly (DFA) -*** Seeks to minimize cost of assembly within constraints imposed by other design requirements. DFA has been the starting point for development of a corporate DFM philosophy and the culture change that accompanies it. The design for assembly is a systematic procedure to maximize the use of components in the design of a product.

✓ ***Design for Safety -*** The designer must develop the habit of constantly evaluating the design for safety, considering not only the design itself but the personnel involved in fabricating the product, using the procedure, and in maintaining and repairing the product or system as well as the end user or purchaser. Developing the manufacturing processes as well as the maintenance and operating procedures early during the design process will assist in revealing safety problems at a time when corrective action can be taken at minimum cost.

- ✓ ***Design for Reliability*** **-** Reliability is defined as the probability that a system device or component will successfully perform for:

1. A given range of operating conditions
2. A specific environmental condition
3. A prescribed economic survival time

- ✓ ***Design for X*** **-** Help to ensure that parts and products are correctly designed to be produced using a particular production process or method such as plastic injection molding or sheet metal stamping.

(b) Enabling Technology

Successful concurrent engineering could not have been possible without the enabling technology of the following manufacturing management entities or operational philosophy.

(i) Group Technology (GT)

- ✓ GT philosophy which states that many problems are similar and that by identifying such set of problems, one solution can be found for the set, thereby saving time and effort (very important for CE).
- ✓ Discrete parts coding system which allows numerical description of individual parts for easy identification of a group of similar parts.
- ✓ Cellular manufacture (processing of a set of similar parts in one cell to eliminate total machine set-up and parts transportation time).
- ✓ Flexible manufacturing (processing of different batches of parts in in one cell)
- ✓ Feasible automated design of parts.

(ii) Composite Material Production and Nanotechnology Automation

- ✓ Automatic Identification system
- ✓ Robots in manufacturing
- ✓ Direct numerical control
- ✓ Computer numerical control
- ✓ Artificial Intelligence in controls

(iii) Systems engineering and Management Science

- ✓ Operation Research Paradigm to problem definition
- ✓ Optimization principles
- ✓ Systems dynamics modeling methodology
- ✓ Scheduling algorithms and software packages
- ✓ Knowledge-based software and expert systems
- ✓ Statistical packages
- ✓ Mathematical programming software packages
- ✓ Control theory

(iv) Total Quality Management

- ✓ Maximum customer satisfaction philosophy
- ▪ Internal customer
- ▪ External customer
- ✓ Team cooperation emphasized
- ✓ All workers involvement in quality and cost management
- ✓ Hospitality
- ✓ Autonomy of the individual and participative management
- ✓ Learning organization
- ✓ Get-it-right at first attempt
- ✓ Total design concept which calls for systematic design activities encompassing product, people, process and organization from stage 1 to the last of product development.

(c) *Integrated Computer Analysis*

This is based on the recognition that steps in the development of a manufactured product are interrelated and can be modeled effectively by using computers. This relationship comes about not only from the characteristics of the part being fabricated but also from the processes, specifications, instructions and data that define and direct each step in the manufacturing process. For sometimes, *Concurrent Engineering* was operational without necessarily being given any name. It worked through the introduction of Computer-Aided

Design (CAD), Computer-Aided Manufacturing (CAM), Computer Aided-Engineering (CAE), Computer Aided Process Planning (CAPP), Computer-Aided Costing (COE), and Computer Integrated Manufacturing (CIM), respectively, into product development process. It is, however, clear now that the following Concurrent Engineering arrangement was what took place: CAD performs the combined activities of the following product development process stages in parallel - preliminary design, prototyping, and detail design; CAM & CAPP perform the activities in stages - Material and process selection, Operations design, Facilities Design, and Cost Estimation; CIM performs the activities in stages - Pilot Production, Commercial production and Assembly, and Production management (PPC, QC, Safety, etc.).

3.5 Application of Concurrent Engineering

The concurrent engineering application as presented in figure 3 has shown that the number of serial stages has been reduced from 15 to 9 as compared to the conventional product development process shown in Fig. 2, with the use of CAD, CAM, and CIM applications which has tremendously increase speed of product development process, quality and reliability of the product, and has greatly shortened the product development process lead time and above all makes the company more competitive.

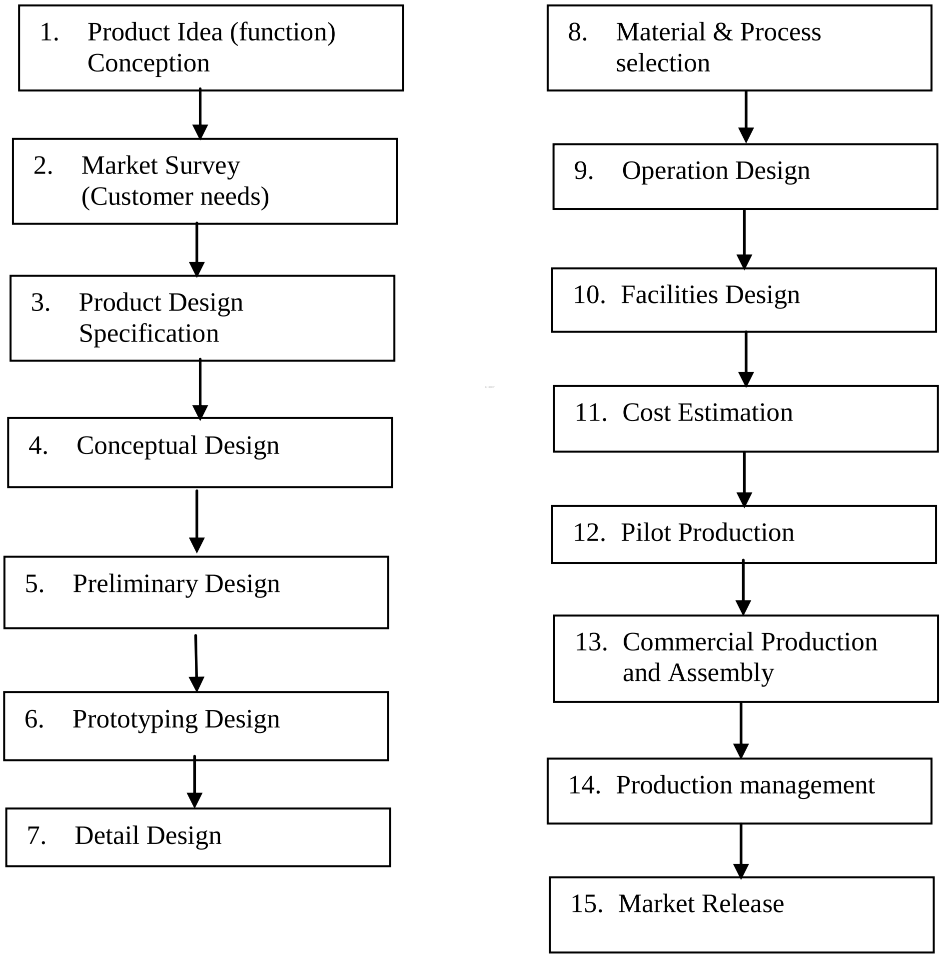

Fig. 2 Conventional Approach in Product development Process

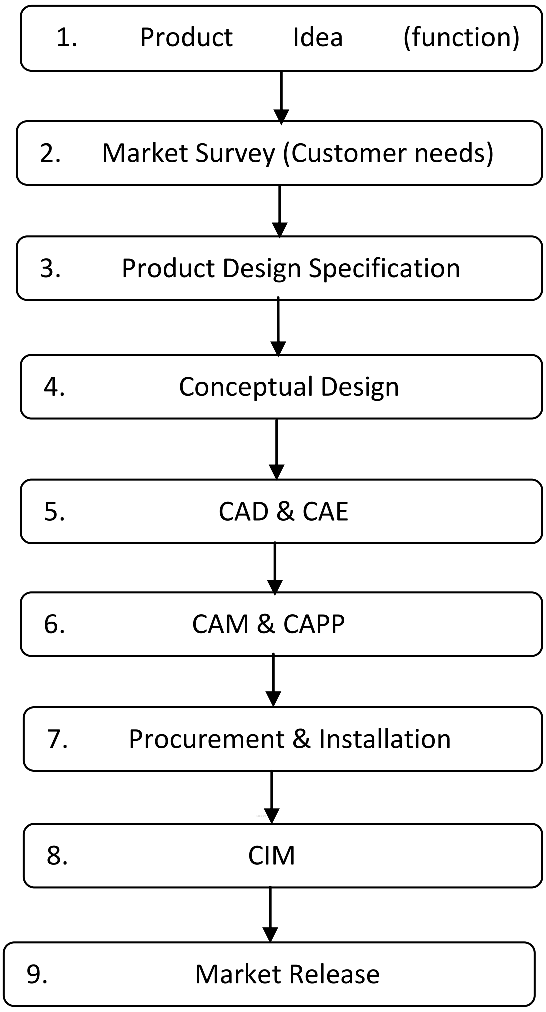

Fig. 3 Application of concurrent engineering in Product development process using CAD, CAM and CIM

Through the introduction of CAD, CAM, CAE, CAPP and CIM, respectively, into product development process. It is, however, clear now that the following Concurrent Engineering arrangement was what took place:

CAD performs the combined activities of the following product development process stages in parallel (see Fig 2):

- 4: Conceptual design
- 5: Preliminary design,
- 6: Prototyping,
- 7: Detail design

CAM & CAPP perform the activities in stages

- 8: Material and process selection,
- 9: Operations design,
- 10: Facilities design,
- 11: Cost estimation.

CIM performs the activities in stages

- 12: Pilot production,

- 13: Commercial production and Assembly,
- 14: Production management (PPC, QC, Safety, etc.).

3 Conclusion

This paper has provided the details of various steps of nominal group technique, its rules of applications and advantages. The most mentionable advantage of NGT is that it ensures balanced and fair participation among the group members. The nominal group technique which is non-interactive approach that can be used to reduce the subjectivity in obtaining preference weights as a result of human factor and has been proven to be useful in generating large number of ideas in a wide variety of contexts. It has been shown how the technique can be applied to solve maintenance related issues in an engineering firm. It also discusses the link between nominal group technique and concurrent engineering.

In addition, this work also discusses the implementation of concurrent engineering in product development process. With respect to design process, the main idea in concurrent engineering is to make sensible trade-offs between different design parameters. The purpose is to find optimum global design with respect to cost, quality and performance of the whole system, and also to meet the market demand due to the competitiveness, and customer satisfaction. The implementation of this concurrent engineering element will reduce rework of the component, because the manufacturing process is considered during the early stage of the product development design. In summary, concurrent engineering leads to improved customer satisfaction, improved quality, reduced cost, reduced new product development time, reduced time to market, and reconciliation of conflicting requirements in product development.

References

[1]. Abdalla, H. S. (1998). A Concurrent Engineering Constraint-Based System. Computers and Engineering, vol. 35, Nos 3-4 Pg. 459-462.

[2]. Abdullah, M. M., Islam, R. (2011). Nominal Group Technique and its Applications in Managing Quality in Higher Education. Pak. Journal of Commercial &Social Sciences. Vol. 5 (1), Pg. 81-99.

[3]. Bandecchi M., Melton, B., Ongaro F. (1999). Concurrent Engineering Applied to Space Mission Assessment and Design. Esa bulletin 99.

[4]. Beywl W., Potter P. (1998). RENOMO – A Design Tool for Evaluations. Designing Evaluations REsponsive to Stakeholders' Interests by Working with NOminal Groups using the Moderation method. SAGE Publications, London, (Thousand Oaks and New Delhi) , vol. 4 (1), pg. 53-71

[5]. Bogus, M. S., Molenaar, R. K., Diekmann, E. J. (2005). Concurrent Engineering Approach to Reducing Design Delivery Time. Journal of Construction Engineering and Management ASCE, Vol. 131, No. 11, pg. 1179-1184.

[6]. Borysowich C. (2006). Using the Nominal Group Method to Drive a Team Decision. Enterprise Technology Architect and EAI Blog Entries. http://it.toolbox.com/blogs/enterprise-solutions/using-the-nominal-group-method-to-drive-a-team-decision-11774

[7]. Burrows T., Finlay N., Killen C., Dempsey S. E., Hunter S. (2011). Using Nominal Group Technique to Develop a Consensus Derived Model for Peer Review of Teaching Across a Multi-school Faculty. Journal of University Teaching & Learning Practice. Vol. 8, Issue 2, No. 8.

[8]. Charles-Owaba O. E. (2002). Civil Services efficiency and effectiveness: Principles and Procedures. Edited by Egbe Ifie, Published by OPUTORU Books, Ibadan, Bomadi, Oleh, Ughelli, Asaba. Civil Service Series 4, pg. 167-181.

[9]. Charles-Owaba O. E. (2004). A theorical basis for industrial ailment diagnosis and remedy. Science Forum Journal of Pure and Applied Science, Vol. 7 (2), pg. 271-284.

[10]. Chen S.G., Lin L. (2003). Decomposition of interdependent task group for concurrent engineering. Computers & Industrial Engineering, Vol. 44, pg. 435-459.

[11]. Clark, K. J., Stein, V. T. (2004). Appliying the Nominal Group Technique to Recreation Planning on Public Natural Areas. Journal of Park and Recreation Administration, vol. 22, No. 1, Pg. 1-22.

[12]. Claxton J. D., Ritchie J. R. B., Zaichkowisky J. (1980). The nominal group technique: Its potential for consumer research.

[13]. Clive B. (2012). The Nominal Group Technique: An aid to Brainstorming ideas in Research. Qualitative Market Research, An International Journal, vol. 15. Iss. 1, pg. 6-18. DOI: 10.1108/13522751211191964

[14]. CTU Course Assignment Blogs (2011). Dephi Method or Nominal Group Technique? Posted by Kamberi, http://cs855sk.blogspot.com/2011/01/delphi-method-or-nominal-group.html

[15]. Delbeg A. L., Van de Ven, A. H. (1972). The nominal Group as a Research Instrument for Exploratory Health Studies. Am J. Public Health, 62(3), pg. 337-342.
[16]. Delbeg A. L., Van de Ven, A. H., Gustafson D. H. (1975). Group Technique for Program Planning: A Guide to Nominal Group and Delphi Processes. Scott Foresman and Company, Glenview IL.
[17]. Dowlatshahi S. (2001). The role of product safety and liability in concurrent engineering, Computers and Industrial Engineering. Vol. 41, Pg. 187-209.
[18]. Dowling K. L., St. Louis R. D. (2000). Asynchronous implementation of the nominal group technique: Is it effective? Decision Support Systems. Vol. 29 (3), Pg. 229-248
[19]. Duggan, W. E., Thachenkary, C. S. (2004). Integrated nominal group technique and joint application development for improved systems requirements determination. Information & Management, vol. 41, Pg. 399-411.
[20]. EducationWorld (2013). Evaluating Ideas and Deciding: The "Nominal Group" Technique. 290 Pratt St. Meriden, CT 06450. http://www.educationworld.com/a_admin/greatmeetings/greatmeetings023.shtml
[21]. Edwards, K. L. (2002). Towards more Strategic Product Design for manufacture and Assembly: Priorities for concurrent engineering. Materials and designs, Vol. 23, Pg. 651-656.
[22]. Evaluation Briefs (2006). Gaining Consensus among Stakeholders through the Nominal Group Technique. Department of Health and Human Services. Centers for Disease Control and Prevention (CDC). http://www.cdc.gov/healthyyouth/evaluation/pdf/brief7.pdf
[23]. Ford N. D., Sterman D. J. (2003). The Liar's Club: Concealing Rework in Concurrent Development. CONCURRENT ENGINEERING: Research and Applications, vol. 11, No. 3, pg. 211-219.
[24]. Gallegher M., Hares T., Spencer J., Bradshaw C., Webb I. (1993). The nominal group technique: a research tool for general practice? Farm. Pract. 10(1) pg. 76-81
[25]. Gresham N. J. (1986). Expressed Satisfaction with the Nominal Group Technique Among Change Agents. A Dissertation submitted to the Graduate College of Texas A & M University in partial fulfillment of the requirements for the degree of doctor of Philosophy.
[26]. Gunasekaren, A., Goyal, S. K., Virtanen, I., and Yli-Oli, P. (1994). An investigation into the application of Group technology in advanced manufacturing systems. Internal Journal of Computer Integrated Manufacturing, vol. 7, pg. 215-228.
[27]. Haque B., Pawar S.K., Barson R. J. (2003). The application of business process modeling to organizational analysis of concurrent engineering environments. Technovation, Vol. 23, pg. 147-162.
[28]. Hegedus M. D., Rasmussen V. R. (1986). Task Effectiveness and Interaction Process of a Modified Nominal Group Technique in Solving an Evaluation Problem. Journal of Management Winter, vol. 12 No. 4, pg. 545-560. DOI: 10.1177/014920638601200409
[29]. Hsiao S.W. (2002). Concurrent design method for developing a new product. International Journal of Industrial Ergonomics, Vo. 29, pg. 41-55.
[30]. Islam M. N. (2003). Functional dimensioning and tolerancing software for concurrent applications. Computers in Industry, Vol. 54, pg. 169-190.
[31]. Ismail A. R., Manap A. H. A., Wahap D. A., Zulkifli R., Makhtar N. K., Sopian K. (2009). Concurrent Engineering Approach in Designing pressure Vessel. European Journal of Scientific Research, Vol. 30, No. 2, Pg. 245-252
[32]. Jones C. S. (2004). Using the nominal group technique to select the most appropriate topics for postgraduate research students' seminars. Journal of University Teaching & Learning Practice, Vol. 1, Issue 1, No. 4. http://ro.uow.edu.au/jutlp/vol1/iss1/4
[33]. Kim, J. S., Kim, C. G., Hong, C. S., Hahn, H. T. (2000). Development of concurrent engineering systems for design of composite structures. Composite Sructures, Vol. 50, pg. 297-309.
[34]. Koufteros X., Vonderembse M., Doll W. (2001). Concurrent engineering and its consequences. Journal of Operations Management, Vol. 19, pg. 97-115.
[35]. Kuo-Hung T., Shi-Jer L., Diez C. R.., Hung-Jen Y. (2006). Using online Nominal Group Technique to Implement Knowledge Transfer. Journal of Engineering Education, pg. 335-345.
[36]. Macphail, A. (2001). Nominal group Technique: A useful method for working with young people. British Educational Research Journal, vol. 27, No. 2, Pg. 161-170.
[37]. Makinen J. T. (2010). Concurrent Engineering Approach to Plastic Optics Design. Dissertation to be presented to the Faculty of Technology of the University of Oulu for public defence in Op-Sali, Linnanmaa. VIT Publications 753.
[38]. McCawley F. P. (2009). Methods for Conducting an Educational Needs Assessment. Guidelines for Cooperative Extension System professionals. University of Idaho Extension, University of Idaho, Moscow, Idaho 83844.

[39]. Minis I., Herrmann W. J., Lam G., Lin E. (1999). A Generative Approach for Concurrent Manufacturability Evaluation and Subcontractor Selection. Journal of Manufacturing Sytems, vol. 18. No. 6, Pg. 383-395

[40]. Mitra, S., Sinha, B. (1999). Application of Concurrent Engineering in New Automobile Design. Operations Management Group. Indian Institute of Management, Calcutta, India.

[41]. Moore, C. M. (1987). Group Techniques for Idea Building Newbury Park, Califonia. Sage Publications.

[42]. Myint S., Tabucanon M. T. (1998). The framework for an expert system to generate alternative products in concurrent engineering design. Computers in Industry, Vol. 37, Pg. 125-134.

[43]. Odu, O.G., and Okereke, N. (2012). The Application of Nominal Group Technique as a Decision Making tool. Journal of Engineering and Applied Sciences, vol. 4, Pg. 61-66.

[44]. Potter M., Gordon S., Hamer P. (2004). The Nominal Group Technique: A useful consensus methodology in physiotherapy research. New Zealand Journal of Physiotherapy, vol. 32 (3), pg. 126-130

[45]. Prasad, B. (1996). Concurrent engineering fundamentals: Integrated product and process organization, Prentice Hall, Upper Saddle, River, N. J.

[46]. Preston G. S. (1998). Concurrent Engineering Team. Chapter 32 The Field to Guide to Project Management, David I. C., Editor, John Wiley & Sons.

[47]. Pullan, T. T., Bhasi, M., Madhu, G. (2010). Application of concurrent engineering in manufacturing industry. International Journal of Computer Integrated Manufacturing, 23 (5), pg. 425-440.

[48]. Rafikul Islam (2010). Group decision making through nominal group technique: Am empirical Study. Journal of International Business and Entrepreneurship Development, vol. 5, No. 2, pp. 134-153.

[49]. Recreation and Tourism Research Institute (Editor) (2007). Nominal Group Technique. What is a Nominal Group Technique? A Guide to Research Tools. Nanaimo. Recreation and Tourism Research Institute

[50]. Ritchie J. E. (1999). Using Qualitative Research to Enhance the Evidence-based Practice of Health Care Providers. Australian Journal of physiotherapy, vol. 45, pg. 251-256

[51]. Rupert N. (2008). Recognition criteria and quality standards for members of the European Pediatric Research Network. Final results of the Dephi Surveys. EULAR Centre of Excellence in Rheumatology.

[52]. Shehab E. M., Abdalla H. S. (2001). Manufacturing cost modeling for concurrent product development. Robotics and Computer Integrated Manufacturing, Vol. 17, Pg. 341-353.

[53]. Siemer, W. F., Connelly, N. A., Brown, T. L., and Decker, D. J. (2001). Methods of inquiring: Some basics for the manager. In D. J. Decker, T. L. Brown, and W, F. Seimer (Eds), Human dimensions of wildlife management in North America, pg. 375-400.

[54]. Sweitzer J. T. (2002). A simulation-Based concurrent engineering approach for assembly system design. Thesis submitted to the Sloan School of Management and the Department of Mechanical Engineering in Partial Fulfillment of the Requirements for the Degrees of Master of Business Administration and Master of Science in Mechanical Engineering.

[55]. The Center for Health Enhancement Systems Studies (CHESS) (2006). The Nominal Group Technique, University of Wisconsin-Madison.

[56]. Valle S., Vazquez-Bustelo D. (2009). Concurrent engineering performance: Incremental versus radical innovation. Int. J. Production Economics 119, 136-148.

[57]. Van Teijlingen E., Pitchforth E., Bishop C., Russel E., (2006). Dephi method and nominal group technique in family planning and reproductive health research. Journal of Family Plaaning Reproductive Health Care 32(4) pg. 249-352.

[58]. Vasile M. (2004). Evolution of the Concurrent Design Process Under Uncertainties. Concurrent Engineering for Space Application Workshop, ESTEC, Noorwiik, Netherlands.

[59]. Vella K., Goldfrad C., Rowan K., Bion J., Black N. (2000). British Medical Journal (BMJ), 320(7240), pg. 976-980.

[60]. WBI Evaluation Group (2007). Nominal Group Technique: Needs Assessment Knowledge Base. http://siteresources.worldbank.org/WBI/resourses/213798-1194538727144/7Final-Nominal Group Technique.pdf.

[61]. Yassine, A. A., Chelst, K. R., and Falkenburg, D. R. (1999). A decision analytic framework for evaluating concurrent engineering. IEEE. Trans. Eng. Management, 46 (2), 144-157.

[62]. Yassine, A., Braha, D. (2003). Computer Concurrent Engineering and the Design Structure Matrix Method. Concurrent Engineering: Research and Application, vol. 11, No. 3, pg. 165-176.