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Decision Making using Dialogue Techniques and AHP applicable to Jet Engines Manufacturing

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Abstract*— Communication by effective dialogue among stakeholders is a key factor to understand and comply with project scope and service contract requirements. The great majority of the failures in projects and in the fulfillment of contract customer requirements is caused by lack of proper communication. In this paper, a process to identify the factors affecting an effective dialogue and a pairwise comparison-based method to identify the priority of factors grounded on AHP (Analytical Hierarchy Process) principles is proposed. The method presents important features that may appeal to decision makers: (1) search in databases to identify key factors affecting dialogue, (2) validation of the factors by specialists familiar with decision-making and (3) prioritization of factors using AHP (Analytic Hierarchy Process). The use of the proposed method is illustrated in one specific application on the jet engine overhaul process. The quality of the services performed on jet engines depends on the analysis of the service contract requirements. In the jet engine, manufacturing and overhauling business, the scope of work for engine manufacturing and overhaul services is documented in formal contracts. The customers (airlines) and the aircraft manufacturers (air framers) define the product requirements in formal contracts. The planning team in the repair station and manufacturing sites normally review the requirements in detail before starting production. Dialogue among stakeholders in this case is very important to ensure that contract requirements defined in contracts with customers are entirely met.

Index Terms*—Communication, AHP (*Analytic Hierarchy Process, Jet Engines, Manufacturing

I. INTRODUCTION

It is widely known that communication is a key factor in the decision-making, mainly in the jet engine manufacturing industry and evidences show that the lack of it can increase the risk of a jet engine failure. The objective of this paper is to study the communication process in a jet engine manufacturing environment to create a methodology to analyze the key factors that could influence dialogue and affect decision-making.

Omnipresent in the industry-manufacturing environment, poor decision making are usually detrimental. This is particularly crucial when decisions are not data driven, due to lack of dialogue and communication on the part of decision makers. This paper concentrates on the study of decision-making process under risk and uncertainty. In order to assess the trends and to identify the most important factors affecting dialogue, 46 experienced individuals with experience in the jet engine manufacturing process, took part in the study. The jet engines manufacturing industry in general faces a variety of risks, many capable of compromising the viability of an organization. The risks in this industry need to be well understood through dialogue to ensure decisions are not taken in real time without considering the probability and severity of adverse consequences on the reliability, safety and quality of the product.

When decisions are not data driven, due to lack of dialogue and communication on the part of decision makers, resulted costs can be high. Costs are expressed as a number, be it US$ or another currency. An educated guess, based on carefully designed and constructed models, is much better than blindly judgments alone [1]. In commercial systems, risk is the chance of being exposed to the hazard of losing business opportunities by making inappropriate decisions when there is a known probability of failure [2]. The objective of this paper is to identify the main factors affecting dialogue that could influence the decision making of leaders and employees in jet engine manufacturing organizations.

The first section of the paper describes the importance of dialogue and communication process in decision-making process, the risks in jet engines manufacturing industry, the need for communication and the costs incurred due to lack of dialogue and communication. The second section presents the context and citations of several authors about communication, dialogue and decision-making process. The third section presents the AHP methodology method and the process followed to build the model. The fourth session presents an application of dialogue techniques and AHP for decision-making in the jet engines process. The fifth session presents the review of results, the conclusion and the limitations of the study.

II. THEORETICAL REFERENCE

A. Dialogue and decision making

Dialogue is a discursive relationship characterized by thought provoking activities such as hypothesizing, questioning, interpreting, explaining, and evaluating issues or problems at hand [3]. Dialogue is a disciplined process for speaking, listening, and inquiry in a group setting. The essence of the dialogue approach is to practice thinking together, to clarify assumptions, and allow for the emergence of new ways of thinking [4].

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Dialogue is a precondition of any legitimate corporate conduct that affects a public of that organization [5]-[6]. Dialogue with stakeholders is a two-way interaction [7]. Drawing on a wide range of scholarship on communication and human interaction, states that dialogue and communication always involves asymmetries of knowledge or there would be no point in communicating at all [8].

The management of these relationships through dialogue, communication and behavioral initiatives is important [9]. Dialogue is a discursive relationship of an intrapersonal or interpersonal nature (including discussions with virtual others), is characterized by thought provoking activities such as hypothesizing, questioning, interpreting, explaining, and evaluating. [10]- [11].

The concept of the feedback-based dialogue emphasizes the individual and social factors of communication for the creation and sharing of knowledge. This author also states that on contrast to a discussion, a dialogue functions like a funnel [12]. This means that the communication does not stay on the surface of understanding like it is often the case in a discussion. The understanding is possible by the feedback-process. It means that people are talking about their different perceptions of the statements (about ideas, emotions, experiences, mental models, etc.) and try to understand the reasons [12].

A business decision made by first evaluating risk and then deciding to take on risk that knowingly puts stakeholders at unwarranted potential harm is morally unacceptable, and thus an unethical decision. It is necessary that managers examine all risks facing the organization and focus on the full picture [14]. Statistical information is crucial for managerial decision-making. The decision-making literature in psychology and mathematical cognition documents how different statistical formats can facilitate certain types of decisions [15].

The process of decision-making in business requires the efficient management of information [16]-[17]. Making decisions on instances of informal learning is possible, both the methodology and the tools behind the gathering of this information should be flexible enough to satisfy the needs of the organization [16]. Decision-making by teams is conceptualized in terms of information exchange [18].

The social structure in teams is a regulator of the amount and type of information that members exchange. Organizations should communicate safety objectives and procedures to all personnel [19]. The communications should be done by bulletins and briefings. Lessons learned and case histories and experiences, both internally and from other organizations, should be distributed widely [19].

B. AHP methodology

The AHP is a powerful multi-criteria decision making (MCDM) method. It was first introduced it in order to provide relative weight of criteria according to hierarchical structure [20]. The method depends on the pair-wise comparison matrix where alternatives are compared respectively. The technique is widely utilized to solve complicated decision problems. The method has been used in numerous disciplines to find out the complex decision problems. The AHP methodology divides the complicated problem into small parts in order to rank hierarchically. Thus, relative importance of alternatives will be weighted accordingly. In this article, the AHP method is used to weight/prioritize the key dialogue factors affecting decision-making.

The AHP is powerful tool to enable relevant weight for criteria, the first stage is to compose a pair-wise comparison matrix (A) [21- [22]. Linguistic relative importance scale [22] shown in Table 1 has been utilized.

Table 1: Relative Importance Scale

Importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Absolute extreme) importance
2, 4, 6, 8	Intermediate values

The matrix A represents criteria pair-wise comparison matrix where each aij (i, j = 1, 2, ..., n) has the relative importance of the elements compared to the jth. This indicates that higher value of aij shows stronger preference of criteria ai to aj. The matrix is shown in Eq. (1).

$$A=\begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad a_{ii}=1, a_{ji}=1/a_{ij}, a_{ij}\neq 0 \tag{1}$$

Thereafter, the priority weights of each criterion is found with Eq. (2)

$$w_i=\frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{k=1}^{n}a_{kj}} \tag{2}$$

The following step in the AHP method is to prove consistency of data. A basic equation is used to control whether the comparison pair-wise matrix is consistent [21]. The consistency index (CI) can be calculated by Eq. (3):

$$\mathrm{CI}=\frac{\lambda_{\max.}-n}{n-1} \tag{3}$$

Where:

n: the order of the matrix

ʎmax: the maximum matrix eigenvalue

ʎmax: can be found with Eq. (4).

$$\sum_{j=1}^{n}\alpha_{ij}w_j=\lambda_{\max}w_i \tag{4}$$

A consistency ratio (CR) calculation is then needed to specify reasonable consistency. The CR value can be calculated by Eq. (5). The CR value will be equal or smaller than 0.10 otherwise the expert judgement will be revised to get consistent result. In the equation, RCI stands for random consistency index [22].

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$$CR = CI / RCI \quad (5)$$

The RCI value table is shown in Table 2.

Table 2: Random Consistency Index

n	1	2	3	4	5	6	7	8	9
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

The AHP methodology is an excellent tool to improve dialogue and communication process in decision-making. In jet engines manufacturing process, the costs incurred due to lack of dialogue and communication may be high [23].

III. METHODOLOGY PROPOSAL

In order to identify the factors affecting dialogue, the following steps were taken: (1) Search in scientific databases were conducted with the words "Dialogue", "Business Management" and "Aviation", focusing on articles that dealt with dialogue in its title or in its abstract. (2) Forty-six leaders with experience in the manufacturing of jet engines reviewed the factors raised in the literature and selected the ones they considered critical on the decision-making process. The participants had experience with jet engines, involvement with operational side, academic training, familiarization and knowledge of the several different aspects of the subject. (3) Design Thinking method was used, the selected factors were copied on insight cards, to build an explicit picture on the main points raised. By using the affinity diagram, the insight cards were grouped by affinity, similarity and dependency. (4) A conceptual map was built to allow the leaders the review of the identified factors in brainstorming sessions, a positioning matrix was then created to verify the compatibility of the factors with the established objectives and criteria and at the end, six main factors were finally identified. (5) In the sequence each leader used a specific protocol to document the factors they consider important. (6) AHP methodology was used to establish the prioritization of the factors affecting dialogue in a specific application: analysis of customer service contract requirements in the jet engines overhaul business. The factors affecting dialogue were distributed in a pairwise comparison matrix showing the relative importance of each factor in this scenario, the priority weights of each factor was found and finally the consistency of data was verified by calculating the consistency index and the consistency ratio.

IV. APPLICATION OF DIALOGUE TECHNIQUES AND AHP FOR DECISION-MAKING

The literature review in databases shows that specific research on the factors affecting dialogue and the risk attitudes and the actual behavior of decision makers in the jet engine manufacturing environment, when handling risky scenarios, is scarce. The factors identified in this literature review are the following: forms of dialogue and communication strategies, Individual differences, awareness of others, organization climate, choice of topics, gaining of knowledge, information on probability estimation. This study adds to the growing understanding that a more close dialogue with stakeholders, taking into account the key factors presented in this paper is essential for good decision-making.

Experts familiar with decision-making process validated the factors normally considered when taking a decision. Table 3 shows the number of the experts participating in the interview process and their choice as regards the factors they consider important.

Table 3: Dialogue Factors Experts Validation

Team	Number of Participants	Forms of dialogue	Individual differences	Awareness of others	Organization climate	Choice of topics	Gain of knowledge
1	7	7	4	5	6	3	7
2	6	4	5	5	1	3	6
3	7	5	5	4	3	1	6
4	7	4	7	4	4	4	6
5	6	3	6	6	3	6	5
6	6	4	6	3	4	5	6
7	7	4	6	4	4	2	6
Total	46	31	39	31	25	24	42

Fig. 1 shows the four most important factors affecting dialogue are gain of knowledge (Score: 42), forms of dialogue (Score: 31), awareness of others (Score: 31) and individual differences (Score: 39).

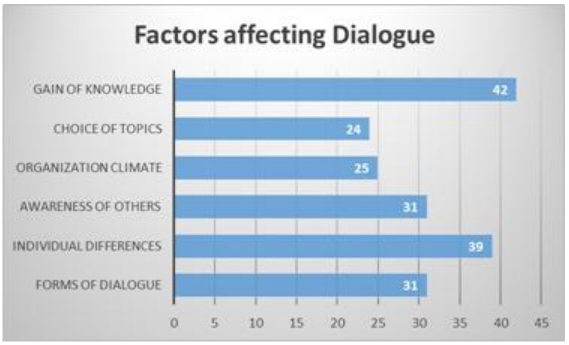

Fig. 1: Factors affecting dialogue

The result of the interviews highlights risk factors that could affect the decision-making and contribute to a poor performance. These factors are negative organization climate and bad organization environment, lack of awareness of others, no consideration of individual differences in physical communication, no choice of topics for meetings, lack of face to face dialogue and no consideration of dialogue as a tool to gain knowledge. The most critical ones are gain of knowledge, forms of dialogue, awareness of others and individual differences.

The literacy and the experience of the participants play a major role in the process. Awareness of others is the second factor; the awareness of the position of the stakeholders taking part in the dialogue is decisive and affects directly the result of the dialogue. The third factor is to organization climate; dialogue should be conducted in the right time and in the right place and an atmosphere of support and trust should exist for the dialogue to succeed. The fourth factor to consider is the selection of the participants and the relevant, challenging and provocative topics of interest to these participants. The focus of the dialogue should be to gain knowledge that can be valuable from a strategic point of view to allow good decision-making.

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In order to identify the most critical factor to consider when making a specific decision, AHP is an excellent tool to help decision makers. The illustration of the tool application to a customer contract review is described in this session. The correct analysis and review of the contract by all the stakeholders is key to ensure the customers' requirements are well understood and complied with.

In the engine manufacturing and overhauling industry the product and scope of work for engine manufacturing and overhaul services is documented in formal contracts. The customers (airlines) and the aircraft manufacturers (air framers) define the product requirements in formal contracts. The planning team in the repair station and manufacturing sites normally review the requirements in detail before starting production. The requirements and the work scope defined in the contracts are also reviewed by all component repair and assembly areas involved. The leaders from the different areas ensure that working instructions, manufacturing manuals, tooling, consumables and qualified technicians are available to accomplish the work.

If the requirements are not complied with, the costs of non-quality and non-safety normally incurred in the overhaul and manufacturing of jet engines, which are material loss, rework, rejection in test cell and warranties and concessions, may be very high. Costs with material loss occur when engine hardware is damaged beyond economic viable repair during processing and needs to be scrapped. Costs with rework occur when the hardware needs to be repaired or reworked to be restored to serviceable condition during process, with additional consumption of material and workforce. Costs with test cell rejection occur when the engine is submitted to test and does not meet the test parameters defined in approval technical data and needs to be re-tested with additional consumption of fuel. Costs with warranties and concession occur when the engine reaches the customer in a non-conforming condition, fail in operation and needs to be returned to the overhaul or production site to be reworked with additional consumption of material, workforce, energy and hardware.

In this application, before the review of a formal contract, the factors affecting the dialogue among the stakeholders were reviewed to identify the most critical one, which might affect the implementation of the actions necessary to meet the customer requirements. A decision about the factor to focus needs to be reached. A decision is a choice made from two or more alternatives. Decision-making is the process of sufficiently reducing uncertainty and doubt about alternatives to allow a reasonable choice to be made among them. Researchers have studied different decision-making problems by using different decision-making methods such as the analytic hierarchy process (AHP). The AHP was utilized in this case to decide which dialogue factor needs to be worked.

The matrix in Fig.2 represents the criteria pair-wise comparison matrix. Experts defined the relative importance of the dialogue factors using the linguistic relative importance scale, provided in Table 1.

Criteria	gain of knowledge	forms of dialogue	awareness of others	individual differences	organizational climate	choice of topics
gain of knowledge	1	3/1	5/1	3/1	3/1	1
forms of dialogue	1/3	1	3/1	5/1	3/1	1/3
awareness of others	1/5	1/3	1	1	3/1	1/3
individual differences	1/3	1/5	1	1	5/1	1/3
organizational climate	1/3	1/3	1/3	1/5	1	1/3
choice of topics	1	3/1	3/1	3/1	3/1	1

Fig. 2: Factors affecting dialogue

Fig.3 shows the normalized matrix and the priority weights.

Criteria	gain of knowledge	forms of dialogue	awareness of others	individual differences	organizational climate	choice topics	Weights
gain of knowledge	0.45	0.38	1.50	0.71	0.17	0.43	0.607570866
forms of dialogue	0.15	0.13	0.90	1.19	0.17	0.14	0.101261811
awareness of others	0.09	0.04	0.30	0.24	0.17	0.14	0.11813878
individual differences	0.15	0.03	0.30	0.24	0.28	0.14	0.137828576
organizational climate	0.15	0.04	0.10	0.05	0.06	0.14	0.160800005
choice of topics	0.45	0.38	0.90	0.71	0.17	0.43	0.187600006

Fig. 3: Factors affecting dialogue

In order to check consistency of data and to verify whether the comparison pair-wise matrix is consistent, the consistency index (CI) was calculated. In order to calculate the consistency index (CI), the Eigen value had to be calculated. First, the weight Sum vector was calculated by multiplying the pairwise matrix by the weight priority vector, as shown in Fig.4.

	1.00	3.00	5.00	3.00	3.00	1.00		2.666667		11.34808
	0.33	1.00	3.00	5.00	3.00	0.33		0.444444		8.305327
	0.20	0.33	1.00	1.00	3.00	0.33	x	0.518519	=	4.196685
	0.33	0.20	1.00	1.00	5.00	0.33		0.604938		5.904504
	0.33	0.33	0.33	0.20	1.00	0.33		0.705761		2.311088
	1.00	3.00	3.00	3.00	3.00	1.00		0.823388		10.31104

Fig. 4: Weight Sum Vector

The consistency vector was then calculated by multiplying the Sum Vector by the inverse of Weight Vector, the result is shown In Fig.4. The average of the elements of Consistency Vector represents the Eigen value: 0.7798. The Consistency Index was then calculated with Equ.3 and its value is 0.955959. The consistency ratio was calculated with Equ. (5) and its value is 0.0770935, which shows the ranking is consistent.

V. CONCLUSION AND IMPLICATIONS

This paper reviewed the critical elements of dialogue that could affect the decision made by leaders in the

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manufacturing of jet engines. The literature review in databases identified the factors affecting dialogue, then experts familiar with decision-making process validated the factors normally considered when taking a decision in the jet engines manufacturing. AHP was then successfully utilized in in a specific application to decide which dialogue factor needs to be worked. The most relevant factor raised in the AHP was "gain of knowledge" on the contract requirements that can be valuable from a strategic point of view, to allow good decision-making as regards the most critical requirements to address and the way to comply with it.

The study contributes to the literature on models of communication and firm performance. The paper examined the factors that affected decision-making in the analysis of customer contract requirements and consequently firm performance. Previous researches examined the factors affecting the dialogue separately, and not integrated into a model. This study developed and proposed an integrated model showing how the different factors affected the decision making process and the way they could be prioritized and used for decision-making.

The study shows how leaders can optimize firm performance by conscious decision making using the proposed methodology. However, in order to prevent wrong decision-making, leaders should also make decisions weighting costs against benefits in each decision scenario. Although the results of this study can aid leaders in the jet engines industry, it has limitations. First, the study does not provide details and the method on how to make a decision by combining AHP and an integrated probabilistic risk analysis under uncertainty. Second the relationship between the decision-making and the probabilistic risk analysis is not explored either. Future research could give more emphasis on how to apply the model to evaluate the different scenarios in the jet engine manufacturing system and how decision-making could affect the performance of firms. Future enhancement of this methodology could be the analysis of the influence of the factors affecting dialogue and decision making on the costs of bad decisions.

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