Learning from Diversity: Model-Based Evaluation of Opportunities for Process (Re)-Design and Increasing Company Resilience

Elena Beauchamp

Technical University Delft
Faculty of Technology, Policy and Management
Jaffalaan 5, 2628 BX Delft, the Netherlands
e.beauchamp@tudelft.nl

Abstract. This paper focuses on the learning process in order to facilitate Integration between distributed designers and other *diverse* groups (Manufacturing, Maintenance, as well as the User) involved in the Product Life Cycle (LC) and Product Development.

Learning is a bridge between the "world-as-imagined" (design) and the world-as-experienced (situated action), where diversity may be a source of innovative problem-solving by combining different types of knowledge (experience-based, specific, or pro-active). Learning, therefore, plays an important role in the transformation of existing knowledge into new design solutions, in order to reflect organizational and human needs for change and the opportunities for such change. Thus, there arises a theoretical issue related to knowledge transformation between experience and design: how to extend the renewal and generalisation of existing frames of interpretation to an integral level, where all voices (of knowledge drivers influencing the design) can be heard.
We argue in this paper that learning occurs as a visualization of these divergent objectives and of the opportunities and risks related to change/ new process design in the search for shared ideas about conflict resolution.

1 INTRODUCTION

An aviation system is a complex multi-actor system with an inter-organizational network. When different functional groups are affiliated to multiple organizations, communication is complex due to relatively high cognitive and cultural differences, geographic distances, diverging interests, and manifold interdependent relationships (Hauptman and Hirji, 1999). Therefore, the design process requires methods and tools which support both the building of consensus, and the learning processes of the various development and user groups involved in new product development.

By 'diversity' we mean a variety of processes and products emerging from different configurations of Stakeholders who have different objectives, knowledge, experience and authority. The potential question is how to facilitate learning processes and to transform knowledge throughout the Life Cycle (LC) in aviation system between partners with divergent professional backgrounds.

In terms of learning for system design there is a need to address two groups of knowledge: knowledge of a product (i.e. design concept); knowledge of the design process (i.e. procedural knowledge and control knowledge).

The working definition of design as process accepted here is "negotiating product, process and organization demands to create an abstract description of an artifact" (Cunningham).

The expected outcomes of Organisational Learning (OL) will be a new understanding, which leads to changed practices/ innovative practices. This may refer to changes in policies, in program design or standards, in structures and procedures, in interpersonal interactions etc.

Much of our thinking and behaviour is rooted in habits and routines, in deeply implicit mental models of how the world works, and in well-concealed assumptions and prejudices (i.e. pre-judgments). On the other hand, our habits, assumptions and mental models impose uniformity and simplification on the complexity and variety of events and experiences, thereby obscuring and negating 'differences'. Learning, therefore, involves both – better reflection and analysis for 'institutional memory' and the ability to 'suspend' our acquired knowledge. The suspension of our acquired knowledge is required to provide the space to recognize 'differences', and to introduce caution in transferring responses, approaches and solutions from one context to another.

According to Boer, a special form of learning process, namely continuous innovation (CI) is '…the planned, organized and systematic process of ongoing, incremental and company-wide change of existing practices aimed at improving company performance' (Boer and Seferis, 2002).

The basic approach in CI methodology is to combine operational effectiveness (i.e. the capability to satisfy today's customer demands) and strategic flexibility (the capability to develop new market approaches, processes, competencies, organizational and management systems that provide for the satisfaction of tomorrow's customers). As Boer and Seferis (2002) explain, CI is about using all the innovative potential in the organization in order to continuously improve the performance of the company, where core aspects are development and learning.

Consequently, within the CI concept OL may be seen both as a process to sustain and optimize existing operational practices in order to increase operational effectiveness, as well as a process supporting the augmentation of the adaptive capacity of a system through a better interpretation of external/ environmental factors driving change, and assisting in new goal-setting.

This should support simultaneously:

- A vertical communication process of goal-setting and deployment (top-down), and information about the company's performance (bottom-up);
- A horizontal communication process of exchanging experience obtained from performing CI activities, and improved practices.

Managing the variety/ diversity of processes, and thus the variety of contexts, requires a holistic approach to learning as a contributing factor to balance Strategic Flexibility and Operational Effectiveness in a Changing Environment. It is assumed that Integral Performance Improvement contributes to the balance between safety, environmental or strategic sensitivities and business results in order to achieve sustainable development.

Therefore, we are looking for a well balanced company performance, and how learning contributes to it.

Since OL has become increasingly important for the industry in its adaptation to changes in the political and economic environments, changing regulatory requirements, changing technologies and organizational models (see e.g., Wahlström et al., 2005), the system should be seen as:

- Stakeholder-based, and thus with multiple-effectiveness criteria;
- Process-based, thus with dynamic, fuzzy and essentially unpredictable processes of ‘organisational structuration’ (H.Boer&F.Gertsen, 2003).

This concept of OL needs to apply a mechanism for the prioritization of suggestions for changes depending on the market and stakeholder-related objectives on the one hand, and work environment-related objectives, including safety, on the other. For such a prioritization, as well as for the modeling of alternatives for improved practices, theoretic decision-making models may be useful. This also applies to the evaluation of alternatives with respect to the overall goal to balance strategic flexibility and operational effectiveness in a changing environment.

Fig.1 represents a contextual model reflecting the dynamics within an aviation network. This model links the Diversity (human and organisational) and the Specificity of the companies within such a network to their Performance. This shows that Diversity increased by external/ environmental factors also takes on a more complex character due to a combination of internal (business-operational-organizational, and user-stakeholder) dimensions of Integral Performance.

In other words, we are looking for ways to enable adaptive learning in order to resolve conflict between safety and efficiency in performance, and between planned/ designed actions and flexibility. Such adaptive learning, in our view, will contribute to building revised models for organizational performance in a changing environment, thus increasing the adaptive capacity of a system. We believe that given the complexity of real work situations, safety cannot be improved by applying the check lists alone.
A more systemic view is needed, where balanced, and thus safe, performance is rather a matter of managing diversity than achieving consistency.

We address resilience engineering by learning from diversity, which may be seen as a possible engine of improvement in company performance through the ongoing process of evaluating opportunities for (re)-design, or re-negotiation between new product, process, or organization demands and resources and experiences.

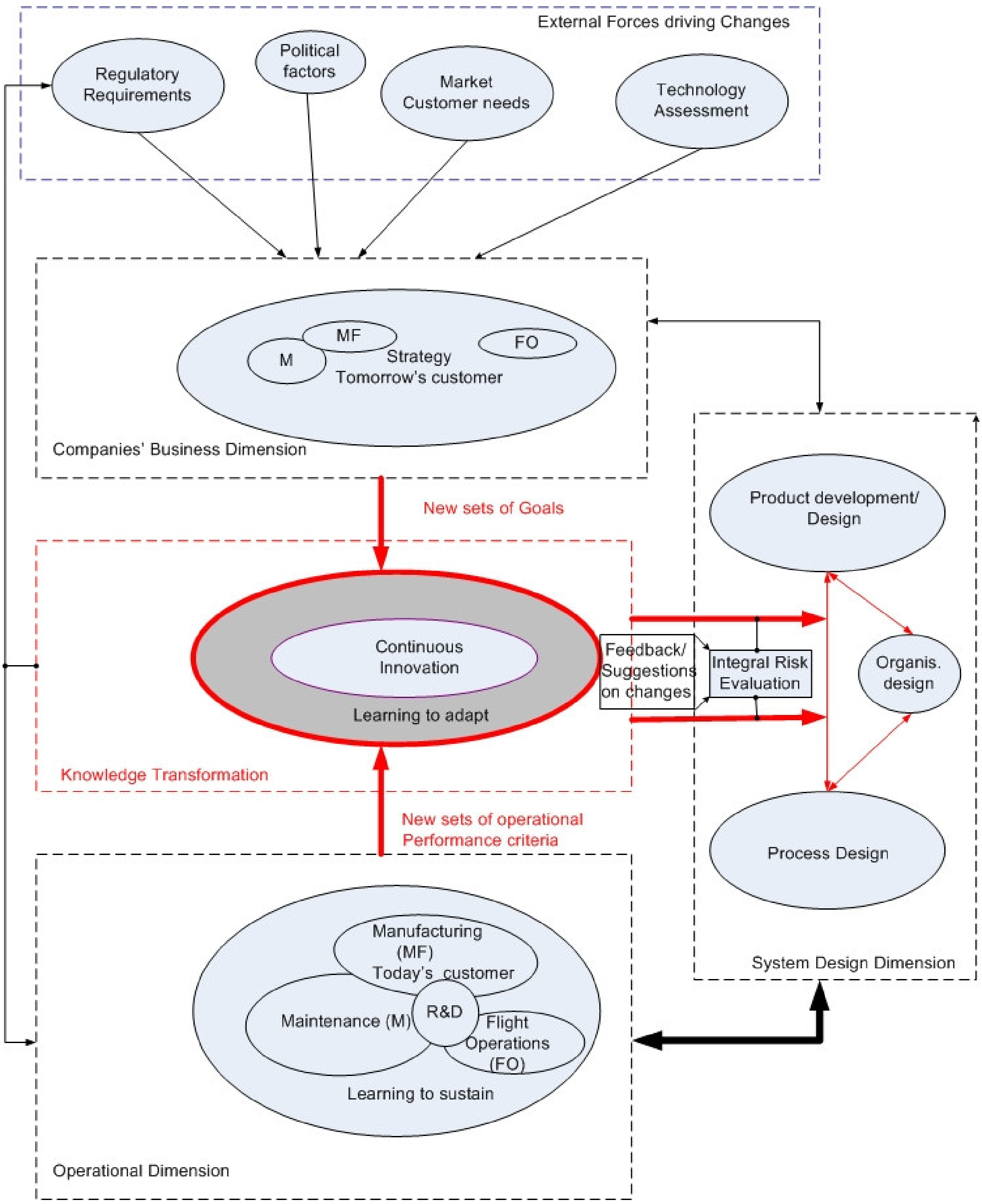

Fig. 1. The impact of human and organizational diversity on company performance in aviation networks

Learning is a bridge between the "world-as-imagined" (design) and the world-as-experienced (situated action), where diversity may be a source for innovative problem-solving by combining types of knowledge (experience-based, specific, or pro-active). Learning, therefore, plays an important role in the transformation of existing knowledge into new design solutions, in order to reflect organizational and human needs for change and the opportunities for such change. In Fig. 2 the basic process model for transformation is outlined:

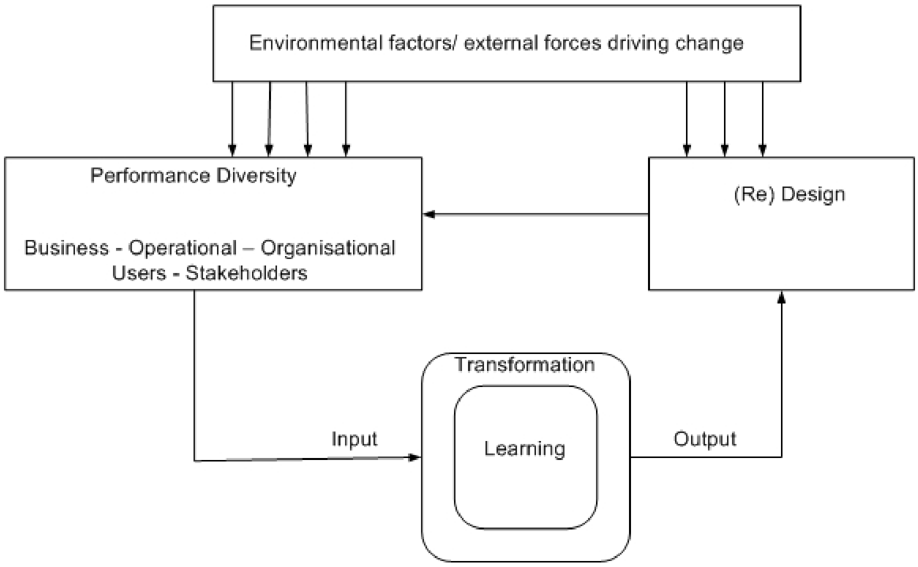

Fig. 2. Basic Process Model for transformation

2 LEARNING FROM EXPERIENCE WITH FEEDBACK TO DESIGN

Industrial experience shows that there are few totally new designs, and more often designers re-use previous solutions. It is therefore important that the designer should be interested in learning about the consequences of badly adapted design of his/her product or part of it. However, designers still rarely take into account these consequences in the workplace and work environment.

The mental image of designers (Fadier E., de la Garza C., 2005) shows a great difference between designers' perceptions and real work situations, especially in estimations of technical reliability, stability of the work process, its predictability, and decisions made in conflicting situations (e.g., between productivity and safety aspects). This illustrates the necessity for an integrated design process taking into account the variability in work situations and the requirements of human activity.

According to the SINTEF-Report (1997), there are several methodologies for investigating the "Man – Technology - Organisation" triangle such as MTO-Analysis, TRIPOD, MORT and CREAM. Some of them (e.g., TRIPOD and CREAM) address Design Failure and Inappropriate Design. Several new approaches to Event Analysis are available, e.g. Human Event Repository and Analysis (HERA, Eurocontrol).

Generally speaking, these methods cannot deal with latent causes. They are based on the assumption that knowledge of faults that caused the last accident/ incident is sufficient to prevent the next one. As we argued in section 1, balanced, and thus safe, performance is rather a matter of the capability to manage diversity than to achieve consistency. Also, one important component in the integration of such analyses for decision-making is missing. That is, no formal mechanism exists for the transformation of information on operational failures or concerns into a template for change in order to prevent future failure and/ or to reinforce a positive outcome.

According to (Fadier & de la Garza, 2005) there are methods which it is possible to apply in order to generate and to integrate the feedback from work situations into the design process. They are:
- Structured Analysis Design Technique (Hasan et al, 2003);
- Methods of operational analysis and treatment of the system (ergonomic and reliability engineering MAFEGRO);
- Software to treat the data resulting from the various analyses: SIMTREE.

However, in these methods there are no standardised or commonly agreed ways to analyse either the causes or the present results of such an analysis. Different investigators and different sectors have very different procedures, and emphasise different issues. Thus the research question arises: How can we learn from diversity (internal, external and methodological) in order to achieve balanced performance for a company operating in a network and in a changing environment?

Despite databases of events (accidents, failures, or damage), and project management software and methodology introduced by quality certification, there is still a need for tools which transform data from operational analyses into an iterative design process.

Since it is difficult to generalise ways of obtaining useful design knowledge directly from operational knowledge (Ishino & Jin, 2002), there are no models which precisely address the integration of operational lessons from experience in a form which allows the improvement of aircraft design for the next generation of operational systems.

The key issues of building such an integrated model are related to the interaction between information, knowledge, learning and decision-making throughout the product life cycle. Knowledge therefore cannot be separated from decision-making, which in turn cannot be separated from the capacity to learn.

3 LEARNING AS A CONCEPTUALISATION OF A HOLISTIC APPROACH FOR COPING WITH DIVERSITY

The Product life-cycle is represented as an open system influenced continuously by different “design drivers” (Moir and Seabridge, 2004) – business drivers, project drivers, product drivers, subsystem development drivers, and the product environment. Thus, design drivers are those entities which perceive the needs for (re)-design.

Organizational learning under the notion of an open system is, therefore, a combination of the interpretation of environmental variables, the application of the impact of those variables on the organization’s current and desired states, and the action taken with the new knowledge that has been created.

Organizations fail to learn because the characteristics inherent in traditional decision support systems do not allow for problem formulation at a variety of levels; neither the necessary feedback loops, nor an infusion of environmental variables into problem solving. In our view, the transformation occurring in the learning process takes place within decision making, where continuous feedback loops should be integrated. The decision process should provide a certain degree of transparency, since each participant should understand not only its own benefits and losses, but also those of the other participants. Such transparency would promote learning for different stakeholders by identifying the criteria important for the achievement of common goals/ objectives; and by thinking about the meaning of individual criteria (through weighting and prioritisation) in achieving the common goals.

If one adopts the view that learning is the conceptualisation of a holistic approach for coping with diversity at the organisational and inter-organisational level as well as for increasing sensitivity towards the environment, then the focus should be on the integration (and not only generalisation) of knowledge from diverse backgrounds.
Thus, the theoretical issue related to knowledge transformation between experience and design arises: how to extend the renewing and generalisation of existing frames of interpretation to an integral level, where all voices (of knowledge drivers influencing the design) can be heard.

In this paper we describe our model of a system's approach to transformation: the transformation of diversity in organizational performance between different stakeholders into a set of suggestions for (re)design, in order to achieve the best possible balanced performance for the benefit of all stakeholders. We also show how learning fits into this model, and which instrumental tools might be used in order to support such a transformation.

Interests and perceptions of reality, which at first sight seem intangible, form the basis for the driver's objectives (Van de Riet, 2003), which can be measured using special qualitative scales.

In an aviation network, where each company possesses both specific, non-shareable knowledge (related to commercial interests) as well as shareable knowledge of common interest (such as safety), there are both a diversity of objectives, and also a diversity in understanding of the ways of achieving such objectives. The conflicts between divergent objectives and between different types of knowledge (e.g., experience-based and specific; shareable and non-shareable; user-stakeholder) are unavoidable.

The process of transformation, therefore, is not only about measuring the driver's objectives, but is more about conflict resolution between divergent objectives (company level to network level) and gaining useful knowledge through learning in order to contribute to the integral, balanced performance of the company. The Process Model of the Diversity-Learning-Performance relationship might be represented as follows (Fig.3):

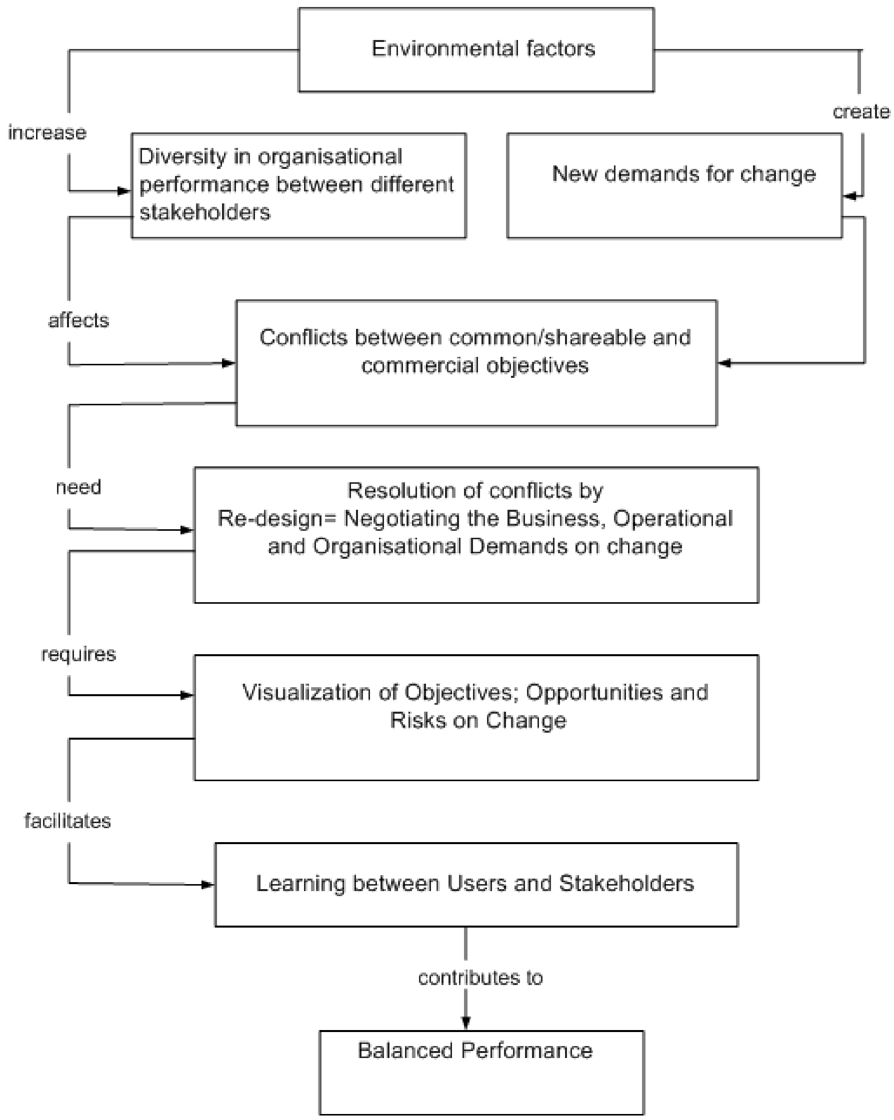

Fig. 3. Process Model of Diversity-Learning-Performance Relationship

We argue that i) learning occurs as a visualization of those divergent objectives, of opportunities and risks related to change/ new process design in the search for shared ideas about conflict resolution; ii) the Implementation of lessons learned is related to different levels of Organisational learning: reactive level – organization of working memory and reporting systems to improve the performance of today's work processes; pro-active level – within the Design phases, an evaluation of the consequences of design solutions/ modifications.

4 METHODOLOGY

In order to develop a holistic model of OL, which suggests "bringing together the concept of different learning levels and step-by-step procedural change processes" (Laehtenmaeki, et al., 2001), we propose to use Analytic Hierarchy Process (AHP)-based methodology.

The comparison with other theoretic decision making models, their advantages and limitations, together with an analysis of their development due to new accents in strategy making, is given in Beauchamp (2006).

In AHP (Saaty, 1989; 1996) pair-wise comparisons of the elements at each level are conducted with respect to their relative importance towards their control criterion. In the case of interdependencies, components within the same level may be viewed as controlling components for each other, or levels may be interdependent on each other.
A special procedure of synthesis allows for a certain degree of sensitivity in integrating all three model levels and in confirming the "right" choice of alternative(s) (e.g. action(s) to be taken to avoid the repetition of specific failure).

Kivijärvi (2004) gives an example of how this AHP methodology might be applied for supporting organisational knowledge management through the transformation of our personal, subjective experiences and judgments into a consistent goal hierarchy.

Davidson and Labib (2003) proposed a model for learning from failures or design improvements using a multiple criteria decision-making process, namely the AHP mathematical model. This model has been made for an analysis of the Concorde accident but in our view is limited by focusing on the repetition of the same failures.
According to Hummel et al. (2000), the AHP can be applied to steer design activities in the earlier as well as later new product development stages. Due to its explicit support for integrating diverse points of view, it facilitates the learning processes and the building of consensus between partners with diverging professional backgrounds. Research methodology based on AHP shows what design changes are acceptable. AHP helps to adapt design activities to changes in users' needs, and to steer and align the inter-organizational partners' design activities.

Our approach is based on the lesson derived from operational experience (normal performance and events – accidents, incidents and/or operational concerns and successes) as a new understanding (knowledge) which identifies a solution (a specific design modification/decision or work process decision) that reduces or limits the potential for accidents, failures and mishaps, or reinforces a positive outcome. This corresponds with the definition of lessons learned which should be applicable for future missions.

We propose that AHP methods can be used as a supporting tool for learning at the operational level, e.g. in Maintenance, Flight operations (see Beauchamp-Akatova, 2006) as well as for learning which helps to cope with variety of values in a changing environment at the organizational or inter-organisational/ network level.

Lessons derived at the operational level from product successes and failures need to be the basis "for an evaluation of the acceptability of design changes" (Hummel et al, 2000).

A pro-active approach is essential in the further Learning Loop addressed to Design and taking place within the Design phases for an evaluation of the consequences of badly adapted design solutions. The possibilities of such an evaluation also are given in AHP and/or Analytic Network Process (ANP).

We provide here an example (Fig. 4), which need to be further developed on the basis of empirical data. This is an attempt to address three dimensions of diversity, Business-Operational-Organisational, in order to achieve a balanced performance in a networked company.

A detailed description of components of all levels for balanced performance throughout the Life Cycle is a subject for future empirical study. This model can be used as a simulation exercise of what will happen (forward process) in terms of a projection of existing policies into likely future scenarios, and also in terms of designing the new policies (actions to be implemented) for achieving the desired scenarios of development (backward process) and the evaluation of the impact of those policies on the overall performance index if the content of one or another objective and/ or policy is changed.

The main Research Question is: How to evaluate the opportunities for change and possibilities for improvement in company performance with respect to achieving sustainable development of a company in a networked aviation system?

By 'sustainable development' we mean 'development leading to competitive, legal and successful business'.

We are developing an empirically based model of the transformation process and propose using AHP as a potential instrumental tool for supporting the integration of diverse "design drivers" and for facilitating the learning processes and the building of consensus between diverse groups in aviation and thus, as a potential evaluation procedure for knowledge transformation in organisational contexts.

The company in a networked and changing environment strives to reconcile the two objectives – to ensure the survival of adaptive plans and also to admit change in the environment for variety and progress in the future. This reconciliation is to be seen as strategic, adaptive planning and thus as a process of learning and development.

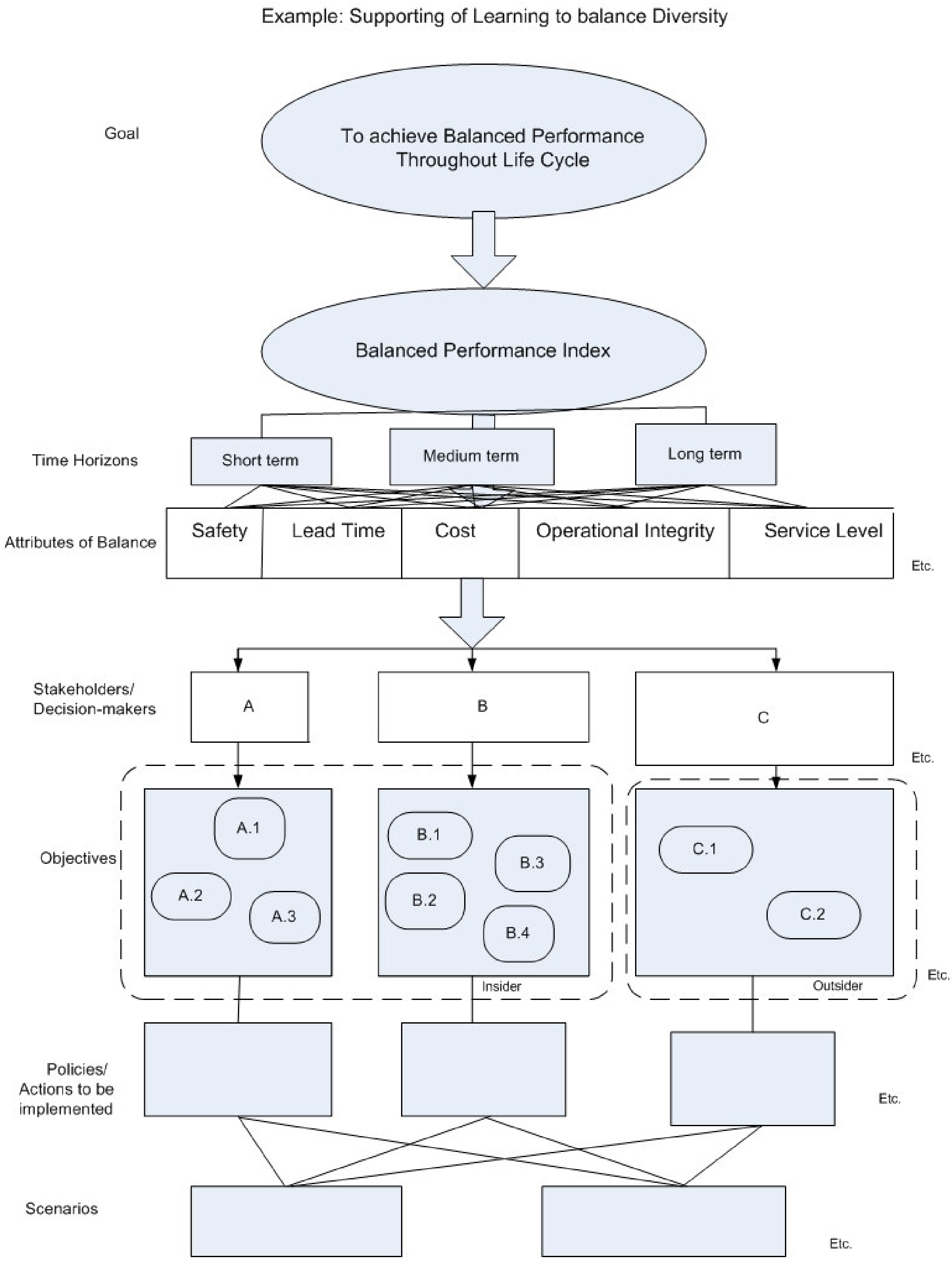

Fig. 4. Model-based evaluation of the opportunities for change and possibilities for improvement in company performance

If adaptive behaviour is a successful strategy for an individual learning (Norros, 2004), then adaptive planning is a strategy for an organization to learn and increase resilience. An adaptive planning process is different from one which moves only in one direction (forward or backward).

In the forward process, one considers the relevant present factors, influences, and objectives that lead to sensible conclusions or scenarios. The factors/ influences/ objectives may be economic, political, environmental, technological, cultural, and/or social in nature. The backward process begins with the desired scenarios then examines the policies that might have achieved those scenarios. To integrate forward and backward hierarchical planning, one projects the likely future from present actions, adopts a desired future, designs new policies, adjoins them to the set of existing policies, projects a new future, and compares the two futures – the projected and desired – for their main attributes. The desired future is modified to see what policy modification is again needed to make it become the projected future, and the process is continued (Saaty and Kerns, 1991).

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