**Aircraft Maintenance Teams**

*by*

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A Dissertation submitted for the degree of Doctor of Philosophy of the University of Dublin, Trinity College, Dublin 2, Ireland

This research was carried out in the School of Psychology

<date>**DECLARATION**

I declare that this work has not been submitted previously as an exercise for a degree at thesis or any other university and that it is entirely my own work. The Trinity College Library may lend or copy this thesis upon request.

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***\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_***

Daniele Baranzini**ACKNOWLEDGEMENTS**

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To all aircraft maintenance people I met.

This work is dedicated to you.

**SUMMARY**

This dissertation investigated *aircraft maintenance teams performing inspections and repairs in the hangar environment of modern commercial aircraft maintenance organisations*. Generalisations of all findings are intended to advance knowledge and research practice on work teams in complex work systems.

After a review in Chapter 1 and 2 of the main team concepts, models and major team research directions in today commercial aviation environment, a number of six new hypotheses were proposed in Chapter 3. These were tested throughout the remaining seven chapters of this Thesis by application of surveys, case studies and in-field research. The new hypotheses addressed different arguments: the impact of team competence versus external systems on operational performance (i.e., team externality), situational teamwork, adaptation and work practices, the concept of team risk distribution (i.e., Friedlander argument), and the relation between organisational resources and team proficiency.

In Chapter 4 a composite model of work team in aircraft maintenance is proposed and the interdependent nature of team operations uncovered. Chapter 5 follows with an analysis of the team-attitude-behaviour-performance relationship by application the AMAS survey across different maintenance organisations over a period of three years. The overall results would confirm how *internal team dynamics, attitudes and teamwork competence are not reliable predictors of operational performance levels expressed by the team*.

Chapter 6 provides evidence on the highly contextual and situational nature of teamwork in aircraft maintenance. Five case studies, mainly based on observation techniques, revealed how team behaviours appear to be driven by situations known in operational terms, difficult to separate into single models of “pure” communication, co-ordination or decision making skills. The importance of early recognition of *skills situations for teamwork* rather than individual skill possession is discussed.

In Chapter 7, 8 and 9 the research focus widens to all processes and systems of the maintenance operation. The organisation of team performances highlights what it is here called the *team externality concept*. A team externality defines the specific performance of a system that is not controllable by the work team, which turns out to be dependent on that external performance. Apparently, different in-field investigations, case studies and statistical analyses across Chapter 7, 8 and 9 corroborated a key hypothesis underlining the entire research: *for highly dependent systems like operational teams in hangar maintenance it is the environment (externalities) that accounts for performance more than internal team capabilities*.

Findings in Chapter 8 and 9 seem to suggest also a form of performance limitation that, *apparently*, work teams in the maintenance operations cannot overcome. Every team locally gets some supports from the organisation but not sufficient to express very high performances. This comes under the name of *team risk distribution* (Chapter 9) and appears to be an implicit organisational strategy to maintain a complex economy of pooled and limited resources: it is possible to provide all local teams with *some but not all* necessary resources. The effect is of spreading potential risks of moderate failures locally and, at the same time, maximising global organisational resilience and production. Such interpretation would corroborate a controversial hypothesis termed here Friedlander’s argument (1987,p. 304):“*A dysfunctional work group participates with all other work groups to maintain a dysfunctional organizational system. Further, the dysfunctionality of a work group may increase the effectiveness of the organization*”.

Finally, in Chapter 10, a new team model, the *team multivariate frame* is proposed and discussed. This can also be considered an attempt, although not sufficient, to provide a solution to the team risk distribution problem. Such model underlines a system requirement proposed in Chapter 8 and termed *minimal critical order of causality*: *the widest source of dependencies (largest set of time/sequence orders) within a process will contain the minimal causal chain to comply with and generate the maximal leverage on the system.* This requirement simply suggests that there is a temporal-sequential and causal order between different upstream and downstream process elements (e.g., teamwork events, contained by work processes, contained by the organisation). In essence, upstream solutions, even external to teams, are to be favoured to optimise, downstream, operational team events and performances.

Overall, causal models and explanations of team performances would miss a serious point if such explanations disregard the model of the overall business approach taken by the organisation to control its economy.

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**Chapter 1**

**Role of Thesis and objectives**

“*Jobs are primarily for the purpose of producing the goods and services of the economy”* (McCormick, 1979, p.3).

# **Role of Thesis and objectives**

The objective of this Thesis is to advance knowledge on the study of work teams and to understand the organisation of teamwork. This is a work on the team concept as it is applied in aviation maintenance operations today. Specifically, the research is organised around the identification and analysis of those work units and their performances in modern aviation maintenance organisations: *hangar* *teams performing maintenance inspections and repairs on commercial aircraft*.

Focussing on applied and theoretical studies on what is termed "team" and "teamwork", the research will be focused on what is to be considered relevant when we analyse and provide explanations about the complex interactions and dependencies within and across work teams, their task systems and situated actions in hangar maintenance. The research problem for such analysis is not that of team dynamics *per se*, but a question about the actual relation between the practice of teamwork and the organisational context.

By studying and representing the properties and the organisation of team performances, a new framework is envisaged to inform the psychological research on the nature of the team concept and advancements on a theory of teamwork in large work organisations. The overall approach will cross over systems approaches, human factors and organisational paradigms for investigation. This will involve:

* A research effort at different levels of analysis of actual maintenance operations, real task environments and work team events.
* Assessment of team attitudes, behaviour and performance relationships in hangar maintenance.
* Determination of the causal factors predicting actual team performances.
* A better understanding of the role of external processes surrounding the organisation of teamwork.
* The development of a new theoretical model to explain the nature of *hangar* *maintenance* *teams as very dependent systems*.
* A more transparent link between studies based on ecologically valid research actions (i.e., naturalistic and ethnographic investigation) and more rational and normative models about team effectiveness, design and teamwork behaviour.

To summarise, two pillars drive this activity. From an academic and scientific point of view this piece of research is centred on the study of maintenance teams in their real-life operations. Efforts to explore their organisation and performances within their larger embedding work processes may suggest new design propositions and innovative models to explain such complex teamwork endeavour. Instead, as pure applied research, the aim is to provide aviation maintenance organisations with new best-practices to support and improve design, organisation and management of systems based on work teams.

## **Levels of team analysis**

Although the main focus will be on the operational hangar teams, that is, a variety of co-ordinated work groups performing inspection, removal, and repair tasks on the aircraft in the hangar environment, the definition of *what* is a team in aircraft maintenance will be certainly a relevant subject on its own due to the complex nature of the organisation of work in such work domain. It will be clear that if the presence of a cockpit crew or a sport team is clearly defined by its environment and recognisable on a clear order of events, places and roles, this cannot be said for the world of maintenance team operations. Several types of teams with overlapping functions, varying dimensions and roles strive to co-ordinate on the same workflow and the boundaries across such teams and their contexts are likely to be loose, sometimes, undifferentiated.

It can be said that the very basic operational teams, which are the main referents to this work, are *composite systems* in nature. Their structure, resources or membership may change over time during the same piece of work. As an example, the following operational scenario may prove useful to describe such a complexity of team events in hangar maintenance:

“A work team is assigned to remove a component from the main landing gear during an afternoon shift. This task should be completed on time in order to move the aircraft out of the hangar and make room available to enter another aircraft scheduled for the night shift operations. This task requires both standard and special tools, which may not always be available. In such cases, more frequently than expected, the team members have to interact with the Materials/Shop unit to look for equipment and tools availability while informing their supervisor of possible operation delays. Concurrently, they realise that more expert technicians are needed to perform the task. The team supervisor will thus interact with other team leaders and look for available technicians. Then, the Planning department will be informed and told to re-schedule and co-ordinate other technicians to perform the task, which should not be delayed further” (Baranzini and Cacciabue, 2006, p. 225-226).

Although the work team depicted in this scenario is fully responsible for the task assignments, its teamwork proficiency depends more likely on the teamwork of other external groups or units. Thus, their internal performance depends more by the way they organise, *or can influence,* these exchanges with their environments. Conceptually, the level of analysis chosen in present work should reflect such conditions to teamwork. Chapter 2 and 4 will review and describe the structure and nature of hangar teams as well as their most common assignments, roles and conditions.

## **Teams with very large interdependencies**

As it is implied here above, maintenance teams define very large interdependencies. This is a critical assumption to understand team performance in several respects. Such an assumption will play a fundamental role in the context of the present work. In particular, performance for teams with very large interdependencies is distributed. Such concept is based on the following logic:

1. Work environments with very large interdependencies tend to contain teams with very large interdependencies.
2. Teams with very large interdependencies with their contexts are dependent on teams which contain the resources they need.
3. Operational teams in hangar maintenance do not contain all the resources to perform complete task operations. Their resources are managed according to the context.
4. Therefore, it follows that team performance is not contained in the single team but it is distributed in the interdependence with the embedding system.

The study of this interdependence-performance relationship and role of the environment on team proficiency will be fully explored and refined from Chapter 4 onwards.

## **Teamwork as “left over” of an organisational design**

Several key determinants to effective or efficient team performance in real work contexts are supposed to be under control of designers, engineers and managers of entire technical and organisational systems. They implement rules, procedures, structures, as well as policy constraints, barriers and best practices in order to guide team performances in most of the organisational tasks.

They also provide technology and resources to operate effectively. In doing so, they are designing the interdependence across all the human and technical systems in terms of *roles*, *functions*, *structures and processes*. But, this design is not organised to contain all the interdependencies arising out of a teamwork activity and it (the design) becomes part of discrete and fragmented historical change of ways of doing and experiencing teamwork in a sustainable, sometimes *subtle* manner. This leaves open the door to the natural growth of team *practices*, as natural teamwork behaviours which make sense of and integrate task objectives, work demands, roles, functions, and processes during daily situated actions and assignments. Such integration then becomes part of a body of knowledge on the natural team concept, that is, a team’s knowledge in the organisation which is socially distributed and interpreted by practicing it. As a learning loop this team knowledge will help maintain and evolve new and better team practices.

In some way, team practices and knowledge are the “left overs” from any organisation design. Such view will be considered specifically in Chapter 4 and 6.

## **A situational view of teamwork**

The individual activity in hangar is always situated in a context of other individual activities. Such context of technical, social and organisational interplay of conditions, knowledge and interpretations is the teamwork practice (why, what and how individuals do things together). This practice can be observed *live* without taxonomies and, arguably, the research issue is not simply a problem of team members’ interaction and teamwork skills to account for team performances, but also a deeper research study on what surrounds teams, how the larger context is used and how such system -the team system- is designed, organised and shared (interpreted) across different organisational elements.

Also, what is less understood and studied in hangar maintenance team research is the organisation and identification of real teamwork events in their completeness. Such events come *in a single package*, and not separated as individual modules of communication, co-ordination, or leadership. Learning to be team-members by learning modules about teamwork attitudes, favourable leadership styles and positive team skills remains highly attractive and valuable, but the present research suggests that teamwork may well be a property of the environment, not simply an intrinsic characteristic to be learned by individuals. The organisation and deployment of different team behaviours is very dependent by the interpretation of operational and environmental demands. This capacity to *read* or recognise a teamwork situation cannot be learned in training sessions by decomposition of the argument in a set of attitudes, skills, and values. But, it turns out to be a natural human response, an almost automatic act of recognition. Apparently, team members happen to be effective team players by early recognition of teamwork events and necessary team demands, not necessarily by displaying prescribed positive and expected teamwork skills or attitudinal orientations.

The interpretation of entire team events and its manipulation in the larger system is a very valuable source of knowledge to understand teams in action in natural work contexts. This argument will be part of Chapter 6, 7 and 8.

## **Causality in team performance**

Knowledge on causality in team performance is always a fundamental aspect in team research. This remains a key argument of this piece of work. The problem of what drives work teams toward proficiency in performance is paramount for research models and theories on prediction as well as for actual business organisations relying on teamwork performance to benefit successful accomplishments.

The question is not simply what variables would lead to performance excellence, but rather what is the order and sensitivity (influence) of different variety team performance determinants. Exploring the true leverage and effects of internal team dimensions (e.g., attitudes and skills) versus external team variables and systems (e.g., organisational systems, supports and team-task configurations) will become a key issue that will be *approached* in this Thesis by what comes under the name of the *principle of minimal critical order* of causality. Very roughly, upstream inefficiencies contain those minimal causal elements which do create downstream disasters in partially ordered events (Baranzini et al., 2007).

More specifically, the *causality and prediction* argument will be thoroughly investigated inChapter 7, 8, 9 and 10.

## **New hypotheses of research**

In Chapter 3 different arguments are proposed to highlight potential new terms of reference for team research and verification. Six new hypotheses about aviation hangar maintenance teams are summarised and presented:

1. *Internal team dynamics and competencies are not reliable predictors of teamwork levels and task performances for teams with very large interdependencies about the context*
2. *Compared to internal team attitudes and skills, impact of external systems and team configurations (e.g., technology demand, proficiency of supports, team variability) account for higher levels of variance in operational performance*
3. *The ability of individual teams to adapt to unexpected situations and events will augment effective task accomplishment but reduce sensibly team efficiency*
4. *Team adaptation will result in accepted team norms and practices that are generally considered routine violations of organisational procedures, norms and practices*
5. *For large systems based on pooled resources (human and technical) single individual teams should become inefficient or ineffective to certain degrees in order to maintain acceptable global organisational performance. The risk of failure is distributed and shared by all local teams so as to reduce concentration of risks which favour global systems breakdowns*
6. *Organisational resources (time, technical, and human resources) are reliable predictors of team efficiency and/or effectiveness*

Among others, these above are a set of key work hypotheses which will be directly or indirectly tested throughout most of the chapters that follow. Arguments about the six hypotheses above are discussed in Chapter 3 and findings in Chapter 10.

## **Levels of explanation**

Over the last 50 years and more, explanations about teams, team behaviour and its variability have received quite a number of interpretations and brought to light a multitude of definitions and conceptual models that frequently remained, and still are, fragmented or lacking of a general and unifying theoretical framework (Goodman and Associates, 1986; Swezey and Salas, 1992). It is thus considered vital that a *dialogue* between perspectives be the true way forward in future team research.

Following on from this, the search for an explicit and sustainable relation across diverse levels of team explanations is not only desirable but will be considered a theory-building requirement underlined by the following argument:

*A single level of explanation for any team behaviour is less probable of verification/falsification in the absence of a measure of the relationships between this level and at least another (possibly) dependent explanatory level.*

Borrowing from the range-theory classification by Merton as suggested, and adapted from Bryman and Cramer (2001), three different explanatory levels could be chosen: high-range, middle-range and low-range theories of team behaviour. The ordering from high- to low-range simply expresses the degree of empirical verification obtained. Generally, high-range explanations are not verified. Instead low-range theories are tested and verified quite frequently. These three levels are depicted Figure 1-1 and described as follows.

***Team system***: this high-range level of explanation defines what the project for teamwork is. This represents the plan about resources that actual work teams will require to perform a complete business operation (e.g., the maintenance operation or the check process). The explanations at this level are the highest and more influential to understanding team behaviour. These high-range explanatory level defines how the team concept is defined and shared in the organisation, how teams are developed, organised and maintained according to the managerial perspectives. It is the definition of the total team system requisite.



**Figure 11 - Levels of team explanations**

***Process team***: this middle-range explanation focuses on what is the particular dependence of any operational team with its close working environment. Basically any maintenance team in hangar happens to be by process (single or multiple workflows). The team problem becomes a problem of multiple teams in interaction and co-ordination. This level of explanation defines the causal affairs between what is supposed to happen and what actually happens during real process events. The explanations at this middle-level are by far the least understood and studied in terms of their impact on the teamwork operations and practices.

***Team process***: this low-range explanation defines what is the team form under investigation and its internal behaviour. This level defines the relationships between conditions of knowledge, behaviours and practices to face operational scenarios. What can be explained at this level in terms of effectiveness is relative to the performance of the preceding levels upon which it depends to display successfully teamwork events.

Overall, the definitions by the three levels above would like to be considered the *relative model* to approach the explanation of teams and their behaviours in real contexts. The basic rationale of this approach is pointing to the fact that what is described and explained at one level can only be relative to the knowledge and explanation of the other levels and cannot be considered as a unique or fundamental explanation *per se*. Moreover, this relativism in explanation has also a very important property for causation: it fits well with the law of minimal critical order of causality as described previously in section 1.5 above (for a full definition of the minimal critical order see Chapter 8). It follows that the present research will avoid any simple combination or *compression* into a ingle level of explanation which is deemed to compromise the general logic of this relative team model described here above. Notably, this combination into single levels of explanation for teamwork processes is by far is the most common approach adopted in team research.

## **Epistemological framework**

As suggested by von Bertalanffy (1968), the epistemological approach to study complex dynamic systems is less favourable to an *analytic strategy* (hypothesis-testing approach) because the interactions across parts of the system are not trivial and cannot be easily represented by linear functions. Work teams do show, *to a certain degree* such kind of dynamic system characteristics. Thus a *systems approach* to study work teams may be more favourable: tracing continuous variables, which interact dynamically, producing multiple changes, where each component, event or action has the potential of affecting the entire system with different sensitivities and final outcomes.

In this view, the epistemological approach chosen here is a tentative convergence between analytic and systemic model-based interpretations of the reality under study, teams. Thus, both interpretations and orientations have been considered. Translating into scientific sources, the analytic paradigm will be mirrored by clear references to applied human factors frameworks (Cacciabue 1997; McDonald and Johnston, 1994; Patankar and Taylor, 2004b; Reason, 1990), and by literature on team performance modelling (Goodman and Associates, 1986; Guzzo and Salas, 1995; Hackman, 1990, 2002). Instead, the socio-technical design, organisational and systems theory literature (Galbraith, 1977, 1994; Herbst, 1974; McDonald, 2005; McDonald et al., 2000; Meshkati, 1989; von Bertalanffy, 1968) will reflect the expression of the systemic paradigm. All these various scientific positions will appear throughout the entire work as key driving scientific references, acting as a form of epistemological co-ordinators.

**Chapter 2**

**Team concepts behind a maintenance team**

“*Team training and competence are not enough*” (anonymous trainee).

# **Team concepts behind a maintenance team**

## **General team concepts**

*A small set of individuals assigned to perform and co-ordinate interdependently a number of tasks as a dedicated work system* is a simple definition of a work team. Obviously, this is one of quite a number of more sophisticated team definitions available to date. Table 2-1 below is a relative short list of such team definitions. In particular, team research over the last thirty years and studies across different work environments and settings converged towards certain common descriptions and models of teams at work (Swezey and Salas, 1992). Nevertheless it should be remembered that team definitions are not neutral elements. The operation of defining of a team can determine to a large extent what is then verified, measured and valued of a team and its meaning.

The majority of team definitions in Table 2-1 focus on human and social dimensions. The implicit model is about individuals in interaction, interdependence, recognition of membership, shared goals and performances. No definition details any specific technical system, technology requirement or any organisational structure. Firstly, work teams are social aggregates within larger systems and, secondly, they represent organisational assignments. This framework, of course, is to be expected by Authors whose backgrounds are similarly grounded in organisational, social and psychological sciences. Implicit in most definitions is that a team is a type of group (Tubbs, 2001). Clearly a number of definitions in Table 2-1, for instance those ones proposed by Forsyth (1999), Shea and Guzzo (1987), McGrath et al. (1995), or Taylor and Felten (1993) put the emphasis on the *internal* elements of the team entity; the focus is more on the elements that should be in place to determine a work team. Shared goals, cooperation and participation among individuals are traits for team identification. Focus is more on internal individual and group characteristics affecting team members’ relationships, communication structures and roles, group norms as well as team diversity (Jackson and Ruderman, 1995).

Instead, definitions like those ones by Salas et al. (1992), Hackman (1987, 1990), Francis and Young (1992) or Friedlander (1987) reflect a more *task- and performance-oriented* framework. Such definitions are more likely to appear in research conducted in industrial, commercial or military sectors. Such descriptions fit in well with the study of real performance teams for high reliability and safety critical systems like the actual aircraft maintenance organisations. In general *task- and performance-oriented* definitions represent the most common descriptors for an aviation maintenance team (Taylor and Christensen, 1998). Preference in this case is on team requisites for efficient team communication, co-ordination, adaptability and decision making (Cannon-Bowers et al., 1995). The orientation is to determine teamwork skills, favourable attitudes, values and requisites for safe and proficient performances.

However, implicit in many of these latter definitions is the assumption that work teams determine their own processes and organisation (Huszczo, 1996) but, notably, the wider organisational systems (e.g., leadership, contexts and supporting environments) are powerful variables that can moderate team processes and performances in several ways (Hackman, 2002). Still, *context* is less central to most of the definitions reviewed. Exceptions are the definitions by Friedlander (1987) and Rifkind (1996) which both consider interdependence with the organisation or other teams as a critical element to consider (see Table 2-1). These two definitions and that one by Morgan et al.’s (1986) reflect precisely the organisational condition of several aircraft maintenance teams.

* + 1. **Advantage of teams**

Teams are used to achieve an aim or a goal that could not be accomplished easily, or possibly even at all, by an individual working alone (Carter and West, 1999). In the early 90’s, work teams were already considered a basic future unit of work (Hackman, 1990), and their functions, roles and visibility are now becoming more and more relevant to any new organisational setting (Guzzo and Salas, 1995). Aviation maintenance was not immune to this team empowerment and research orientation. In this line of thought, some considerations on the practical advantages *inspiring* the use of team concepts in hangar maintenance are given below.

#### **Teams** **augment work performance**

One of the most simple advantage to use teams instead of individual task assignments is based on the very simple fact that today’s work in large

**Table 21 - Definitions of team**

| Forsyth, 1999 | Teams are specialized types of performance groups. They stress cooperation among members, higher levels of structure and coordination, cohesion and identity, and goal attainment. |
| --- | --- |
| Tubbs, 2001 | Work groups are the formation of people on the job |
| Napier and Gershenfeld, 2004 | In human terms, a team is a group working cooperatively to accomplish a mutually satisfying goal or goals in a manner that maximises the resources of the group and results in an outcome that could not be accomplished without such participation and support |
| Guzzo, 1995 | The teams and groups are bounded social units with work to do in larger social systems (i.e., work organisations). They have an identifiable membership and an identifiable task or set of tasks to perform – *(adapted)* |
| Salas et al., 1992 | A *team* is defined as a distinguishable set of two or more people who interact, dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have a limited life-span of membership |
| Shea and Guzzo, 1987 | A set of three or more people that can identify itself and be identified by others in the organisation as a group |
| Hackman, 1987 | Work groups in organisations are 1) real groups (intact social systems complete with boundaries and differentiate roles among members), 2) groups that have one or more *tasks* to perform, resulting in discernible and potentially measurable group products, and 3) groups that operate within an *organisational context – (adapted)* |
| Nieva et al., 1978 | Two or more interdependent individuals performing coordinated tasks toward the achievement of specific task goals |
| Sundsdrom et al., 1990 | Work teams are defined as interdependent collections of individuals who share responsibility for specific outcomes for their organisations |
| Hackman, 1990 | Production teams take raw materials and transform them into products using tools, technology, and members’ labour. The *materials* from which a production team is developed include a facility, pieces of technology (some already in place, some on order), individual team members and managers (with more to come), and the all-important audit checklist that specified in detail what the team was supposed to accomplish – *(adapted)* |
| Francis and Young, 1992 | A high performing task group whose members are actively interdependent and share common performance objectives |
| Sian and Robertson, 1996 | A team is two or more individuals working interdependently to complete a specific task |
| Morgan et al., 1986 | A team is a distinguishable set of two or more individuals who interact interdependently and adaptively to achieve specified, shared, and valued objectives |
| Rifkind, 1996 | A team is a diverse group of people who are interconnected with shared responsibilities and strive toward mutually defined goals. A team works within the context of other groups and systems |
| McGrath et al., 1995 | A work group is a dynamic system, made up of an integration of *people*, *purposes*, and *tools*, which become the group’s *members*, *projects*, and *technology*, respectively |
| Tannenbaum et al., 1992 | Teams are a particular subset of small groups in which members are required to interdependently interact |
| Mohrman et al., 1995 | A group of individuals who work together to produce products or deliver services for which they are mutually accountable. Team members share goals and are mutually held accountable for meeting them, they are interdependent in their accomplishment, and they affect the results through their interactions with one another. Because the team is held collectively accountable, the work of integrating with one another is included among the responsibilities of each member |
| Friedlander, 1987 | A work group is broadly considered to be a small set of people with a common overall goal, who are, to varying degrees, socially structurally, and technically interdependent with each other and with the larger organisation – A work group is simply a subsystem of the larger organisational system that it serves and upon which it depends for human, technological, and financial resources, for information and power, and eventually for its very existence |
| Taylor and Felten, 1993 | From a systems perspective a team is constituted by 1) several individuals who are jointly responsible for their performance, 2) their tasks and activities are interdependent, 3) the interdependence centres on a whole work process, flow, or product, 4) members bring different skills, 5) high need for integration of skills, and 6) members share a common and conscious purpose – *(adapted)* |
| Huszczo, 1996 | A self-directed work team is an intact group of employees who are responsible for a whole work process or segment that delivers a product or service to an internal or external customer |
| Reason and Hobbs, 2003 | A team is a number of people working together to fulfil some common purpose or task |

organisations has almost always a certain degree of complexity/interdependency which requires controls by division of labour. A form of division of labour is the design of a work group structure, although this structure might not be the easiest to develop and manage (Weldon, et al., 1991).

Notably, complex and large task performances could theoretically be performed by single individual operators in single sequenced linear operations if the main task interdependencies can be controlled accordingly. But this simple configuration of individual work activities would certainly result in unacceptable task delays, undesirable levels of human and technical resources expenditures (i.e., efficiency factor) or ineffective work performance results (i.e., effectiveness factor). Instead, what can be done to better manage a complex and large work activity is to organise and manage the overall tasks and their relationships by working concurrently, merging different resources and skills together, and finally containing (or bounding) such resources and interdependencies in a proficient team architecture (Urban et al, 1995).

Work teams, have also the potential advantage to cope with workload fluctuations more easily than individuals alone (i.e., distribution of workload), and allow for more flexible work configurations to respond faster and more effectively to unexpected events by mutual support and back-up behaviours across members (Swezey and Salas, 1992). Specifically, unplanned work conditions and unforeseen events (highly frequent in modern complex socio-technical systems) call for a work system based on rich and reliable communication, collaboration and co-ordination functions which help maintain efficient and effective cross-tasks progression, interdependencies and performance delivery. Such functions characterise the workings of a well formed team-based organisation (Shonk, 1997).

#### **Teams maintain operational safety**

Organisation of work in single or multiple work teams or groups has an intrinsic property very relevant for safety matters: it can provide more operational *redundancy* as well as resource flexibility and *availability* to secure performance. In practice, a piece of work (e.g., an entire operation or a task) is not only fragmented into subtasks but it is also *shared* across different individuals. These individuals can then increase awareness of each other’s actions and decisions augmenting the chance to spot risk conditions (Endsley and Robertson, 1996a, 1996b). Clearly, a shared work context, which allows for real effective teamwork, is a better condition to prevent, detect or mitigate failures that would go undetected at individual level (Reason and Hobbs, 2003). Put simply, “more eyes on the same task”, in a full-fledged team context, can potentially increase safe performance.

#### **Teams manage complex interdependency**

For complex work systems such as hangar maintenance operations with distributed supply chains, the operational and support teams are required to optimise/regulate flows of work processes, lateral organisation and communications which contain *operating* interdependencies affecting several functions, departments and work units (Galbraith, 1994; Shepherd et al., 1991; Taylor, 1990). That is, *the more the operating interdependencies to be controlled the more the need of having the entire work systems based on co-ordinated team systems* (Baranzini and Cromie, 2002; Baranzini and Cacciabue, 2006).

Clearly, and to a large extent, expectations on controlling safety, productivity and complexity of work paved the way to the introduction of work teams in aviation maintenance (ICAO, 1995; Patankar and Taylor, 2004b).

* + 1. **Team models**

Models of team performance and training effectiveness have shown that team processes are influenced and shaped by organisational and situational characteristics, task and work characteristics, as well as individual and team characteristics (Guzzo and Salas, 1995). Such interplay of internal and external team factors is especially important to represent the complexity and reality of hangar maintenance teams (Ivaturi et al., 1995). In particular conceptualisation of work teams in aircraft maintenance was influenced by different frameworks or models defining team input-process-output relations and performance. A number of these models still act as main theoretical drive to maintenance team representation and analysis. The following team models are presented here for review.

#### **Hackman’s Normative Model**

The normative model by Hackman (1987) is shown in Figure 2-1. This model is applicable to different type of work teams in organisational contexts. It highlights the impact on group effectiveness of different organisational, group, and resource factors such as, for instance, information and reward systems, group composition, facilitation to process gains, and materials availability. The model defines group effectiveness criteria in terms of outcome acceptance by the final customer, group development and satisfaction in team experience.



Intrinsic in Hackman’s model is a shift towards the identification of *organisational and contextual* criteria as enablers of team performance rather than the more common identification of causal factors internal to team processes and dispositions. Group processes are a function of upstream organisational settings and contexts. Group outcome (e.g., Group Effectiveness) is moderated by resources allocated to the group’s work. Finally, the suggested *ordering* between input and process variables might be a useful criterion to prioritize interventions toward group improvement.

#### **Gladstein’s Task Group Effectiveness Model**

The Gladstein’s Task Group Effectiveness Model (1984) defines team effectiveness as a function of both group internal processes (e.g., supportiveness and boundary management) as well as external organisational factors (e.g., group rewards and supervisory control). The model is shown in Figure 2-2 below.



To note, group tasks properties play a moderating role between group process and final group effectiveness. Dimensions like task complexity, uncertainty and team interdependencies do moderate the combined effects of group and organisational levels on the final group outcome.

This is one of the few models formally tested with a large sample of real work groups in organisations. The results showed that the effect of group structure on process relationships was supported. However, internal group process did not predict group effectiveness and group process-effectiveness relationship was not mediated by group tasks dimensions (Goodman and Associates, 1986). Finally, according to Salas et al. (1992), Gladstein’s model suggests that training alone would not enhance team effectiveness.

#### **Morgan et al.’s TEAM Model**

The Team Evolution and Maturation (TEAM) Model by Morgan et al. (1986) introduces the dynamic evolution of teams as performing units. It links to previous studies on team formation and growth (Gersik, 1988; Tuckman, 1965). Two behaviour tracks are modelled. These are the operational task orientation and the generic team skills or 'teamwork' aspects of learning. The former addresses competence on tasks skills, procedures and technical behaviours. The latter is on teamwork and co-ordination orientated dispositions, attitudes and collaborative behaviours. Both tracks evolve and integrate before or at the point of task performance. Notably, the model suggests that the experience and knowledge of teamwork as well as of task-work is then *remembered* as teams disband.

#### **Nieva et al.’s Team Performance Model**

The team performance model by Nieva et al. (1978) defines team performance as separate element from task performance. This model is depicted in Figure 2-3. The individual task performance combines with team functions to determine an overall team performance.



Also the model describes different antecedent conditions impacting on proficiency. External conditions, such as the wider organisational and social context, have indirect effects on the final results.

The main moderating variable is team characteristic (e.g., intra- and inter-team co-operation, communication, cohesiveness) that interfaces with individual member resources and task characteristics elements. All together the antecedent conditions determine team performance. In general such model contains high level descriptions and no finer-grained performance measures criterion is implied.

#### **Aviation Maintenance Team Model**

The team effectiveness model by Ivaturi et al. (1995) is the adaptation to maintenance environments of a framework originally proposed by Tannenbaum et al. (1992) and revisited by other researchers over the mid 90’s (Cannon-Bowers et al., 1995; Urban et al., 1995). The model presented in Figure 2-4 below is based upon tasks analyses of inspection and maintenance operations (Drury et al., 1990), site visits to repair stations, observations with maintenance training personnel and instructors. Basically it mirrors and integrates all the models that have been described here above: “In general, team performance is the outcome of dynamic processes reflected in co-ordination and communication patterns that teams develop over time. The processes are influenced by organisational and situational characteristics, and task and work characteristics, as well as individual and team characteristics.” (Salas et al., 1992). Ivaturi and colleagues make an effort to model the actual maintenance *context* and satisfy a criterion here termed *team model specificity*: team models should address and describe properties unique to teams under evaluation and their natural work environments (Cannon-Bowers et al., 1995; Salas, 1992).

This model has the advantage to define a maintenance organisation by discriminating between repair facility, airline division or general aviation environments. This implies that teams are affected by differences of the embedding organisation. It considers type of aircraft operations involved (e.g., A, B, C, or Heavy checks) or task types like, for instance, avionics, power plant or hydraulics. Environmental factors differentiate whether maintenance is done in hangar or in flight-line (i.e., apron).



These above are external factors interacting with internal team factors like individual competence on different aircraft types and systems, as well as specific *teamwork skills* like communication, co-ordination and assertiveness. Together, internal and external factors influence the team processes and capability. The total output is modelled to separate process measures at individual and team level from task performance measures (e.g., task completion speed, accuracy, safety indexes). Also, the training element becomes a critical element of the model. It reflects the evolution and developmental aspects for successful teamwork.

This model is finer-grained than the other ones presented, but still it cannot explain any differential leverage on performance by the various individual or combined input or process variables (e.g., significance of effect of external factors on Task Performance Measures). Nevertheless it remains one of the very few examples of team models directly applied to aviation maintenance teams.

* + 1. **Team competence**

The various team models presented should be considered means to guide and align interventions about teamwork. And one type of intervention has been emphasised in maintenance environments: team competence. Team competence can be described as the *knowledge*, *skills* and *attitudes* required to be an effective team member (Cannon-Bowers and Salas, 1997).

#### **Team knowledge**

Knowledge requisites entail principles, concepts on team’s equipment, task and forms of interactions (e.g., how team members communicate). Knowledge types range form declarative, that is, expected roles and relations among members, to procedural, how to perform together, and explanations on why team members are required (Cannon-Bowers et al., 1993). Such knowledge forms the basis of team members’ expectations in a task situation. For instance, a team player who has these kind of knowledge not only will have expectations of possible behaviours but he will be able to recognise what is going wrong and implement strategies to combat ineffective team behaviours.

#### **Team skills**

Together with knowledge, team skills embody a capacity to display teamwork as a complex set of behaviours and expectations to cooperate and share awareness, coordinate and communicate as well as adjust and adapt reciprocally towards shared (or combined) task objectives. This condition demands considerable organisational effort and requires clear orientation to teamwork by the team members overall as well as by the non team members surrounding the team.

Notably, team skills competencies can be specific to a particular activity and context, but some others are independent of the task context or work situation. These latter ones are called by Cannon-Bowers and colleagues (1995) *transportable team competencies*, which are by far the most targeted and investigated items in applied team research. Adapting from the same Authors, Table 2-2 displays an example of core teamwork skills which are supposed to represent team processes and govern the enactment of effective teamwork performance.

#### **Team attitudes**

Finally, dispositions to teamwork define the realm of teamwork attitudes. Dick and Carey (1990) define an attitude as an internal state that influences an individual’s choices or decisions to act in a certain way under particular circumstances. The importance of attitudes toward teamwork in collaboative oriented and communication intensive domains is well recognised, and aviation maintenace has been particulary receptive to this psychological measuring in connection with training needs and resource management (Baranzini et al., 2001; Gregorich et al., 1990; Taylor, 2000).

Such *collective orientation* is an attraction to the team as a means of task accomplishment (Driskell and Salas, 1992). It involves the *capacity* to take others’ behaviors into account during group task interactions (Davis, 1969). Such person oriented approaches should be considered as part of the overall team performance competence together with goal or task orientations (Foushee, 1982).

**Table 22 - Core tamwork skills (adapted from Cannon-Bowers et al., 1995)**

| ***Teamwork skills*** | ***Definition*** |
| --- | --- |
| Adaptability | The process by a team is able to use information gathered from the task environment to adjust strategies through the use of compensatory behaviour and reallocation of intra team resources |
| Share situational awareness | The process by which team members develop compatible models of team’s internal and external environment; includes skill in arriving at a common understanding of the situation and applying appropriate task strategies. |
| Performance monitoring and feedback | The ability of team members to give, seek, and receive task-clarifying feedback; includes the ability to accurately monitor the performance of team-mates, provide constructive feedback regarding errors, and offer advice for improving performance |
| Leadership/team management | The ability to direct and co-ordinate the activities of other team members, asses team performance, assign tasks, motivate team members, plan and organise, and establish a positive atmosphere. |
| Interpersonal relations | The ability to optimise the quality of team members’ interactions through resolution of dissent, utilisation of co-operative behaviours, or use of motivational reinforcing statements. |
| Co-ordination | The process by which team resources, activities, and responses are organised to ensure that tasks are integrated, synchronised, and completed within established temporal constraints |
| Communication | The process by which information is clearly and accurately exchanged between two or more team members in the prescribed manner and with proper terminology; the ability to clarify or acknowledge the receipt of information |
| Decision making | The ability to gather and integrate information, use sound judgement, identify alternatives, select the best solution, and evaluate the consequences (in team context, emphasises skill in pooling information and resources in support of a response choice) |

Overall team competence in terms of transportable skills, knowledge and attitudes will always demand presence of a real team with people in interaction. Team behaviours and decisions underlying such competencies are ultimately responding not only to operational interdependencies among tasks, but also to an expected and highly desirable *attitude of interdependence*, that is, a clear disposition of all members to recognise the need to rely on each other (McIntyre and Salas, 1995). In general, it is acceptable to suggest that fostering such within-team interdependence and mastering transportable team skills together and in a real team context can augment the likelihood of both teamwork performance efficiency and effectiveness *and* *consequently* the overall team’s task outcome (Patankar and Taylor, 2004b; Swezey, and Salas, 1992).

## **Research on teams in maintenance**

A large portion of aviation maintenance work is accomplished by work groups (Shepherd et al., 1991; Taylor and Christensen, 1998). The challenge is to work autonomously but still be part of the team (Ivaturi et al., 1995). Any daily operational tasks assigned to a team of technicians in a hangar require timed interactions between and across several departments and functions. A common organisational scenario follows: as the sales personnel sign for a new maintenance contract with a customer, the engineering department produces high order and long-term planning for all the aircraft maintenance scheduling, which will be sent to the planning department, which in turn, will produce and dispatch several work-packs for the scheduled maintenance to the appointed shift/hangar managers and supervisors in the operational departments. These will finally break work-packs down into job-cards for the daily work of small teams of technicians. Notably such type of workflows and assignments led on one hand, to continuous work specialisation, compartmentalisation and functional differentiation, while, on the other hand, it amplified a strong need for intensive integration and higher levels of teamwork (Baranzini and Cromie, 2002).

* + 1. **Maintenance team identification**

Little research addressing real operational teams in hangar maintenance exists. This is despite competency requirements about teamwork in maintenance has produced a wide body of knowledge and research applications.

Characterisation of hangar maintenance teams did arise out of organisational and in-field studies which instrumentally revealed several team structures co-ordinating several hangar operations together. Configuration of hangar work teams is described by Shepherd et al. (1991) as follows:

* An average of 25 mechanics working together per check operation per shift for a total of about 75 mechanics total on the average C-Check (i.e., a maintenance operation on the aircraft requiring even more than 2 weeks work)
* Between four and six maintenance subgroups are employed on various jobs on the aircraft during overhaul. These subgroups consist of the occupational specialties of sheet metal mechanics, riggers/general A&P, cabin mechanics, cleaners; and sometimes painters, and contractors (specializing in particular repairs such as fuel tanks)
* Other regular subgroups or occupational specialties involved in the normal C-check are inspectors, parts or materials clerks (two or three to a group), and planners or coordinators (usually organized in groups of two to four)
* These subgroups do not change themselves in composition during the check although they may change in membership as usual members rotate through their individual shift schedules, or work overtime on another shift
* Occasionally a mechanic can be reassigned by the foreman to work with mechanics in another subgroup, or a foreman would request all available members of a subgroup to assist in a task to which they normally would not be assigned

Interestingly, several sub-groups of the total crew per shift are distributed over different zones of the aircraft. An example of such *zonal* configuration is described in Figure 2-5. Apparently, team configurations are dependent on technical configurations of the aircraft: e.g., dedicated wok groups for wings, engines, cabin, cockpit etc. Also other descriptions from an organisational perspective show how each sub-group will interact and communicate with several external services and support units (Endsley and Roberson, 2000; McDonald, 1999).



It is clear that the problem of teams in maintenance may be more a problem of a system of teams in interaction and less of single individual internal team factors: it is system of teams and units in reciprocal interaction that has leverage on the total system (Baranzini and Cromie, 2002).

* + 1. **The need of team-based systems in aviation maintenance**

From a maintenance business point of view the need for team-based systems became a necessity during the mid 80’ies in order to overcome what Shepherd et al. (1991, p. 28) identified as “A certain degree of co-ordination difficulty and miscommunication results from the way the systems were structured”.Obviously this is a simplification of very intractable problems of complex organisations of work. In several respects this co-ordination difficulty in maintenance is just one of the visible negative effects arising out of complexity of division or labour, standardisations of work, span of control, cross-functional requirements, departmentalisations issues as well as high needs of reliably in planning, scheduling, and logistics systems (Herbst, 1974;Mintzberg, 1993;Taylor and Christensen, 1998). Interestingly, the response to such organisational factors was unanimously towards the adoption of teamwork structures. And the main scope of this convergence centred on two key dimensions: business proficiency and safe performance of the operation.

* + 1. **Business proficiency and teamwork**

According to Taylor and Christensen (1998), teamwork, communication and team-based systems can be powerful assets that any maintenance organisation should seriously consider to improve business results. A systemic approach to managing maintenance work is to replace an outmoded management approach that follows a top-down, shift-to-shift, and linear mechanical thinking. This *replacement* and *change* is possible by introducing multi-skilled, highly communicative teams.

Research in aircraft maintenance showed that such new business approach is fruitful, and effective implementation of work teams can facilitate solutions towards higher productivity. In the last three decades, the introduction of work teams, discussion groups, participatory leadership and new open-communication strategy in maintenance departments improved performances, management-workforce collaboration, technicians’ well-being and competitiveness among several commercial airlines such as Air Canada, British Caledonia Airlines, Scandiavian Airlines, People Express, United Airlines, Southwest Airlines, Continental Airlines, TWA, USAirways, Aer Lingus, and many others (Cromie, 1999; Taylor and Christensen, 1998).

For instance, the application of training courses called Crew Resource Management (CRM) to maintenance departments at Continental Airlines improved team identity, skills and teamwork attitudes in the workforce. This change revealed to be associated to subsequent improvements on important key performance indicators such as on-time departures and reduction of job injuries (Stelly and Taylor, 1992; Taylor and Roberston, 1995). Ramirez (1989) reported how Japan Air Lines (JAL) instituted in 1985 a system of teams (*kizuki*teams), responsible for one single company’s Boeing 747 aircraft at all times. This system of work based on teams was reported as a success to improve performance and quality of service, although, as pointed out by Shepherd and colleagues (1991), no specific results or costs were related.

Successful team-based projects in military aircraft maintenance are reported by U.S. Air Force (Rogers, 1991). Maintenance divisions separated by functions and reporting structures (e.g., dispatch, plans and scheduling, job control) were re-engineered into team-based systems. Improvement in operational results was straightforward: aircraft utilization rates and readiness increased 43% and 59% respectively. On-time departure rates increased from 75% to over 90%. Basically, reassignment of technicians to three separate 24-aircraft squadrons, decentralized leadership with different levels of authority and responsibility, and institutions of group membership showed to be key factors fostering such operational proficiency (ICAO, 1995).

Overall, these few examples above reveal how effective implementation and utilization of work teams based on open communication and cooperation systems can increase business proficiency and greater job satisfaction in aviation maintenance settings.

* + 1. **Safe performance and teamwork**

Safety and teamwork is certainly another key argument in aircraft maintenance. Intrinsic in any teamwork event is the increased opportunity to failure due to multiple communication, interdependence and complex co-ordination requirements. Nevertheless such risk is counterbalanced by higher capacity in error detection and recovery (Sasou and Reason, 1999). Unfortunately this is not always the case, especially in complex environments like hangar operations where maintenance team failures led to very serious aircraft accidents. For instance, the Maui and Eagle Lake accidents in 1988 and 1991 respectively showed how faulty collaboration and communication, that is, teamwork across work groups combined to produce in the first case the death of one flight attendant and many injuries on onboard of an Aloha Airlines’ 737 aircraft (NTSB, 1989). In the second event, 11 passengers and a crew of three of a Continental Airline commuter aircraft died in the crash (NTSB, 1992).

Poor communication across maintenance crews resulted in a very similar event just after 14 months after the Eagle Lake accident. In this case, 12 out of 51 screws went missing on a left wing panel in flight. Fortunately, the flight crew recognised the problem just in time to return and land back safely. This just avoided another hull loss accident (Sharn, 1992).

Other maintenance case studies about event occurrences due to teamwork hazards are described by Reason and Hobbs (2003) and summarised in Table 2-3. Although these case studies are very different in terms of impact and associated operations (line versus hangar maintenance) the same Authors suggest that in general “team management errors are one of the most serious threats to safety”. They also list the most common elements associated to team errors in the aviation domain:

* Team leaders being over-preoccupied with minor technical problems
* Failure to delegate task and responsibilities
* Failure to set priorities
* Inadequate monitoring and supervision
* Failures in communication
* Failure to detect and/or challenge non-compliance with standard operating procedures
* Excessively authoritarian leadership styles
* Junior members of the crew or team being unwilling to correct the errors of their seniors

Table 2-3 reveals that maintenance is an error prone condition for teamwork. People initiating a task are not always the same completing it. More teams and shifts can be involved on the same activity, thus co-ordination and communication become more critical across groups.

Communication and co-ordination failures *across* maintenance teams or crews are very frequent problems associated with preventable aircraft accidents (Wenner and Drury, 1996). In particular, an important Australian survey about aircraft maintenance personnel over a sample of 600 incidents reports revealed that co-ordination issues added up to 12% of all occurrences. Misunderstanding, ineffective teamwork, communication, false assumptions are at the base of such co-ordination dysfunctions (Hobbs, 2001).

The problem of real teams and safe operations is well stated by Patankar and Taylor (2004b): “That is not to say that a mechanic does not know whether or not he is working on a “C” check, but that he may not know how his work might impact another mechanic’s work (p. 77)…an effective team will be capable of absorbing certain types of errors by individual members because they will have an effective defence mechanism such as cross-checking each other’s work, briefing each other of the potential errors in a particular job, and finally simply doing a team-member’s task if that member is unable to perform that particular role/task. In reality, we find that some mechanics who are supposedly working in a team with engineers, inspectors, and management, rarely communicate with each other (p. 78)”.

**Table 23 – Incident events and teamwork failures**

| **Incident case studies\*** | **Description** | **Teamwork failure** |
| --- | --- | --- |
| *Aircraft dispatched improperly* | Aircraft dispatched with a critical inoperative and undocumented system | A maintenance crew commenced an A-Check on a twin engine jet aircraft. The crew deactivated the thrust reverse system and did not write up this operation. A second crew completed the work on a second shift with no reactivation of the system |
| *Boeing 747 oil leaks incident* | Oil leaks during an engine run were not solved. And aircraft suffered an in-flight engine shutdown | Poor interaction and group norms across maintenance crews and ramp personnel led to inaccurate engine tests and consequent in-flight engine shout-down |
| *Nose steering minor incident* | An aircraft was dispatched with the nose steering by-pass pin left in | Faulty assumptions between two technicians: both assumed that the other had removed the pin before the aircraft was dispatched |
| *Oil line event* | An airframe and engine tradesman did not secure an aircraft oil line. | Ineffective communication practice across different trades and work specialties |
| *Special tool left in aircraft* | A pilot detected a special tool attached to the aircraft after a per-check flight | A first maintenance crew left the special tool attached to the aircraft and also failed to report the activity and did not informed second shift (shift-handover failure) |
| *Boeing 747 Engine oil leaks* | A 747 aircraft was turned back to its departure airport, due to clear reduction on oil levels in two engines. | A mechanic performed engine-related tasks *following procedures to the letter*. A second maintenance crew took over the engine tasks and made faulty assumptions on the work done on the components of the four engines. Communication and co-ordination across different teams and shifts caused uninstalled protections for oil spillage to go undetected before the aircraft departure |

\*source: Reason and Hobbs (2003)

Over the last two decades such forms of communication/co-ordination problems raised a serious call about maintenance workforce preparedness to teamwork. This key competence for aviation maintenance teamwork is reviewed here below.

## **Team oriented interventions**

Maintenance activities are frequently *team-driven* operations requiring above-average 1) communication, 2) co-ordination, and 3) interdependence between team members and across different work groups, units, as well as departments. Unfortunately, team skills competency required to manage several *team-driven* activities is not part of the “current training background” of aircraft maintenance technicians and supervisors (Ivaturi et al., 1995). Also, current human factors training requirements *fix* the problem mostly by improving attitudes towards teamwork, team knowledge and awareness (ADAMS, 1996; Stelly and Taylor, 1992; Taylor, 2000). Maintenance technicians, supervisors, support staff as well as management need to be all trained to work across functional boundaries and towards team-based structures (Patankar and Taylor, 2004a, 2004b).

Following on from this, an important step forward in this direction was the aircraft maintenance adaptation in the early 80’s of the Cockpit Resource Management (CRM) training for pilots (Taggart, 1990; Wiener et al., 1993). From a safety perspective, such resource management training intervention was driven towards factors typically not considered for change, but instrumental to favour safe operations and proficiency of cockpit crews. In this perspective, *soft elements* of the system like communication, group decision making, human error, interpersonal relationships, assertiveness or deeper latent conditions of work were identified by both industry and research as key issues demanding real focus and intervention also in maintenance environments. For instance, team relationships and exchanges across work teams, teamwork attitudes, leadership styles and group norms paved the way to dedicated training systems generally called Maintenance Resource Management (MRM) for aircraft maintenance technicians and managers (Sian and Robertson, 1996). In general, this new intervention, in its varying forms and applications was chosen as the principal mechanism enabling organisational changes toward team-based systems in maintenance.

* + 1. **Maintenance Resource Management approach**

The MRM is a “general process for improving communication, effectiveness and safety in aircraft maintenance operations” (Robertson, 1998). In its basic form, MRM is a training system which systematically aims at standardising human factors competence towards teamwork, communication and interpersonal relationships. In particular, improvement of internal teamwork attitudes, values, and group norms, as well as direct influence on external behaviours and teamwork skills are the two main approaches constituting the overall MRM training strategy (Patankar and Taylor, 2004a, 2004b; Taylor and Robertson, 1995; Taylor, 1997). Notably in previous Table 2-2 are teamwork skills (Cannon-Bowers et al., 1995) which are nowadays basic competency requirements taught via MRM training courses. A common MRM training syllabus about teamwork is reported here below in Table 2-4.

**Table 24 - Behavioral Team Skills in MRM (source: Roberston, 1998)**

| *Communication & Decision Making*   * briefings * assertiveness * conflict resolution * communication |
| --- |
| *Team Building & Maintenance*   * leadership * team climate * interpersonal climate |
| *Workload Management & (Team) Situational Awareness*   * preparation * planning * vigilance * workload management |

Other team training oriented interventions preceded the MRM like the Crew Coordination Concept (Stelly and Taylor, 1992) and the Delta Airline’s Team Resource Management programme (TRM) (Cabera and Predmore, 1997), as well as programmes like the Team Situation Awareness training for maintenance work teams (Endsley and Robertson, 1996a, 1996b). Nevertheless, the basic training content remained substantially the same, that is: promote assertive behaviour and positive attitudes toward teamwork, developing interpersonal skills, enhance team decision making and problem solving, command structure, communication and co-ordination skills.

Also, examples of more behavioural oriented approaches were implemented with success, especially with the help of advanced computer-based training systems and simulations of maintenance tasks performances (Gramopadhye et al., 1996). The basic objective was to show how teamwork skills improvements bring performance and safety improvements as well in maintenance simulated tasks (Gramopadhye et al., 1994).

Overall, the MRM or similar competence-oriented interventions aimed at establishing effective team building, attitudes and skills for effective proficient teamwork for safety and performance. Such approach in the aviation maintenance world revealed to be highly successful, but only on a limited and *ad hoc* basis. And a critique is in order.

* + 1. **Effects of teamwork attitudes, behaviour and performance**

The attitude-behaviour-performance path is a causal model implicitly assumed by different theories about team performance and teamwork. Tubbs (2001, p. 120) defines that “group members may hold several types of attitudes...all these attitudes will ultimately affect their behaviour in the group, which in turn will affect the group's results”. Individual attitudes toward teamwork are frequently input variables assumed to affect team processes and ultimately performance (Urban et al., 1995). Research on maintenance teams amply supports this causal model (Patankar and Taylor, 2004a, 2004b; Robertson, 1998).

In aircraft maintenance, internal team performance (e.g., proficient teamwork skills) and positive attitudes have been frequently *associated with*, if not taken as causal factors of higher maintenance check performances: the technical and safety performance levels of a complete maintenance check operation, which is obviously controlled by a large work team. This is a very important and challenging research question. Still, too little empirical studies proved such strong linkage. For example, a longitudinal training study on aviation maintenance managers’ attitudes toward teamwork revealed that assertiveness and disposition of sharing command responsibility were correlated, favourably, with the subsequent maintenance safety indicator of lost time injuries. Significant correlations between attitudes and this safety indicator ranged -.26<ρ<-.22 (Patankar and Taylor, 2004a). Also, this lost time injuries index decreased by 80% over the two years following this training study (Taylor and Robertson, 1995).

In the same line, further training studies by Taylor et al. (1997) found significant relationships between aircraft mechanics’ attitudes about teamwork (i.e., assertiveness and stress-management) and reduction in maintenance induced ground damage events. Significant correlations in the expected direction ranged from *r*= -.75 to *r*=-.71. Other subsequent studies reported such significant relationships between teamwork attitudes and safety indicators (Taylor, 1997; Taylor and Patankar 2001).

Also, learning teamwork skills by dedicated team training courses showed that maintenance technical performances of trained groups increased consistently with respect to control groups over a set of dedicated engine repair tasks. Safety and speed in simulated task performances increased and the number of overall team errors per task decreased (Gramopadhye et al., 1994). As suggested by Patankar and Taylor (2004a, p. 159): “Correlations reported in all these studies were in the expected direction– i.e., attitudes improved, then behaviours changed, and safety increased”.

Overall, such results may satisfy in principle a number of hypotheses and theoretical expectations, but consistency of such findings, statistical procedures and controls remain doubtful or at least very weak to several respects. In particular, all aircraft maintenance research on the effect of teamwork attitudes and behaviours upon performance and safety was assessed and tested via simple bivariate correlational studies. A fairly simple statistical approach that is easy to understand, but cannot be sensitive and powerful enough for research with implications for causality. Thus, in the study above on lost time injuries and teamwork attitudes improvement the average correlation value is ρ=-.24. This *non-parametric* value revealed that the average variance accounted for by the measures is about .06%, a very weak proportion of variance explained indeed. The other correlational study between ground damage incidents and teamwork oriented attitudes identified relationships averaged around *r*=.73. Although this correlation value is quite high (providing a more interesting 53% of variance accounted for) a very delicate question remains on the type of statistical protection, like Bonferroni’s correction (Stevens, 1996; Tabachnick and Fidell, 2007) that was needed to such longitudinal study, containing a large series of non-independent tests (i.e., correlations), repeated over time. Apparently, no such desirable and important protection for inflated Type I errors rates were applied to any measure whatsoever. Very likely, this can indicate that several such significant correlation values may well have been type I error rates. A very unreliable condition to any study validation.

Another very important aspect is the study of *mediator* variables. Unfortunately, all correlational studies reported above did not control (e.g., use of covariance analysis) for any potential technical or contextual variable as mediator for indirect effects. All tests performed direct relationships between attitudes and performances indexes. Furthermore, the improved level of engine task performance for the groups trained in teamwork skills was studied with no reference or control of possible effects of external variables (supports) on teamwork tasks. In particular, team training research on simulated maintenance tasks by Gramopadhye et al. (1994) did not realistically consider the potential moderating effect of external systems. All teams in their training experiments were given the same expected spare parts, tools, information, equipments, documentations and supports. In this sense, the environment effect *was kept constant/neutral*, despite the fact that in real maintenance operations such conditions about services, materials, equipments and tooling are the very first one varying and impacting teamwork performances (Reason and Hobbs, 2003).

To this regard, quoting Patankar and Taylor (2004b, p. 22): “When we scale this teamwork down to maintenance tasks, we realize that mechanics depend on parts suppliers to provide them with good quality parts, they depend on the company to provide them with accurate and up-to-date maintenance instructions, and they depend on other teams such as Maintenance Control to provide them with reliable guidance on specific Go/No-go decision”*.* Results and findings in hangar maintenance team research so far are not likely to reflect and generalise on such external factors and impact about teamwork. Overall, the model of relations among performance, safety and teamwork is still under debate.

#### **Results from team skills interventions**

Such uncertainty about the true relation between team improvement and performance in aircraft maintenance is not new or surprising though. The linkage between performance and team proficiency based on individual and team skill training has received mixed support industry-wide. *Yet nearly 30 years after conflicting results were reported, there is little understanding as to why both individual and team skills training improve team performance in some investigations but fail to do so in others* (Swezey and Salas, 1992, p. 18).

One cause suggested is that effective methods for training communication and co-ordination demands are not been achieved yet (Jones, 1984). Another interpretation refers to the content of any team training which is frequently centred on separate modules of team skills. Co-ordination, communication, leadership responses and decision making skills are trained as basic modules. They are trained as prescriptive explicit models. But work teams determine their behaviours during a complex set of events, changing operational scenarios, not via models of separated behavioural skills. Team skills in context in fact may address very different elements, which may be even conflicting from those team skills and models exposed during a training session.

Apparently, systems like MRM for aviation maintenance teams aim at standardising teamwork skills to ultimately remove unwanted organisational variation and general group inconsistency like *process or co-ordination losses* (Forsyth, 1983; Steiner, 1972). Nevertheless, such a position towards skill standardisation may limit, especially in unplanned situations, team readiness to adaptability, creativity and flexibility in teamwork. Team members react to patterns of events and skill situations which undoubtedly require a simple pre-defined response. And adaptation is always learned by practice.

* + 1. **European research contribution**

The European funded ADAMS project (1996) was the first major European project to investigate the current state of human factors in aircraft maintenance. It identified a range of common deficiencies in current European maintenance systems for ensuring quality and reliability. Quite clearly, team performance and co-ordination issues revealed to be critical key variances affecting work/task design as well as functional departmentalisations. For instance, the maintenance planning functions are frequently de-coupled from their direct *receiving areas* such as production units. Timing and scheduling human and technical resources to allocate task activities does not match operational demands and varying condition of task. In fact, co-ordination of work and tasks activities as well as interactions across operational work teams and supports is frequently a matter of local adaptation and adjustment of prescribed activities and standard procedures in order to manage unexpected task variance and situational factors (McDonald, 1999; Reason and Hobbs, 2003). An example of the complex inter-groups relations are depicted in Figure 2-6. Obviously, these are system problems exacerbated by teamwork demands at the sharp-end of the overall process.



Job design issues were also reported to affect team building and development: short shifts provide the existence of work teams composed by personnel that change, this is quite evident in one large north European company. Such shift structure influenced team-working negatively. Integration functions across servicing and production departments were reported to augment team-working.

Out of the ADAMS Project research it is evident how the increased complexity of aircraft systems requires more teamwork, skill, and more co-ordination design among operational as well as support areas. But, despite this, no guideline to audit teams or design team systems was provided.

Notably, following on from the ADAMS *approach*, other European funded research projects such as HILAS (HILAS, 2007), ADAMS 2 (ADAMS2, 2004) and AITRAM (AITRAM, 2002) highlighted respectively the importance of team factors ranging from integration into the total aviation life cycle, methods of auditing teamwork and co-ordination systems as well as training technologies to address team-related scenarios (e.g., communication with supervisors, maintenance tasks requiring a group effort, etc.).

* + 1. **Regulatory environment**

From a regulatory point of view the requirements to address team factors have been mostly considered in terms of human factors training for certifying staff (Baranzini, 2007). Presently, the European Aviation Safety Agency (EASA) has introduced *communication within and between work teams* as basic knowledge competence requirements for maintenance staff. Also in the late 2002, the UK Civil Aviation Authority (CAA, 2003, Chapter 8, p.2) published CAP 716, a recommendation document to maintenance organisations in order to comply with dedicated regulations on human factors topics. Among these topics, communication and teamwork were well considered. Notably, CAP 716 warns about team related interventions as follows: “…*teamwork is an important issue, and should be addressed within human factors training. However, care should be taken to address teamwork issues in context, and not to try to impose possibly inappropriate concepts developed in other areas of aviation (such as CRM) or even non-aviation applications. Teamwork is not the same across industries. There are good lessons to be learned from CRM, and some areas which apply both to the flightdeck and hangar floor, but the differences between the two contexts should not be under-estimated”.*

Finally, from the regulators point of view, it has been stressed that maintenance teams need adequate job design and identity. Team concept is not simply a question to put together a group of technicians and call them a team (ICAO, 1995). A team concept is to be shared and a real team identity also has to be considered very carefully. This has the advantage that a group of engineers will recognize one another’s capabilities and weaknesses as a work group (CAA, 2002).

**Chapter 3**

**New hypotheses about maintenance teams**

“*A new hypothesis is like a present: sometimes unexpected, but rarely new*” (anonymous).

# **New hypotheses about maintenance teams**

Literature review in the previous chapter revealed that the focus about maintenance team research is on the *internal* aspects and variables of team behaviour. The relationship between internal versus external team dimensions has received scarce attention and more research is needed in such direction.

To a large extent, the focus on teams’ operational tasks has limited maintenance teamwork analysis on single separated dimensions of activity. The implication is that team performance, when measured, is still conceptualised in terms of teamwork values about an operational task *at a time*.But any team task in hangar maintenance (likewise in several other settings) is a measure of the capacity to perform in a much larger context, which is made of several other organisational competencies: that is, the *organisational region* of a team.

For instance, the role of organising maintenance teams or systems of teams in maintenance is less understood. More research is required to understand what control the determinants of a team organisation and management. Little is known as well on the organisation of team performances, their daily operations and work practices, as well as their daily environments, shared work practices, workspaces and territories. This internal-external dilemma about maintenance teamwork is described in the following sections.

## **Multivariate levels of team analysis**

Two basic functions support *intra- and inter-team* processes:

1. Interact to *send-receive-share* portions of reciprocal products or processes
2. *Co-ordinate* their activity of interaction

It follows then that team *interactions* are instrumental to achieve efficiency or effectiveness and should result co-ordinated and monitored over time. Nevertheless, proficiency of a group of operators to co-ordinate their exchanges is both a function of a set of shared internal competencies within the team *and* of the set of those shared organisational structures and practices supporting co-ordination and interaction *across* various groups.

Within this conceptual framework, the analysis of work teams and how to provide methods to assess their performance outcomes in actual maintenance environments is differentiated if the assessment of team proficiency is *within* a work team in action or *across* work teams in a process. This assessment requires a double level of analysis about maintenance teams.

Specifically, the first condition details single work groups and its members as the unit of analysis. This will be the basic level of intra-team assessments. On the opposite, the second orientation shifts the unit of analysis at the organisational level where cross-group relationships are to be assessed by detailed investigations of those structures supporting co-ordination, interaction and managerial competence across groups, the *organisational region of a team*. This model of team analysis, shown in Figure 3-1, suggests that when the analysis is centred on internal team factors, the team members’ knowledge, skills, attitudes and values will drive the requirements for internal team competence. On the contrary, the assessment of organisational competence across teams will take into account higher-level requirements to enable proficient teamwork capability across different groups, units, work teams and supports across the same process.



Most important, this framework defines the hypothesis that the internal team competence is *dependent on* and *fulfilled by* deployment of those organisational competencies that maintain interaction and co-ordination with any team’s external environment (e.g., other groups, units, departments, environments, and functions). Therefore, team proficiency and effective performance is dependent on the organisational competence to mange the interdependence across groups embedded in continuous workflows: such organisational competence is here called *team system*.

* + 1. ***Team system***

A key hypothesis in this work explores the way team models and their performances are *conceptualised*. Maintenance operational teams are too complex objects to be analysed and predicted by a disjointed analysis of internal and external team variables. Multiple interactions of such variables give the emergence of recurrent team behaviours, or practices, which will fit into cyclical hangar scenarios and operational conditions. The entire system, the team system, is to be considered in order to understand and predict individual team behaviour, performance and impact. In particular, *the team system is the available work system which enables different work-units (teams) to operate a service or product*.

This new research model is about the analysis of teams directly delivering the service *and* their relation with the support groups surrounding them and enabling their work activities. Such framework would suggest that a work team is an organisational choice that deliberately brings forward several important concepts about how to approach division of labour. Unfortunately much less is known about real team-based services and means to sustain the team concept itself, especially in hangar maintenance.

Maintenance teams are highly dynamic entities embedded in ever changing operational scenarios. Their configuration and operability should be constantly supported by designing a viable and sustainable team system. This approach should not address teams directly, but their interaction and interdependence systems, which, in turn are hypothesised to have more *leverage* on performance than internal team variables effects. It is suggested that the level of self-organisation, and change of team behaviours is so automatic that cannot be directly controlled by the management (at knowledge, skills and attitudes levels). The control of the context, the enabling operational conditions is more than a favourable candidate to control and augment the likelihood of team performance proficiency and quality. Mirroring Hackman’s view (2002), it is important to move from causes to conditions when interpreting team behaviours and performances.

The team system is basically a natural theory of teamwork, a conceptual framework that contains the *intention* by any organisation to introduce the team concept in the real operational scenario and equip this concept with adequate organisation-level performances and arrangements. A natural theory of teamwork emerging from conceptualisations on the meaning given to collective activities. Activities, which cannot be reversed, but where a theory about them will generate the latent conditions about any team in the organisation.

Adopting an empirical approach, the proposed concept of the team system is here addressed by focussing on those real work systems set up to enable and foster organisational performances of work teams: the unique configuration of resources available to a network of teams.

* + 1. ***Process* team**

Maintenance teams, quite uniquely, combines properties and characteristics common to very different type of work groups, for instance production and service teams, crews and task forces (Jackson and Ruderman, 1995). Depending on the very maintenance hangar check operations addressed, one can refer to a maintenance team while describing a crew of 90 people carrying out the total check operation, or the smaller service team of 5 members dealing with an engine change on the wing zone of the aircraft, or, instead, a group of 10 supervisors re-scheduling daily assignments based on the available manpower. It is clear that teams in hangar maintenance represent various configurations of work structures, but differently to other work units, such teams perform concurrently into the very same workflow of operations and structure. Such type of work team configurations dedicated to the same check process is here defined a *process team*. The process team of a team system as it is set up by the parent organisation.

A clarification of terms follows. All teams in hangar happens to be by processes, therefore they can be termed process teams. A process team is a type of work group that, independently by the particular form or function must occur by processes in order to carry out its purpose. Notably the system generating a process team is the *team system*. In this view, the team system can thus be described as *the capability of an organisation to render process teams available, reliable and dependable. It is the available work system that enables process teams to perform their functions*.

In this framework it can be assumed that if the team system is the organisational capacity which accounts for process teams, then the assessment of this organisational capacity can determine any presence of potential teamwork hazards and associated team risks about the organisational business. In fact, from a management perspective, most of the effort in designing and then maintaining teams should be dedicated on how to apply risk analysis on teamwork events, and not simply focussing on team performance and competence requirements.

* + 1. ***Team* process**

According to Guzzo and Salas (1995, p. 385): “*Group process* includes all manner of inter-member communication, leadership acts within a team, flows of information within a group, chaining of members’ actions in the service of a group product, attitudes and beliefs that arise from group interaction, and so on”.

Work teams are all about processes and the chosen team structure is only necessary to support and maintain the behavioural event of teamwork, its process. Also, the more the team members spend time together (either to perform teamwork or social interaction) the more a shared team knowledge became available. This knowledge and the underlying actions and events contribute to develop a practice, a team’s most common mode to *create, initiate or react* about group tasks, team-members, non team-members, the team itself and the embedding organisation. This *team process* evolves dynamically within each *process team* that, in turn is dependent by the *team system*.

The proposition here is that the three interconnected team levels or explanations (i.e., team process, process team, team system) are frequently kept separated in team analysis and research. But, as previously suggested in Chapter 1:

*A single level of explanation for any team behaviour is less probable of verification/falsification in the absence of a measure of the relationships between this level and at least another (possibly) dependent explanatory level.*

## **Team and teamwork performances**

In this Thesis, the term team and teamwork performances entail two different meanings. *Team performance* defines the effectiveness or efficiency measured on the team outcome, the team’s product within a work process: e.g., maintenance check recoverability, downtime efficiency, manpower effort, lost time injuries, customer satisfaction, etc. It is a measure of the expected work product delivered by the teamwork activity. In essence, a *key performance indicator*. On the opposite, *teamwork performance* is a measure of effectiveness or efficiency about teamwork processes. Common indicators are communication, co-ordination, group decision making, team management and interpersonal relationship skills, etc. These are composite measures of how team members work together proficiently, configured efficiently and effectively to maintain teamwork behaviour.

It is frequently *assumed* that a significant positive correlation is expected between these two performance types. The latter (teamwork performance), predicts the former (team performance): the better the teamwork the better the final outcome (i.e., a work product by the team). The expected hypothesis is that *team performance becomes the probability that expected teamwork events are positively correlated to expected and desirable team outcomes*. The underlying assumption is that the concept of performance is a desirable outcome and it is the team determining/causing it, that is, teamwork causes team outcomes.

This view is intrinsic in the most common definitions and models about team performance as it satisfies the researchers needs to identify (and control) simple and clear cause-effect models of relationships between actions and outcomes for team events. Nevertheless, this view is challenged by empirical evidence about the *true* effects of team dependency about the context.

* + 1. **The logic of performance in hangar**

Performance in hangar maintenance is about large repair operations where interdependence across groups is very critical. The basic proposition here is that team and teamwork performance for groups with very large interdependencies with the environment *cannot be contained within the work teams only*. Part of this variance in performance may well be accounted for by external arrangements and exchanges with the context.

If the assumption is that the performance outcomes of a work system is determined by the exchange of behaviours, material and information with environment in a constant flux, then the organisation of such continuous exchange, or flux, becomes the key factor in performance proficiency of such system: this is the behaviour of a system which does not fully control its performance, *the environment does*.

Now, if the system is taken as hypothetical model for an organisational team like the hangar maintenance one, then the exchange of technical and human resources and the degree of dependency with the external support groups can determine its performance output:

*it is the organisation of the environment embedding the team that could explain the major proportion of variance in performance, not the internal properties of the team.*

This hypothesis suggests a new relational framework about team inputs, processes and outputs for teams with very large interdependencies with the context. In particular, the model suggests that the individual team events are distributed in the larger system. This implies that to understand team or teamwork performance one needs to measure and understand the larger work process as it occurs. The model assumes that the single team or teamwork performance is embedded in a larger work process, and generally, a real maintenance work process contains a variety of large work processes. Thus, if the team functioning is proved to be largely dependent on external factors (e.g., human and technical resources) then team behaviour will expand beyond the team boundaries in order to maintain its normal functioning. This means that the expected individual teamwork requirements have to be shared with the larger system and *become general property* of the system itself, a team practice socially shared by the organisation. Consequently, the competence of a team assumes organisational properties that cannot be fully controlled by the team members alone.

* + 1. **The study of team variables and performance**

Several team models refer to social performance dimensions (e.g., interpersonal relationship, communication skills) to account for technical performance *achievements.* But how much technical results are actually a function of social-driven results?

It is important to note that the addressed performance outcome in a real work system is the technical one. From the business side of the organisation, the social performance (favourable teamwork skills, attitudes and values) is to be considered *instrumental* to obtain technical results. Furthermore, the leverage of certain social skills and attitude change interventions upon actual technical performances has yet to be fully verified despite the fact that such relation has always been promoted and asserted (Goodman and Associates, 1986; Hackman, 2002; Shea and Guzzo, 1996).

Notably, the evidence from the team performance models applied in hangar maintenance suggests a *universal* interest by the researchers (mostly social and organisational psychologists) in selecting human factors dimensions and *non-technical* variables. Apparently, the technical variability and the technical arguments are kept as background factor. The *system context* or team *environment* has long been ignored or simply considered *a given*.

The team’s hangar-context is often reduced to a set of moderating variables which exert some sort of influence upon the work team/s. Such variables are frequently modelled as generic support systems, work and task complexity, training systems, managerial/supervisory structures, reward systems, and so on. Unfortunately, this perspective has made organisational-technological variables loose any real explanatory power on certain group behaviours. It is here suggested that such an “attitude” in team research focus may have biased to a certain degree the analysis of team events, behaviours, performances. Put simply, false assumptions have been made about *what* variables are really critical to account for teams and teamwork in hangar operations. And too often, this seems to reveal a researchers’ difficulty in measuring the context, that, hardly surprising, appears to be more difficult to manage in real settings than a one-shot survey measure about teamwork attitudes and skills.

Overall, most of the team variables investigated are not *measured against* the real operational and technical indicators embedding teams and their organisation. This is because:

* The technical processes are verified at a minimal or general level only
* No model of technical efficiency or effectiveness is fully elaborated into team models
* Human dimensions are separated from the technical analysis of the very same work system
* Organisations are reluctant to disclose actual figures on business performance outputs

The end-result of such weaknesses is a partial analysis showing very weak or no relations between teamwork and technical variability. The variety of technical variables and team factors has to be understood and assessed in more detail.

## **The Friedlander’s argument**

Friedlander (1987) suggests how teams are not only sub-systems of the larger organisation systems, but also they tightly depend on them for human, technical and financial resources, for information and power. Teams are present and exist as design choice. The same Author suggests that *instead of explaining teams by reducing them to their components it is necessary to extract the explanations of the group from an explanation of the organisation which contains it.* From this it follows that a model of team performance is extracted by a model of the organisation performance and the explanation of team performance could be extracted by explanations of an organisation performance.

Friedlander’s views about team and organisational performances suggest that local and global measures of performance work on different, sometimes conflicting criteria as shown below:

1. "a work group may well operate somewhat inefficiently in order to maximise its contribution to the organisation"
2. "if each component work group operates as efficiently as it can, the organisation as a whole will probably operate inefficiently"
3. "if we get the organisation behaving as well as it can, it may be that none of the individual work groups will work optimally on their own terms"

Such propositions seem contradictory in some way. But interestingly most of this Thesis’ work seems to corroborate the validity, or, at least, the utility of this set of propositions that are now termed all together the Friedlander’s argument, and operationalised into a research hypothesis:

*For large systems based on pooled resources (human and technical) single individual teams should become inefficient or ineffective to certain degrees in order to maintain acceptable global organisational performance. The risk of failure is distributed and shared by all local teams so as to reduce concentration of risks which favour global systems breakdowns*

* + 1. **A *paradox* suggested by the Author**

It is possible to interpret the Friedlander’s argument as a system’s paradox. The paradox stands on the fact that a set of interdependent teams (or work units) are exposed to a condition of *shared resources in shared work processes*, human and technological resources that are limited and cannot satisfy all demands. In particular, the economy of scale imposes that production lines (teams on the operations) should rely on or be granted certain levels of support, but this support structures instead are *always limited* to contain the costs of the total supply.

The strategy here is that the organisation *prefers* to provideteams with faulty supports overall, rather than maximally improve support efficiency and effectiveness per single check operation: optimising organisational production by maximising spread of risk and failure locally. Apparently, it is more effective for organisational production to prefer average/below-average team performances overall, than few/single high team performances which apparently cost too much to maintain because they simply absorb too many resources that are limited and pooled across groups. Full support given to single *local* checks (i.e., teams) has the effect to *drastically limit the service to several other checks*, which, consequently, translates into a *global* reduction in performance and augment exponentially the costs of recovery.

Last, but not least, the more the risk is distributed the harder it is to pinpoint the source of that risk, therefore the responsibility/liability attached to it.

## **The intact team problem**

Different conceptual models of team activity and performance assume, and most of them implicitly, what should be considered internal and external to a team (Swezey and Salas, 1992). This approach has been frequently used in team research considering *closed* the system’s boundaries and *fixed* the internal/external elements, that is, the focus of research being on *intact teams*. However, a rigid separation of external and internal factors might result an inconsistent manner to model work teams in hangar (Ivaturi et al., 1995).

* + 1. **Team manpower flow and configuration variance**

Team members in hangar *would* remain in the same work group to complete tasks, unless shortages in other groups, shift changeovers, unexpected events or unplanned work will require a move to other project teams: team membership will vary as the workload fluctuations change. In hangar maintenance, this flexibility on team configuration is more a normal practice rather than the exception. There is a need to understand to what degree this *team manpower flow* (in and out of the same operations) could interfere with the actual team’s check performances. Therefore, this supports the idea that a work team in hangar operations is not easily determined upon who is the actual team member because technicians working on certain tasks may change during the very same set of operations. The problem exists both for the team loosing man-power as well as for those team members forced to catch up with the new team.

In general, a work team may change its composition, dimension and relationships from work-shift to work-shift. In this case, it could be likely that different team events, and performance outcomes cannot be considered the operation of a single team, but it is the combination over time of the concurrent and changing configurations of team structures, functions and resources. The changes in configuration of work teams, in particular for those teams which modify regularly over time, could be expected to be a significant *new* variable to explain teamwork and team performance outcomes. Simply, a *team configuration variance* defines the exposition of a work team to various (expected and unexpected) changes/modifications/developments in resources, functions and organisations while performing sets of tasks under certain conditions and operating times.

It is here proposed that the configuration variance of a team could be a very important indicator of how much the results of a team in a process are being determined not so much by the presence/absence of a specific properties or characteristics internal or external to the team, but more often by their variable configuration over time. In particular, the proposition for investigation is that *the more the team configuration varies the lower the team proficiency and the more the performance will depend on the external performances.*

## **New hypotheses of research**

All the arguments proposed in the previous sections above (e.g., levels of team analysis and performance, causal models, etc.) should highlight potential new terms of reference for team research and verification. Some of these hypotheses about hangar maintenance teams are summarised as follows:

1. *Internal team dynamics and competencies are not reliable predictors of teamwork levels and task performances for teams with very large interdependencies about the context*
2. *Compared to internal team attitudes and skills, impact of external systems and team configurations (e.g., technology demand, proficiency of supports, team variability) account for higher levels of variance in operational performance*
3. *The ability of individual teams to adapt to unexpected situations and events will augment effective task accomplishment but reduce sensibly team efficiency*
4. *Team adaptation will result in accepted team norms and practices that are generally considered routine violations of organisational procedures, norms and practices*
5. *For large systems based on pooled resources (human and technical) single individual teams should become inefficient or ineffective to certain degrees in order to maintain acceptable global organisational performance. The risk of failure is distributed and shared by all local teams so as to reduce concentration of risks which favour global systems breakdowns*
6. *Organisational resources (time, technical, and human resources) are reliable predictors of team efficiency and/or effectiveness*

Among others, these above are a set of critical hypotheses which will be directly or indirectly tested throughout most of the chapters that follow. Arguments in favour (or against) these hypotheses above will be highlighted accordingly and reviewed in Chapter 10.

**Chapter 4**

**What is a hangar maintenance team?**

“*My rule of thumb is that no work team should have membership in the double digits, and my preferred size is six*” (J. Richard Hackman interviewed by Mallory Stark, 2007).

# **What is a hangar maintenance team?**

## **Team definition and concept**

Description of hangar teams requires a preliminary understanding of the team concept in hangar. A minimal team definition is given followed by a characterisation of the concept.

* + 1. **Minimal hangar team definition**

A simple definition of a work team in hangar is given:

*Hangar team*: *Ensure maximum attention to meeting aircraft safety standards, schedules, quality of work, company and legislative authority requirements. Maintain a high standard of house keeping at all times in work area.*

This definition is from a very experienced aircraft maintenance manager of a large North European Maintenance and Repair Organisation (aircraft maintenance manager, personal communication, March 19, 2007). Clearly, the “*operational goals of the team*” replaces the more traditional views of “*a team made of or composed by*”. This definition is structure- or process-free. In fact, it is not about *what* a team is; it does not reflect a composition or structure, and does not even mirror a common (expected) research oriented definition about internal team dynamics. It is a definition that highlights the *why* a team exists for: safety standards, quality of work and shared responsibility about meeting operational objectives.

Clearly, this description reflects the experience of who actually does lead hangar teams, their operations and performances on a daily basis. Thus, it should be understood that way. For these very basic reasons such definition is preferred to most of the definitions of work teams given in Table 2.1 of Chapter 2. Nevertheless, in terms of hangar team composition, a characterisation and description is in order, as the complexity of work teams in such environment is less understood.

* + 1. **Team concept in hangar: zonal teams**

A set of 2-10 technicians and supervisors performing a set of dependent or interdependent tasks is the common configuration of resources required to carry out *part of* a maintenance check operation. Performance and teamwork of such a relatively *small* combination of resources surely expresses the most common concept of an aircraft maintenance team. And this form of operational team is the main focus of several human factors research in aviation maintenance (Patankar and Taylor, 2004b).

The configuration of a maintenance operational team assigned to a check operation is composed of:

1. different *trades* (e.g., mechanic, avionic, electrical engineer, sheet metal technician, trimmer, power plant specialist, paint, inspector, cleaner, shop technician, etc.)
2. different *grades* (e.g., generic assistant, apprentice, qualified mechanic, certified aircraft technician, supervisor, team lead, check manger, clerk, planner, support engineer, etc.)

These trades and grades, together, define one of many work groups allocated and responsible to specific zones of the aircraft. Thus, cockpit, wings, airframe, engines and different other aircraft zones do represent teams, *zonal teams*.

Figure 4-1 below shows the typical *presence* and the *actual context* of two zonal teams of three and two members respectively. The former team is performing on the left-wing section of a wide-body aircraft. The latter one is inspecting the engine removed from the same wing. Generally, a number of eight or nine zonal teams are allocated to the same aircraft within the same shift, and across shifts. Once allocated, all zonal teams would become interdependent by some functional or structural relation. Aircraft parts, systems, shared tools, equipment and supplies, as well as shared manpower contribute to increase such reciprocal dependence. From a pure operational view, such interdependence is function of work schedules that dynamically determine priorities and sequences about what, who and when tasks will be carried out.

Most critical, zonal teams become reciprocally interdependent by the process itself where task delays, interruptions in one part of the aircraft or a lack of responsiveness from a company’s department elsewhere will propagate delays, interruptions and necessary counter-plans on other parts of the aircraft managed by other zonal teams: *this is not a problem of a single team in action, but a system of teams in reciprocal interactions*.



* + 1. **Extended team concept: project team**

In hangar maintenance settings, the concept of team is an expression of the maintenance check operation, the repair service. In its broadest sense it refers to the *likely* team configuration that will carry out and manage a project over different timeframes: an aircraft-specific and customer-agreed programme of maintenance (e.g., inspections, parts removal/replacements, troubleshooting and tests).

The level of teamwork required for a complete aircraft maintenance visit in hangar is called the *project team*. This level of team activity *encompasses* all zonal teams described so far. In this case, a project team configuration refers to the configuration of all zonal teams together, the contribution of the *total manpower* used day-by-day on an entire check operation: for instance, 25 technicians of which 5 trimmers, 5 avionics, 7 airframe and 8 power-plant specialists, 5 contractors, 4 check supervisors, and an expendable daily 5% overtime of the total planned overtime available.

The project team is thus the maximal expression of teamwork across different zones, functions and even departments. The actual dimension of a project team for a medium-large check operation can vary over time. As an example, the configuration of a project team assigned to a large maintenance check operation (C-check) follows:

* 15.000 man/hours plan for 3 work weeks (three shift per day)
* 7 or 8 zonal teams and multiple supports units (e.g., planning, stores, engineering, etc.)
* Variability from 2 to over 80 team members a day
* Average configuration during very high peak activity is of 40-50 technicians a day.

The configuration of a project team by zonal assignments (zonal teams) is shown in Figure 4-2 below.



* + 1. **Team flexibility**

The members of a zonal team would remain *together* until completion of a task, unless shortages in other zones or unexpected demands and priorities will require a *move* *to* other aircraft operations. Thus team members of the same team might be moving around to make up shortages or to react to new priorities and plans: this is a critical form of flexibility imposed in the system. Even more important, *team membership varies as workload fluctuations change*. Below in Table 4-1 is an example of such high team flexibility demand.





Table 4-1 shows a real personnel chart replacement with description of the actual configuration of all daily zonal teams (e.g., Fuselage & Structures). The check managers in charge of the operations required as much as 16 *revisions* in the overall project team configuration over a 5 days period (“Rev 16” circled in red at bottom of Table 4-1). This was due to guarantee adequate team responses to workload fluctuations arising over that work week. Obviously this is a considerable team planning and scheduling problem. In this specific case there was a re-scheduling effort over project team of 63 technicians, 21 Crew Mangers allocated across eight different zonal teams.

Variability and flexibility on team membership makes clear how the team concept cannot be easily defined upon who is the actual team member because the technicians working on certain tasks *may change during the course of the very same set of operations*.

Overall there exists a real continuum between the concept of *project* and *zonal teams*. The simple focus on one level, the zone, cannot express the social and technical richness of what a teamwork activity is for the other level, the project, and *vice-versa*.

* + 1. **Supervisory and Support teams**

Project teams need supervision and support. These two critical functions are implemented in hangar check operations by dedicated supervisory and support teams respectively. In simple terms, *supervisory teams* are composed of senior supervisors/check managers, shift zonal supervisors, project planners, material co-ordinators, customer representatives as well as vendors. Their main role is to co-ordinate, schedule and organize activities in terms of control about the zonal work and team assignments, monitoring of parts orders and materials supplies, administration and overall external support management. Their supervisory functions allow taking decisions back to upstream levels as well as downstream by regulating operational conflicts across zones and adaptation to workload demands. This level of management is the lowest level of management into the operational systems in hangar. A supervisory team counts about 8-12 members per aircraft operation.

Sales, planning, engineering, materials, stores are all examples of *support teams*. They contain single groups or service teams external to the check operation. These external systems are designed to support all zonal teams. Support teams are highly variable on the type of support function constituted. Generally there exists a certain *service level agreement* that regulates the level of support expected into an operation per each support team. Common support teams are outlined here below:

* Planning – work plans/schedules/maintenance programmes
* Engineering – service bulletin/work-orders/full technical support
* Back-shops – components overhaul/troubleshooting
* Materials and Facilities – tooling, parts, equipment, scaffolding, stores
* Sales and Procurements – project bids and technical resource
* Human Resources – manpower administration, pay, attendance and control
* IT – information systems and technology support, data-base and software solutions
* Quality and Safety departments – quality, audit and monitoring safety indicators
* Training departments – competence and certification
* Technical documentation units – records and storing of technical data on projects

Support teams are critical to maintaining different work processes. Their relationships and organisation is vital to any check operation in hangar. It can be said that any dysfunction at their (support) level propagates dysfunctions practically everywhere else in the system. Notably, any specific team cannot be considered autonomous because it cannot control its supply system. Also, the dependence is higher for zonal teams.

## **Team Function allocation and integration**

How do zonal, supervisory and support teams get organised into a project team? The description of functional relations in Figure 4-3 provides a first answer. However, a complete answer may require a process analysis perspective, which is discussed over the next chapters.

In particular, Figure 4-3 describes major functions and roles associated to the three teams respectively.



Services levels, supplies, and procurements are the main functions allocated to support teams, which will allow supervisory teams to schedule assignments, monitoring, and control functions over all zonal operations. The zonal teams instead deal with reception, organisation and task performances on the aircraft. The work process which enables this overall system of performances remains the maintenance check operation.

* + 1. **Teams in the check operation**

The project team composed by zonal, supervisory, support teams is generally organised to fit in with a complete maintenance check operation. To understand their interactions and links in a real work process it is it necessary to define the core elements of a maintenance business process. This business process is common to most of the organisations performing aircraft maintenance in hangar. An example is presented in Figure 4-4 here below. This very simple description shows the general *sequence or workflow* of basic events for a generic maintenance check operation according to a plan or schedule. This overall process contains all the different teams as defined above. As it will be fully investigated later, any work team in operation happens to be by process. And this condition makes all teams in hangar definable as *process teams*.

The boxes in Figure 4-4 represent various main sub-processes throughout a mainstream. It is important to note that there are *upstream* and *downstream* events depending by the sub-process under analysis. Notably, it is apparent that any specific local team could not be considered autonomous because it cannot control its supply system at the source. And, mostly revealing, any team happens to be influenced by a sequence of partially ordered events occurring upstream with respect to its position in the order.



More specifically, the initiating element is the *Planning and supply* system, that is, all support teams preparing the organisation of the maintenance check visit and all necessary support. This flow of processes then moves towards co-ordination systems, that is, supervisory teams controlling the *Check processes*. Supervisory teams, in turn, will regulate all zonal teams operations and performances.

Considering the system of interdependence embedded with this work-flow, it is very likely that dependence, influence and effects would be stronger for those teams in the *operation performance box* (zonal teams): this downstream level inherits all others upstream teams’ effects (positives and negatives).

* + 1. **The integration in the process**

Zonal, supervisory and support teams require high *integration* into the larger system. Such integration should be maintained by effective co-ordination, pace and timing of exchanges across all work units. When one team falls behind, it is the entire system which suffers. Basically, several internal team processes in the hangar are dependent on the actual external relations of effectiveness and efficiency. Such approach reflects some more naturalistic models of team effectiveness described by Sundsdrom and colleagues (1990): external factors of a work team may exert *more leverage* that those elements internal to the team itself.

In order to better understand this relation a finer-grained model of a check operation is provided in Figure 4-5 here below. This simple descriptive model was developed in the ADAMS 2 Project (ADAMS 2, 2004) by mapping (flowcharting) normal check processes across 5 different European aircraft maintenance organisations. This very simple descriptive model extends Figure 4-4 above.



Clearly, Figure 4-5 shows where the zonal, supervisory and support teams spread and distribute across different business segments of the process. In the overall activity there is regularity and sequence that will predict what team will intervene at what point in the flow of activities. Such flow of activities will affect different teams over different timeframes.

Such framework can be exploited to make considerations on what team requirements can be envisaged depending on the area or time of the events in the process. Also, this model brings into question the formation of the three teams as formal assignments and/or emergent structures from the operational needs.

* + 1. **Impact of hangar layouts on team organisation**

Any project team is not the *sole* participant within the hangar business: the size of one operation does not represent the actual hangar business activity in several circumstances. This means that a medium size company may have at disposal more than a single bay, that is, more than one *area* to perform multiple check operations at the same time. This is shown in Figure 4-6.

The actual co-ordinative effort across supervisory teams and multiple concurrent check operations is self-explanatory in Table 4-2. The example in the table is given in terms of human resource demands for four different project teams, one per bay. This represents a real hangar configuration of a North European maintenance facility, which turns out to be the same one depicted in Figure 4-6.

**Table 42 - Hangar with four active bays: Bay a, Bay b, Bay c, Centre Bay**

|  | Bay a | Bay b | Centre Bay | Bay c |
| --- | --- | --- | --- | --- |
| Check Managers | 3 | 1 | 2 | 2 |
| Mechanics | 85 | 22 | 25 | 35 |
| Supervisors | 15 | 10 | 9 + 2 acting cm | 15 |
| Avionics | 14 | 5 | 5 | 11 + 2 apprentices |
| Cleaners | 9 | 3 | 4 | 8 |
| Support Staff | 5 | 3 | 3 | 4 |
|  |  |  |  |  |
| Total | 131 | 44 | 50 | 77 |

In terms of man-power the four project teams range from 44 to 131 *planned* personnel for a total of 302 over the four active bays. Trades or skill specialties vary with a major demand for mechanics and supervisors. It is to note that this represents a configuration for a single hangar. Medium and large organisations can count on multiple hangars, each one multi-bay (see Figure 4-6).



**Figure 46 - Hangar configuration and layout with six active bays**

This condition highlights a very simple but fundamental condition for any project team in hangar maintence:

*any large aircraft maintenance system must rely on some sort of limited pool of resources as it is not feasible to fully provide each bay with complete human and technical resources as well as supplies.*

Simply, the costs of work teams are not fully sustainable, and some optimisation strategy and trade-off is required. Apparently, no single system of planning and schedule is today available to contain such volume of interactions across several teams, workload demands and group schedules. A contention of resources is almost always present. For instance, hangar managers prioritize operations in terms of maintenance checks similarities, plans, schedules, overlaps of resources. Any team activity in a single check operation is to be controlled with respect to other concurrent team performances. Thus, the more the anticipated co-ordination across teams the more the effective overall performance. Clearly, teamwork is to be considered dependent by this network of external relations.

* + 1. **The social meaning of teams: the crew in hangar**

The combination of zonal, supervisory and support elements for a maintenance check operation is generally defined by the same maintenance technicians as the *crew in charge of the operations*. Nevertheless, their reference to the term *team* or *crew* reveals to be obviously richer than its functional definitions as developed here above.

The team concept is attached to social events in hangar. The story of those events and all lesson learned are beyond any potential description available. Also, the simple reporting and sharing of such team events and the practice attached to it will generally shape the actual meaning of the word *crew* or *teamwork* for the very same people involved in it.

As an example, Table 4-3 and Table 4-4 below are examples of how an aircraft maintenance company would *interpret and generate* the concept of team far beyond a formal definition. The meaning attached to a hangar team is all about a story of responsibility, achievements, success and difficulties, and it is transmitted to share and instil a social meaning, an organisational value.





**Chapter 5**

**Team attitudes, behaviour and performance**

“*The goal of many such interventions is to help group leaders and members become more aware of those aspects of their personalities, attitudes, and behavioural styles that change agents think are key to team effectiveness. The hope is that improved team functioning will come about more or less automatically if each member understands his or her personal style and recognizes the need for good communication and coordination. I know of no evidence that supports this assumption*” (Hackman, 2002, p. 38).

# **Teams attitudes, behaviour and performance**

## **Testing the *attitudes-behaviour-performance* model**

Team attitudes and group-oriented behavioural styles refer to the degree of individual dispositions to practice and engage in teamwork activities. Measures in the form of questionnaires and surveys of attitude toward teamwork, co-ordination and communication are nowadays handled as training, evaluation and research tools, and have become common practice also in the aviation maintenance field (Taggart, 1990; Taylor, 2000). Basically, a questionnaire on group behaviour and attitudes towards teamwork needs to focus on *known* behavioural and attitudinal aspects that are expected to affect positively the team conduct (Gregorich et al., 1990; Taylor, 1995). In such instances, the purpose of measuring attitudes and other group-related characteristics becomes critical for a work organisation. Such measurements could provide differentiated information: attitude differences or trends within and across work teams and organisations, pre- and post-training evaluations on individual and group changes, identification of team attitude patterns or teamwork styles that may be ameliorated or refined. Most importantly, the patterns of relationships between observed/reported team behaviours, performances and attitudinal levels can be verified. This latter aspect is certainly relevant both for applied research in work settings (i.e., using team attitude measures to predict team performance) as well as for theoretically important questions about a model’s prediction capability.

Over the last 20 years, research in aviation maintenance on measurement of team attitudes, dispositions and team behaviours has taken three main directions: design and psychometric validation of team attitude instruments (Baranzini et al., 2001; Taylor, 1991), study of team attitudes differences and attitude change as a result of team-oriented training interventions such as the Maintenance Resource Management - MRM (Taylor and Christensen, 1998), and assessments of actual relations between attitudes, behaviour and team performances (Patankar and Taylor, 2004a, 2004b; Taylor, 1997).

According to this latter point, there exists an implicit model about attitude-performance relations that is widely accepted (unchallenged!) by the maintenance aviation human factors research community (ICAO, 1995; Patankar and Taylor, 2004b; Reason and Hobbs 2003). Such a conceptual model suggests that equipping the workforce with favourable attitudes and team oriented behaviours could predict and lead to increased quality in teamwork behaviour that, *in turn* will increase operations and safety performances. The rationale behind this hypothesised causal path is that change interventions directed to improve *soft skills* of communication and co-ordination across technicians, front line managers and support staff will affect operational proficiency. For instance, quoting Taylor (2000, p. 202): “…positive attitudes in the maintenance arena can lead to improved communication, cooperation, coordination, performance quality and flight safety ”.

In practice, though, there seems to be very little empirical research consistent enough to confirm that specific team-oriented dispositions and attitudes lead to better teamwork behaviours, or even predict operational performance or safety levels. For instance, a longitudinal research by Taylor and Robertson (1995) conducted for over three years across the maintenance divisions of a large US airline carrier identified significant bivariate relationships between attitudes towards teamwork and safety measures. By the use the Maintenance Resource Mgt/Technical Operations Questionnaire (MRM/TOQ) (Taylor, 1997) the Authors identified two team-related attitudinal measures, assertiveness and sharing command responsibility, that were correlated, in the expected direction, with subsequent maintenance safety indicators of lost time injuries. Nevertheless, the range of significant correlations across the samples was -.26<ρ<-.22 (Patankar and Taylor, 2004a). Clearly, a range of very low correlation values accounting for very little proportions of variance overall: averaged coefficient of determination was (-.24)2=0.05. Such correlational findings were replicated in at least two other different longitudinal studies. But again, as previously elaborated in Chapter 2 (*section 2.3.2*) and Chapter 3 (*section 3.2*), such findings cannot be considered solid evidence for such direct attitudes-behaviour-performance association and potential causal path. Further investigation is necessary to verify reliability, consistency and generalisability of such a model.

Following on from this, the main objective addressed by this chapter is threefold:

1. Replicate findings on discriminatory power of known team dimensions and measures
2. Test the relationship between attitudes and team behaviour performance
3. Test teamwork attitudes and behavioural performances as predictors of operational performance

Overall, an exploratory action is presented here to verify *discriminant*, *concurrent* and *predictive* validity of the predicated team attitudes-behaviour-performance model by application of survey analyses (Cooper and Phillips, 2004). Discriminant validity will assess how likely well known team attitudes, styles and behavioural measures can differentiate among different work groups, contexts and demographic variables. Teamwork attitudes and team behaviour performances will be tested for potential correlations in order to verify their degree of concurrent validity*.* Finally, team attitudes and team behaviour performances will be used as predictors of team’s operational performance levels. This will verify predictive validity of the constructs.

The main instrument, and related versions, applied to such longitudinal analysis is the Aircraft Maintenance Attitude Survey (AMAS) (Baranzini et al., 2001) as originally designed and developed within the framework of the EU funded project ADAMS - Human Factors in Aircraft Dispatch and Maintenance Safety (ADAMS, 1996). The AMAS instrument is described here below and reported in Annex 5A.

## **The AMAS survey**

Research on maintenance teams, within the ADAMS project, was conducted across different European aircraft maintenance organisations. The study focussed on team attitudes, values and behavioural measures as the level of analysis, and the development of the AMAS survey, was primarily directed to assess: 1)-*team attitudes* that impact effective and safe team performance, 2)-*team cognitive styles* as potentially intervening variables on team decision making and problem solving activities, and 3)-*perception of communication practices* as a measure of team performance in terms of self-reported teamwork behaviours.

The AMAS questionnaire can be considered an extended version of some previous tools developed for team attitude studies training and human factors research in aviation domain such as the Maintenance Resource Mgt/Technical Operations Questionnaire (MRM/TOQ) (Taylor, 1997), the Crew Resource Mgt/Tech Operations Questionnaire (CRM/TOQ) (Taylor and Robertson, 1995), the Cockpit Management Attitude Questionnaire (CMAQ) (Gregorich et al., 1990) and the Flight Management Attitude Questionnaire (FMAQ-2.0 International version) (Helmreich et al., 1993).

* + 1. **Structure of the AMAS survey**

Three conceptual dimensions were used to design the structure and contents of the AMAS questionnaire, i.e. teamwork attitudes, group-oriented behavioural styles and perceived team performance quality. Consequently, three scales were developed constituting the AMAS questionnaire, namely: *Technical Operation Attitudes (TOA) scale*, *Cognitive Style (CS) scale*, *Perception of Communication Practices (PCP) scale*.

The factor structure as well as the statistical and psychometric properties (validity and reliability measures) of the AMAS questionnaire is fully described in Annex 5B.

* + 1. **The Technical Operation Attitudes (TOA) scale**

The 20-items TOA scale of the AMAS questionnaire was developed on the basis of previous studies and tools used to assess individual’s attitudes toward teamwork and communication for aircraft maintenance personnel as well as for flight crews (Gregorich et al., 1990; Sherman, 1992; Taylor and Robertson, 1995). Three facets were identified and confirmed by factor analysis studies (Baranzini et al., 2001). The three factors of the TOA measure are: Teamwork communication and co-ordination (TOA F1), Recognition of stressor effects (TOA F2) and Sharing command responsibility (TOA F3). The three factors are described here below respectively:

**TOA F1**, *Teamwork communication and co-ordination* is characterised by eight items that address the importance of team briefing, debriefing and self critique, suggesting an orientation toward interpersonal awareness, and crew co-ordination. Items also address the importance of both verbal and written communication, as well as the relevance of being assertive and communicate any potential problem, regardless of one’s position in the team. Theoretically, endorsement of these items imply an improvement of shared situation awareness across team members and better sharing mental models enhancing team members communication and co-ordination.

**TOA F2,** *Recognition of stressor effects* addresses the awareness of stressor effects due to situational adversity. Items ask if personal job performance, as well as judgement or decision-making skills, may be affected by fatigue, personal problems, critical or high time pressure maintenance. This scale of six items measures respondents’ reactions toward stress: a positive/negative stress management at work.

**TOA F3,** *Sharing command responsibility* is involved with the expectations regarding the appropriateness of the shared responsibility of team members in technical operations. This cluster of six items reveals attitudes about the way authority is exercised, the delegation of responsibility, the importance of the manager’s technical proficiency, or whether it is appropriate to question supervisor’s or senior team member’s plans and decisions. Endorsement of these items reflects an orientation toward a “flatter” command structure, with less distance and formality between manager or supervisor and other team members.

The three scale measures are indicators of a favourable team orientation and disposition. Endorsement of these three factors are expected to give positive disposition toward teamwork, open communication, co-ordination and team leadership.

* + 1. **The Cognitive Style (CS) scale**

The CS scale of AMAS refers to learned thinking habits, as individual differences in gathering and processing information to make decisions and solve problems in teams or groups (Driver, 1983; Guilford, 1980; Messik, 1984). This measure of style was identified by different researchers as another critical intervening variable in group performance (Kirton, 1994; Meshkati, 1989). Specifically, similarities in preferred ways of working and associated decision making and problem solving styles within and between teams can be defined as the “group’s mode of preferred cognitive style held by the consensus subset” (Kirton, 1994).

The development of this measure was based on previous instruments measuring cognitive and working styles dimensions: Kirton Adaptation-Innovation Inventory (Kirton and McCarthy, 1988, 1994), Decision Behavioural Questionnaire (Radford et al., 1991), and Working Style Index (Warr and Conner, 1992).

The study on the factor structure of the CS scale confirmed the presence of three factors over a total of 20 items:

**CS F1**, *Propositive Style*,describes the active and proactive role of subjects in team decision making and problem solving processes. The nine items of this factor characterise subjects who tend to suggest solutions even when they are not asked for, enjoy to propose several new and innovative perspectives to approach problems and decisions, showing a preference to actively participate in such team processes. These subjects tend to be flexible in their thinking, searching proactively for new and still undiscovered problems.

**CS F2**, *Collaborative Style*,emphasises the role of opinions and advice of others when solving a problem, and the degree of collaboration among team members to make decisions. These five items describe subjects who tend to have a consultative approach, always considering the importance of shared information and interaction to make decisions and solve problems with others team members.

**CS F3**, *Conformist Style****,*** emphasises a preference for group dependency in approaching decisions and problems. They ultimately tend to follow and rely more on the team’s view than on the individual perspectives. The six items of this factor characterise subjects who tend to be conventional and methodical, who prefer to adapt to what other co-workers decide (“passive approach”), and conform to the team way of thinking. These subjects tend to carry out superiors’ decisions without raising difficulties and show to be careful with authority and general opinion. They fit the so called “bureaucratic structure” (Westrum, 1995).

The overall scale describes three different but related teamwork style orientations. The first two factor scales, the Propositive and Collaborative styles measures (CS F1 and CS F2), are to be preferred for complex and ill defined problem situations, where high participation and proactive orientation to team decision making and problem solving are more relevant characteristics than a conformist style approach (CS F3).

* + 1. **The Perception of Communication Practices (PCP) scale**

The PCP scaleiscomposed of five items and it was added to the other two scales of the AMAS questionnaire. This scale measures respondents’ perception on team behaviour performance and the effectiveness of information co-ordination (i.e., level of shared information about task decisions taken, tasks accomplished, level of teamwork and co-ordination between teams). This measure is a useful means to gauge the level of team situation awareness and task-related exchanges (Robertson and Endsley, 1995). In particular, the effective exchange of information, documentation and communication flows within and between maintenance work teams revealed to be a critical factor for task co-ordination and efficient team performance in complex aircraft maintenance activities (Taylor and Christensen, 1998). Effective team communication and teamwork also appears to be related to safety events as documented by several accident investigations involving maintenance personnel (Moshansky, 1992; NTSB, 1992; NTSB, 1997).

In practice, the PCP scale can be considered a measure of (self-reported) teamwork performance and it can be compared against the other two scale measures of the AMAS in order to explore any teamwork attitude-behaviour relationship.

## **Applications of the AMAS questionnaire**

Three different applications (and versions) of the AMAS questionnaire were delivered in 1998, 2000, and 2001 within two different maintenance companies. The AMAS applications were driven by specific research purposes under the auspices of two different EU funded Projects, ADAMS (1996) and AMPOS (AMPOS, 1999) and one large company-led initiative called People Partnership and Improvement (PPI). Overall, the application of the AMAS instruments provided a composite but valid research framework to verify a model of team *attitudes-behaviour-performance* relationships for aircraft maintenance teams. This research effort across different periods and research actions is described in the Table 5-1 below.

**Table 51 - Overview of AMAS versions and applications**

| **Survey - time** | **Company/organisation** | **Project** | **Survey objectives** | **Team measures in AMAS survey** | **Performance measures available** |
| --- | --- | --- | --- | --- | --- |
| AMAS-1998 | Company A | ADAMS | Human Factors and team training needs | Attitude/Behaviour | No |
| AMAS-2000 | Company B | AMPOS | Attitudes analysis and operational needs for new quality processes | Attitude/Behaviour | Yes |
| AMAS-2001 | Company B | PPI | Organisational readiness to change | Attitude/Behaviour | Yes |

## 

## **The application of the AMAS-1998 (ADAMS version)**

The objective of the original AMAS survey was to identify and study team attitudes and teamwork orientations in aircraft maintenance teams (Baranzini et al., 2001). Such survey served the purpose of a human factors training needs analysis for aircraft maintenance personnel according to the objectives of the European funded ADAMS project (ADAMS, 1996).

***Subject and measures***

The AMAS was administered to a sample of 89 aircraft maintenance technicians from the aircraft maintenance division of a major airline company in north of Europe. The maintenance division is here called Company A. The overall sample comprised 43 technicians (mechanics and aircraft engineers) and 46 supervisors (shift/crew managers and supervisors). Referring to work team membership, 32 respondents were from Line Maintenance teams (activity on the apron in short time-frames, no use of hangars), 57 from Heavy Maintenance teams (activity in hangar, larger time-frames, heavy/complex checks, repairs and troubleshooting). The overall sample of respondents ranged in age from 26 to 62 years with a mean of 44.5 years (sd=8.71), were all males. Participants’ experience in their current job ranged from 1 to 36 years with a mean of 13.6 years (sd=10.86).

All respondents completed the *Technical Operation Attitudes (TOA)*, *Cognitive Style (CS)*, and *Perception of Communication Practices (PCP)* scales of AMAS. In particular, the participants replied to the items of the TOA scale on a 5-point Likert scale anchored by *disagree strongly* (coded as 1) and *agree strongly* (coded as 5), in order to evaluate their agreement with them. In the CS scale, respondents were asked to describe on a 5-point Likert scale ranging from *very seldom* (coded as 1) to *very frequently* (coded as 5) how often the items are true of their behaviour, consistently and for a long time. In the PCP scale, participants were asked to indicate, on a 5-points scale ranging from *very seldom* (coded as 1) to *very frequently* (coded as 5), how often the items are true descriptions of their work team performance. All statistical analyses were performed with SPSS (SPSS version 12).

* + 1. **MANOVAs, correlation and multiple regressions**

***Factor structure, validity and reliability of AMAS-1998***

In general, the factor structures of TOA, CS and PCP scales of this first AMAS application proved to converge toward adequate and reliable factor models (Comrey and Lee, 1992). Adequate psychometric properties were found in each of the sub scales of the questionnaire. All the validity and reliability analyses are fully described and reported in the Annex 5B.

***Overall descriptive statistics***

Descriptive statistics, observed means and standard deviations on the total sample, for the three scales composing AMAS are presented in Table 5-2. Referring to the TOA scale, participants exhibited very high positive attitudes towards *Teamwork communication and co-ordination* (TOA F1, M=4.48, sd=.42) and a less marked disposition both for the *Recognition of stressor effects* (TOA F2, M=3.73, sd=.74)and leadership based on *Sharing command responsibility* (TOA F3, M=3.40, sd=.72).

**Table 52 - Means and Standard Deviations of the scales of AMAS-1998**

| **AMAS-1998** | **n** | **Mean** | **sd** |
| --- | --- | --- | --- |
| TOA scale | 89 |  |  |
| F1 Teamwork communication and co-ordination |  | 4.48 | .42 |
| F2 Recognition of stressor effects |  | 3.73 | .74 |
| F3 Sharing command responsibility |  | 3.40 | .72 |
| CS scale | 89 |  |  |
| F1 Propositive style |  | 3.59 | .58 |
| F2 Collaborative style |  | 3.86 | .63 |
| F3 Conformist style |  | 3.63 | .53 |
| PCP (Perception of Communication Practices) scale | 89 | 2.96 | .69 |

With respect to the CS scale, the overall sample of respondents did not show a unique preference toward any of the three styles showing similar average ratings in *Propositive* (CS F1, M=3.59, ds=.58), *Collaborative* (CS F2 M=3.86, ds=.63) and *Conformist Style* in teamwork(CS F3, M=3.63, sd=.53). Nevertheless, the TOA and CS scales received average scores above the mid-point 3. These patterns of ratings differ in intensity, not in direction.

Mean score for the PCP scale was 2.96, sd=.69. Respondents indicated how teamwork performance (communication practices in teams and co-ordination of information) was perceived moderately low. Overall, from a descriptive point of view, the presence of favourable team attitudes ratings (TOA and CS scales) does not translate directly into expected high team performances (PCP scale).

***Between-groups comparisons: factorial MANOVAs***

Two factorial MANOVAs were carried out in order to assess differences on the linear combination of teamwork attitudes (TOA scale), cognitive styles (CS scale) and perception of teamwork performance (PCP scale) as dependent variables. Participants were grouped by different background information used as independent variables: Age, Team membership, Job experience and Grade. The objective was to study if the AMAS measures in combination, or individually, could separate and discriminate subjects grouped by relevant background or demographic data. The use of multivariate statistical models was preferred over unvariate ANOVAs in order to enhance sensitivity of the analysis, protection against Type I error rates, and better assessment of significant effects by combining dependent variables together (Tabachnick and Fidell, 2007).

Both 3x2 between-subjects MANOVAs were performed on the overall seven measures composing the AMAS questionnaire: the three factors of TOA and CS scale respectively, and the PCP scale. The grouping variables for the first factorial MANOVA were Age (<44 yrs, 45-51 yrs, >52 yrs) and Team membership (Hangar versus Line Maintenance team). Job experience (<7 yrs, 8-19 yrs, >20 yrs) and Grade (Technician versus Supervisor) for the second factorial MANOVA.

SPSS MANOVA Syntax and GLM procedure were used for both analyses with sequential adjustment (Type I SS) for non-orthogonality. Order of entry for the effects in the first multivariate analysis was Age given priority over Team. Job experience given priority over Grade for the second analysis. Total N of 89 was screened for assumptions in both analyses and adjusted accordingly: plausible range values, presence of within-cell univariate and multivariate outliers (p<.001), missing values, assumptions of multivariate normality, homogeneity of variance-covariance matrices, linearity and multicollinearity. No serious violation was noted in both MANOVAs.

***Stepdown analsyis following up MANOVAs***

Finally, whereas omnibus MANOVAs showed significant results, Roy-Bargman stepdown F analysis was performed to further investigate the impact of each main and interaction effect on each single AMAS measure taken individually (Stevens, 1996; Tabachnick and Fidell, 2007). In stepdown analysis each dependent variable is analysed, in turn, with higher-priority measures treated as covariates. Simple univariate ANOVA with no covariates is performed on the highest-priority variable. Priority of variables is decided upon empirical or theoretical grounds. Assumptions of pooled homogeneity of regression for all variables acting, in turn, as covariates in the full stepdown model is verified accordingly. Notably, stepdown analysis is to be preferred over univariate ANOVAs as this method provides a pure look at the unique contribution of each measure to the multivariate effect by controlling statistically (multiple ANCOVAs) any intercorrelations (overlapping variance) among the dependent variables. Such intercorrelations, common among dependent variables, do threaten and bias results of correlated univariate Fs (Bray and Maxwell, 1985; Stevens, 1996). Finally, the power of tests and apportionment of alpha adjustments to protect from increases in Type I error rates are more easily managed and solved in stepdown. Thus, stepdown Fs were performed on prioritised AMAS measures. The order of priority assigned to the AMAS variables was from the conceptually most to least important dimension to detect team dispositions and teamwork behaviours: PCP, TOA F1, CS F2, CS F1, TOA F3, CS F3, TOA F2.

***Age x Team MANOVA***

Adopting Pillai’s (*V)* criterion, both multivariate main effects for Age and Team as well as their multivariate interaction were statistically significant. These effects showed to reliably discriminate respondents on the linear combination of the AMAS measures: Age, F(14, 156)=1.799, p<.04, *V*=.278; Team F(7, 77)=2.611, p<.02, *V*=.192*;* and Age by Team interaction,F(14, 156)=1.856, p<.04, *V*=.286. The strength of association between the main effect of Age and the combined dependent variables was modest, partial η2=.14. The association for Team was slightly more important, partial η2=.19. The association for the Age by Team interaction was as modest as for the Age effect, partial η2=.14. Overall, the results evidenced that age and team membership did affect the AMAS measures and discriminate respondents accordingly.

Following up multivariate tests, the results of the overall stepdown analysis are summarized in Table 5-3. The total experimentwise error rate was kept to .15 by apportionment of alpha as shown in the last column of Table 5-3.

**Table 53 - Stepdown F of Age, Team and Age by Team**

| **IV** | **DV** | **Univariate F** | **df** | **Stepdown F** | **df** | **α** |
| --- | --- | --- | --- | --- | --- | --- |
| Age | PCP  TOA F1  CS F2  CS F1  TOA F3  CS F3  TOA F2 | 6.08a  1.22  4.15b  1.08  0.47  0.36  0.61 | 2/83  2/83  2/83  2/83  2/83  2/83  2/83 | 6.08\*  1.81  4.01\*  0.78  0.02  0.05  0.36 | 2/83  2/82  2/81  2/80  2/79  2/78  2/77 | .03  .03  .03  .02  .02  .01  .01 |
| Team | PCP  TOA F1  CS F2  CS F1  TOA F3  CS F3  TOA F2 | 8.78a  7.85a  3.23  2.35  3.24  0.90  0.10 | 1/83  1/83  1/83  1/83  1/83  1/83  1/83 | 8.78\*  5.24\*  0.22  0.19  2.95  0.01  0.66 | 1/83  1/82  1/81  1/80  1/79  1/78  1/77 | .03  .03  .03  .02  .02  .01  .01 |
| Age by Team | PCP  TOA F1  CS F2  CS F1  TOA F3  CS F3  TOA F2 | 0.33  3.59b  5.13a  5.07a  1.40  0.28  0.05 | 2/83  2/83  2/83  2/83  2/83  2/83  2/83 | 0.33  3.41  4.40\*  3.30  0.72  0.47  0.30 | 2/83  2/82  2/81  2/80  2/79  2/78  2/77 | .03  .03  .03  .02  .02  .01  .01 |

asignificance level cannot be evaluated but would reach p<.01 in univariate context  
bsignificance level cannot be evaluated but would reach p<.05 in univariate context

\*p<.03

The Age by Team interaction was significant. This effect is discussed first and takes priority over the main effects, which are to be interpreted in the light of this significant interaction.

In particular, the collaborative style measured by CS F2 uniquely contributed to the Age by Team interaction effect, stepdown F(2, 81)=4.40, p<.03, partial η2 =.10. No other AMAS variables contributed significantly to the effect. Four simple comparisons were performed to dissect the interaction further and study in more detail the patterns of collaborative style between younger and older personnel across the two different teams. The total experimentwise error rate across the four simple comparisons was kept to .08 by apportionment of alpha .02 per comparison (Bonferroni correction .08/4=.02).

These contrasts showed that younger personnel from Hangar teams (< 44 yrs group, M=4.04, SE=.09) endorsed significantly more collaborative style than older personnel (45-51 yrs, M=3.50, SE=.17), t(43)=2.85, p<.02; although such difference did not replicate for the oldest group (>52 yrs, M=3.92, SE=.17), t(44)=.60, p>.05. Interestingly, this pattern of results reversed somewhat for Line Maintenance teams. Younger team members (<44 yrs, M=3.98, SE=.16) showed more collaborative style than the oldest personnel (>52 yrs, M=3.34, SE=.19), t(19)=2.49, p<.02, but not with respect to the age group in the middle (45-51 yrs, M=3.91, SE=.17), t(21)=.33, p>.05.

Screening the main effect of Age, two AMAS measures made unique significant contributions: perceived teamwork performance of the PCP scale, stepdown F(2, 83)=6.081, p<.03, partial η2 =.12; and the collaborative style expressed by the CS F2 factor (adjusted for PCP and TOA F1), stepdown F(2, 81)=4.013, p<.03, partial η2=.09.

Contrasts on the PCP scale compared the oldest group against the other two younger groups (Bonferroni adjusment 05/2=.025 per comparison). Results revealed that the grouping of the oldest personnel (>52 yrs, M=3.38, sd=.65) perceived better teamwork performance than the other two younger groupings (<44 yrs, M=2.83, sd=.61; 45-51 yrs, M=2.81, sd=.76), t(65)=3.14, p<.025 and t(41)=2.84, p<.025.

Applying the same type of contrasts for CS F2, the youngest group (<44 yrs, adjusted M=4.02, SE=.08) had more collaborative style than the oldest group (>52 yrs, adjusted M=3.68, SE=.13), t(65)=2.11, p<.038. This result was statistically significant, although slightly above the chosen Bonferrroni protection (05/2=.025). The oldest group, was not significantly different from the age group in the middle (45-51 yrs, adjusted M=3.70, SE=.12), t(41)=.08, p>.05.

Finally, for the main effect of Team (Hangar versus Line Maintenance team) significant stepdown Fs resulted for PCP, F(1, 83)=8.783, p<.03, partial η2 =.10; and for teamwork attitudes of the TOA F1 factor, F(1, 82)=5.243, p<.03, partial η2 =.06. Apparently, Hangar teams perceived better teamwork performance measured by the PCP scale (adjusted M=3.18, SE=.09) than Line Maintenace teams (adjusted M=2.75 , SE=.11).

This pattern is replicated in teamwork attitudes expressed by TOA F1 where Hangar teams (adjusted M= 4.54, SE= .06) favoured teamwork dispositions more than teams in Line Maintenance (adjusted M=4.33, SE=.07). Although statistically significant the effect size was low as well as the mean difference between the groups. Simply, both ratings were well above the mid point value of 3 suggesting that attitudes toward positive teamwork could be well favoured in both types of team.

In summary, Hangar teams showed higher teamwork attitudes and perceived better teamwork performance than their counterparts in Line maintenance. Younger personnel favoured more collaborative style than older personnel, which, in turn, revealed higher teamwork attitudes toward teamwork.

***Job experience x Grade MANOVA***

Multivariate main effects for Job experience and Grade of respondents as well as their multivariate interaction were investigated adopting Pillai’s (*V)* criterion. Overall, only the main effect of Grade resulted statistically significant, F(4, 80)=3.581, p=.01, *V*=.152. The strength of association was modest, partial η2=.15. No other multivariate effect reached statistical significance.

It is to note that the set of dependent variables used in this second multivariate analysis was reduced to those AMAS measures which satisfied stepdown homogeneity of regression as required by the stepdown procedure (Tabachnick and Fidell, 2007). Thus, the measures selected and ordered from the most to least important were: PCP, TOA F3, CS F3 and TOA F2.

Stepdown results are summarized in Table 5-4. The total experimentwise error rate was kept to .14 by apportionment of alpha as shown in the last column of Table 5-4.

In particular, inclinations towards sharing command responsibility, the TOA F3 factor, as well as dispositions for a conformist style in teamwork, the CS F3 factor, contributed to the main effect of Grade: TOA F3, stepdown F(1, 82)=7.63, p<.04, partial η2 =.09; and CS F3, stepdown F(1, 81)=4.50, p<.04, partial η2 =.05. Technicians (M=3.17, SE=.11) showed to be significantly less inclined toward sharing command responsibilities at work than their Supervisors (M=3.60, SE=.11).

**Table 54 - Stepdown F of Job experience, Grade and Job experience by Grade**

| **IV** | **DV** | **Univariate F** | **Df** | **Stepdown F** | **df** | **α** |
| --- | --- | --- | --- | --- | --- | --- |
| Job experience | PCP  TOA F3  CS F3  TOA F2 | 0.08  0.34  1.22  1.24 | 2/83  2/83  2/83  2/83 | 0.08  0.43  1.20  1.04 | 2/83  2/82  2/81  2/80 | .04  .04  .04  .02 |
| Grade | PCP  TOA F3  CS F3  TOA F2 | 1.81  6.00a  5.38a  0.27 | 1/83  1/83  1/83  1/83 | 1.81  7.63\*  4.50\*  0.02 | 1/83  1/82  1/81  1/80 | .04  .04  .04  .02 |
| Job experience by Grade | PCP  TOA F3  CS F3  TOA F2 | 0.09  0.06  2.85  0.10 | 2/83  2/83  2/83  2/83 | 0.09  0.03  2.70  0.12 | 2/83  2/82  2/81  2/80 | .04  .04  .04  .02 |

asignificance level cannot be evaluated but would reach p<.05 in univariate context

\*p<.04

Also, Technicians (M=3.75, SE=.08) expressed significantly more inclination for conformist ways of working with respect to their Supervisors (M=3.51, SE=.08).

Technicians preferred a more directive and hierarchical leadership as well as more conformity towards actions and decisions in teamwork than their Supervisors. Thus, attitudes and styles discriminated across job positions.

***Correlation: team attitudes, style and behaviour***

Relationships between the AMAS measures were investigated to tests the hypothesis that teamwork performance is positively associated with attitudes and teamwork styles. Bivariate correlations were carried out with particular attention to associations between attitude and style scales of TOA and CS scales on the one hand, and teamwork performance levels expressed by the PCP scale on the other hand. Correlations were performed on the original sample N=89.

Overall bivariate correlations are reported in Table 5-5. In particular endorsement of teamwork attitudes, TOA F1, was positively associated to recognition of stressor effects, as well as proactive and collaborative behaviour styles in team, TOA F2, CS F1 and CS F2 respectively: r= .26, p<.05; r=.36, p<.01; r=.39, p<.01. Collaborative, proactive and conformist-oriented styles were also positively associated, CS F2 with CS F1, r=.46, p<.01 and CS F3 with CS F2, r=.22, p<.05.

In the opposite direction, tendency to favour a flatter command structure, TOA F3, was negatively associated to conformist-oriented style in teamwork, CS F3: r=-.21, P<.05. These significant inter-factor correlations were very low to moderate in magnitude, but they evidenced patterns of associations in the expected direction.

**Table 55 - Inter-correlations of the scales of AMAS-1998**

| **Three scales of AMAS-1998** | | **TOA scale**  **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** | | | **CS scale**  **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** | | | **PCP scale** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | F1 | F2 | F3 | F1 | F2 | F3 |  |
|  | | | | | | | | |
| *TOA scale* | F1 Teamwork com. co-ord.  F2 Rec. of stress effects  F3 Sharing command resp. | ---  .26\*  .07 | ---  -.06 | --- |  |  |  |  |
| *CS*  *scale* | F1 Propositive style  F2 Collaborative style  F3 Conformist style | .36\*\*  .39\*\*  .01 | -.01  .13  .01 | .03  .16  -.21\* | ---  .46\*\*  -.03 | ---  .22\* | --- |  |
| *PCP*  *scale* | | .14 | -.15 | -.17 | .10 | .11 | .12 | --- |
| *N=89* | | | | | | | | |

\*P<.05, \*\*P<.01

Most important, no significant relationship between the PCP scale and any TOA and CS factors was found: no team-related attitudinal or style factor appeared to be linked to reported levels of *internal* teamwork effectiveness (e.g., communication effectiveness in the teams, co-ordination on tasks statuses, etc.). Notably, this result is of particular importance because it suggests, at least in this first AMAS application, that team attitudes and work styles do not seem to relate with team performance levels. Such finding is not in the expected direction according to previous researches of team attitude-behaviour-performance relationships (Patankar and Taylor, 2004a, 2004b).

***Multiple regression: team attitudes and styles predicting performance***

Bivariate correlations test pairwise variable-by-variable associations. That is, simple correlations do not account for *combined* effects of two or more variables correlating with or even predicting an outcome measure. By this logic, the set of hypotheses to explore is the following: Can a combination of attitudes and style measures predict jointly team performance? Are both dimensions contributing significantly to prediction of team performance? What proportion of variance in team performance is accounted for by the individual as well as combined measures?

To test this set of hypotheses, a combined standard-sequential multiple regression was performed to test if TOA factors, as first block in regression, and CS measures adjusted for TOA factors, the second block, could successfully predict ratings of the PCP scale. Regression method was thus sequential over blocks (TOA first entry, CS second entry) but standard within blocks (each scale factors assessed for unique contribution to prediction). Multiple regression was tested being aware of the non-significant low correlations values between TOA and CS scale against the PCP measure (see Table 5-5).

Check of assumptions led to some data adjustments over the total N=89: TOA F1 was log-transformed to reduce impact of univariate outliers and skewness, and two multivariate outliers were dropped from the analysis to improve normality, linearity and homoscedasticity of residuals. A final adjusted data sample of N=87 was used in the following analysis.

Table 5-6 displays unique and incremental values of beta weights (B), standardized beta weights (*β*), squared semi-partial correlations (sri2), R and R2 and adjusted R2 for each step of the analysis. The regression model at Block 1 was significant, multiple R=.32, F(3,83)=3.20, p<.05 and R2 =.10. R regression failed to reach significance for Block 2 (TOA scale plus CS scale), multiple R=.35, F(6,80)=1.80, p>.05.

After Block 2, with CS factors added to prediction, R2 =.12 and sri2 (per block) =.02, F(3, 80)=0.46, p>.05. Addition of the CS scale revealed no significant increments in R2 beyond what was already accounted for by the combined TOA factors, R2 = sri2 (per block) =.10. Overall, findings of non significant R and no increment in R2 at Block 2 of the model is not very pleasing. The addition of CS measures is not useful to the analysis and will be discarded from further assessments.

Focussing on the first regression model only (Block 1), unique squared semi-partial correlations of *Teamwork communication and co-ordination*, TOA F1, sri2 =.05, *Recognition of stressor effects* TOA F2, sri2 =.05 and *Shared command responsibility,* TOA F3, sri2 =.05, were all significant at p<.05 (*t* statistics with 83 *df*).

**Table 56 - Standard-sequential multiple regression of TOA and CS factors on PCP scale**

| **Step** | **Predictors** | **B** | ***β*** | **sri2**  (unique) | **sri2**  (per block) | **R** | **R2** | **R2**  (adjusted) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Block 1 | TOA  F1 Teamwork com. co-ord.  F2 Rec. of stress effects  F3 Sharing command resp. | 1.426\*  -0.228\*  -0.214\* | 0.228  -0.228  -0.219 | .05  .05  .05 | .10\* | .32\* | .10a | .07 |
| Block 2 | TOA  F1 Teamwork com. co-ord.  F2 Rec. of stress effects  F3 Sharing command resp. | 1.053  -0.216  -0.227\* | 0.169  -0.216  -0.233 |  | .02 | .35 | .12 | .05 |
|  | CS  F1 Propositive style  F2 Collaborative style  F3 Conformist style | 0.036  0.139  0.016 | 0.029  0.118  0.012 | .00  .00  .00 |  |  |  |  |

\*p<.05

aunique variability =.15

Overall, the *combined* TOA measures accounted for 10% of the variance in PCP (R2 at Block 1). To put this into perspective, as much as 90% of teamwork performance measured by PCP remains unaccounted for.

Notably, the three attitude facets at Block 1 showed comparable levels in prediction, but opposite signs in their relationship with the PCP scale. Very close *β* values (at 83 *df*)in Table 5-6 showed that: higher ratings in team performance were positively related to attitudes towards communication and co-ordination, but negatively associated both to sharing command leadership and disregard of stressors effects.

These latter findings should however be treated with great caution and direct interpretations should be resisted. Apparently, further regression investigation revealed that each TOA measure acted reciprocally as a suppressor variable on the other two (Pedhazur, 1997; Tabachnick and Fidell, 2007). That is, each TOA factor in the context of the other two assumed importance to PCP’s prediction by suppressing irrelevant variance, although full bivariate correlations in Table 5-6 revealed no significant relationships between any one TOA and PCP measure.

Back to the research hypotheses, it should be highlighted that, in this first exploratory AMAS application the leverage of attitudes on performance was very modest, if of any impact at all: improving teamwork attitudes may not *actually* reflect appreciable or practical changes in team performance. Also, this finding can be misleading itself as all TOA factors showed to be potentially reciprocal suppressors. Cognitive styles, both separately as well as in combination with team attitudes measures failed to account for performance levels and weakened the regression model overall. In general the findings are quite in contrast to a simple model of attitude-behaviour-performance relationship.

## **The application of AMAS-2000 (AMPOS version)**

A revised version of the AMAS-1998 questionnaire was employed within a wider survey on aircraft maintenance safety climate, proficiency and change (Corrigan et al., 2002). The investigation was carried out within the framework of the EU funded project AMPOS (1999). The structure of AMAS was based on the previous measures of team attitudes (TOA scale), cognitive styles (CS scale) and perception of communication practices (PCP scale). The PCP scale was maintained in its original form (5 items), instead the TOA and CS scale were both reduced to a number of 12 items each. The items selected showed to be the most consistent and reliable measures according to previous psychometric and statistical validation of the questionnaire in 1998 (Baranzini et al., 2001). In particular, only those items with factors loadings ≥.41 and higher stability on their respective scale factors were retained. One measure (i.e., item 2 of Part 2) of the original CS scale was reverse scored to better satisfy content and face validity criteria. The AMAS-2000 is reported in Annex 5C.

***Subjects and measures***

The AMAS questionnaire was distributed to a sample of 87 maintenance operators from a large aircraft maintenance company in north Europe, here called Company B. The sample comprised 54 Technicians (mechanics and aircraft engineers), 16 Supervisors (shift/crew managers and supervisors) and 16 Support staff (engineers and support staff) from Workshop, Quality, Engineering and Planning department. Referring to membership to specific work teams, 70 participants work in Hangar teams, 16 in Support teams (Workshop, Planning, Engineering or Quality departments). The Hangar teams are further sub-divided into three different teams in of function of bays of work, respectively hangar 6-Bay1, hangar 6-Bay2 and hangar 2 with 45, 24 and 3 operators each. Participants’ current job experience ranged from no experience to 36 years with a mean of 7.6 years (sd=6.9). Respondents experience in the company ranged from none to 36 years with an average of 12.2 years (sd=10.5).

All respondents completed the three scales of AMAS replying to the items of *Technical Operation Attitudes scale* on a 5-point Likert scale anchored by *disagree strongly* (coded as 1) and *agree strongly* (coded as 5), in order to evaluate their agreement with them. In the *Cognitive Style scale*, respondents were asked to describe on a 5-point Likert scale ranging from *very seldom* (coded as 1) to *very frequently* (coded as 5) how often the items are true of their behaviour, consistently and for a long time. In the *Perception of Communication Practices scale*, participants were asked to indicate, on a 5-points scale ranging from *very seldom* (coded as 1) to *very frequently* (coded as 5), how often the items are true descriptions of their work team environment.

* + 1. **MANOVAs, correlation and multiple regressions**

***Factor structure, validity and reliability of AMAS-2000***

The factor analytic study and reliability analysis of the AMAS measures confirmed adequate construct validity and reliability of the instrument. Factor structures of TOA, CS and PCP replicated those ones of the previous AMAS in 1998. A single notable difference was found in the CS scale. The items of the Conformist style factor failed to differentiate from the Collaborative style measures across different factorial solutions. These items always collapsed together under a single dimension. A decision was taken to favour internal consistency with previous research findings (AMAS results in 1998 version) over the present factor analysis results. The items composing the two measures were kept separated.

Overall, all variables showed good psychometric properties and consistency. Validity and reliability results are described in the Annex 5D.

***Use of weighted averages for TOA and CS***

Differently from the 1998 AMAS application, weighted averages were computed for TOA and CS scales. Scores for each scale factors were standardized and then given weights reflecting their theoretical importance to obtain single average value for each scale. In TOA scale, *Teamwork communication and co-ordination* factor (TOA F1) was given more importance than *Recognition of stressor effects* factor (TOA F2)and *Sharing command responsibility* factor (TOA F3): weights of 1.5, 1, and 1 respectively. In CS scale, *Collaborative Style* factor(CS F2) was assigned more importance than *Propositive style* and *Conformist Style* factor: weights of 1.5, 1, and 1 respectively. PCP scale was not weighted.

***One-way MANOVA: Support versus Hangar teams***

Team membership effect was tested in a multivariate analysis of variance with TOA, CS and PCP scales as dependent measures. Omnibus MANOVA was followed up by Roy-Bargman stepdown Fs. Order of priority from the most to least important AMAS dimensions was: PCP, TOA, CS. The rationale for all MANOVA procedures above is fully described in section 5.4.1.

SPSS MANOVA Syntax and GLM procedure were used for this analysis. Total N of 87 was screened to test assumptions and adjusted accordingly. A multivariate outlier was detected and dropped from the analysis, leaving a total N=86.

Adopting Pillai’s (*V)* criterion, the multivariate main effect for Team was statistically significant, Team F(3, 82)=3.331, p<.02, *V*=.109. The strength of association was modest, partial η2=.11. This effect showed to reliably discriminate respondents on the combined AMAS measures.

Omnibus MANOVA was followed up by stepdown Fs (and univariate Fs) to study which of the three AMAS scales contributed uniquely to the significant multivariate effect. Results are summarized in Table 5-7. The total experimentwise error rate was kept to .05 by apportionment of alpha as shown in the last column of Table 5-7.

Endorsement of favourable teamwork attitudes contributed to the multivariate main effect of Team: TOA, stepdown F(1, 83)=8.67, p<.02, partial η2 =.10. Personnel in Support teams (M=23.15, SE=1.11) showed to be significantly more inclined toward teamwork attitudes than members of Hangar teams (M=19.53, SE=.53).

**Table 57 - Stepdown F of Team (Support vs Hangar teams)**

| **IV** | **DV** | **Univariate F** | **Df** | **Stepdown F** | **df** | **α** |
| --- | --- | --- | --- | --- | --- | --- |
| Team | PCP  TOA  CS | 0.45  9.21a  3.90 | 1/84  1/84  1/84 | 0.45  8.67\*  0.85 | 1/84  1/83  1/82 | .02  .02  .01 |

asignificance level cannot be evaluated but would reach p<.01 in univariate context

\*p<.02

Likely, this higher team attitude orientation by the support teams may reflect an actual operational difference in team configurations and task requirements by the two different work groups. The support team operations are likely more predictable and self-contained than the highly fluctuating operations of operational work teams in hangar. Also a support team is somewhat simpler in its job structure. Its configuration (i.e., membership) tends to be the same over time and it is less likely dependent by the external environment. This context in turn may trigger more positive attitudes for collaboration, co-ordination and communication. To note though, that team performance scores of PCP and cognitive styles ratings of CS were not significantly different between the two types of teams. Apparently better attitudes for the personnel in support teams did not translate in better performance. Other variables might mediate attitude-behaviour relationships.

***Multiple regression: team attitudes and styles predicting team performance***

A sequential multiple regression was performed to test if the TOA scale, as first block in regression, and CS measure adjusted for TOA, the second block, could successfully predict ratings of the PCP scale. This model-testing approach mirrored the analysis conducted previously in 1998 for Company A: do teamwork attitudes and/or styles predict team behaviour?

After screening of residuals to check assumptions for analysis, regression results on a final total N=86 revealed that, neither the composite TOA scale, multiple R=.16, F(1,84)=2.07, p>.05 and R2=.02, nor the composite CS scale, multiple R=.26, F(2,83)=2.91, p>.05 and R2=.07, showed to be significant predictors of the PCP measure. Neither the TOA scale taken singularly nor addition of the CS scale, adjusted for TOA, significantly contributed to prediction of the perceived team performance. Put simply, teamwork attitudes and working styles were not reliable predictors of team behaviour performance.

Overall, discriminant validity of the AMAS measures was confirmed again in this 2000 analysis in Company B. MANOVA results showed how the TOA scale discriminates among respondents grouped by type of team membership. This corroborates previous findings for Company A in the AMAS 1998 application. Nevertheless, predictive validity of team performance was not achieved by the regression analysis. Clearly, this shows again that the model team attitude-behaviour-performance is *not* a linear simple phenomenon. This seems to suggest again that other variables within or external to operational teams do moderate direction and pattern of such hypothesised relationships.

***One-way MANOVA: team dimensions and technical performance***

Can the AMAS measures discriminate between members of different work teams which displayed different technical performance levels? To study this hypothesis, an exploratory one-way MANOVA was carried out with TOA, PCP, CS as combination of dependent variables. Team membership of the two available hangar teams, work team of hangar 6-Bay1 versus hangar 6-Bay2, was the grouping factor upon which the AMAS measures were tested for differences. The two teams differed in their check *Recoverability* ratios, a well known index of technical performance efficiency commonly measured over the maintenance check operation (see Table 5-11 for further details). The averaged Recoverability was .92 for team of hangar 6-Bay1 (mean rating for 2 check operations) and 1.02 for team in hangar 6-Bay2 (mean rating for 3 check operations). The two figures described quite a difference in check performance: the former team was certainly less efficient than the latter one. The measures were taken over the same period of the AMAS survey collection, May 2000. From a business process perspective, the two teams represented opposite business performance levels.

SPSS MANOVA Syntax and GLM procedure were used for this analysis. From an original sample of N=70, all diagnostics check of assumptions and data adjustments were performed accordingly. Three cases were dropped from further investigations. Total N was 67.

Adopting Pillai’s (*V)* criterion, the multivariate main effect for Team was not statistically significant, Team F(3, 63)=1.365, p>.05, *V*=.061. The strength of association was poor, partial η2=.06. The team membership effect (teams with different levels of performance) did not discriminate respondents on the combination of AMAS measures.

Considering a univariate context of analysis, separate one-way ANOVAs were performed to test which of the three AMAS scales independently could be significant measures. The total experimentwise error rate was kept to .05 by apportionment of a Bonferroni adjustment per each test at p<.01.

No Fs test did reach statistical significance: TOA scale, F(1,65)=1.10, p>.05; CS scale, F(1,65)=1.08, p>.05; PCP scale F(1,65)=0.04, p>.05. Overall, no AMAS measure discriminate between the two teams. Average attitudes, styles and teamwork performance levels between teams with different operational performance levels were not significantly different.

The exploratory findings presented above seem to indicate that hangar maintenance crews *grouped by* different check performance levels, could not be discriminated by teamwork attitudes, styles and mostly important by *internal* teamwork proficiency levels such as communication, co-ordination and feedback performance. This, despite of the fact that technical performance, measured as check Recoverability ratio, may well reveal to be circumstantial and subject to many more factors than those assessed here.

## **The application of AMAS-2001 (PPI version)**

A reduced version of the AMAS-2000 questionnaire was applied for a second time in Company B during June and July 2001. This research action was part of a wider survey investigation directed to assess the readiness of the organisation to embark upon new company’s initiatives in human factors, partnership, continuous improvement and change. In particular, the new survey instrument, containing the AMAS elements, was called People, Partnership and Improvement (PPI).

The PPI survey retained and adapted some of the AMAS measures on attitudes toward teamwork and communication, the TOA scale. Instead, previous measures on team styles and teamwork performance (CS and PCP scales of previous AMAS-2000/1998 versions) were replaced by two scale measures targeting more specific operational and team performance dimensions in accordance to the main goals of this wider company’s assessment.

In order to maintain consistency, the refined AMAS version within the overall PPI is reported in Table 5-8 here below, and called AMAS-2001 (PPI version). The relevant parts of the survey are reported in Annex 5E.

**Table 58 - AMAS-2001 (PPI version)**

| Section 1 – Teamwork Behaviour (TB) scale |
| --- |
| Section 3 – Operational Support (OS) scale |
| Section 4 – TOA scale (items adapted from AMAS 2000) |

*Section 1* is the Teamwork Behaviour (TB) scale. It can be paralleled to the previous PCP scale of AMAS. This scale comprises seven items measuring self-reported perceptions on teamwork behaviours: effective team co-ordination within and between groups at work (e.g., “work is co-ordinated with other sections/departments to ensure a smooth operation”), collaborative communication and information sharing (e.g., “share information openly about operational matters”), and effective team-oriented problem solving and decision making (e.g., “Are good at resolving problems involving different views or interests”). Endorsement of the items of this scale suggests a favourable presence of positive and effective teamwork behaviours and communication patterns. This scale can be used to test the relationships between teamwork attitudes, behaviours and operational performance.

*Section 3*, the Operational Support (OS) scale, measures how well *external* organisational environments (i.e., all support groups) provide operational teams with effective and high quality technical support and responsiveness. This OS scale comprises twelve items measuring tools and parts availability (e.g., “the tools required are available, in the right condition, when they are needed”), manpower and information availability (e.g., “there are sufficient qualified personnel available”), and the presence of effective quality support and assistance (e.g., “the quality department ensures that my work is done to the highest possible standard”). Endorsement of these items suggests the presence of an effective and efficient external support system. Most important, this scale could help verify the actual impact of external factors on internal team attitudes, behaviours and their relation with technical performances for operational teams working in hangar. This can allow exploratory tests on a previously stated hypothesis: for highly interdependent systems *effective* *team performances depend more on external support effectiveness than internal team behaviour proficiency and disposition* (see Chapter 3). In particular, the level of team behaviour and performance can be tested controlling for the level of external support provided.

Finally, in *Section 4*, the TOA scale comprises seven original TOA’s items with factors loadings ≥.50 on their respective scale factors and good psychometric properties. Some of the items were improved in the wording and adapted to this new investigation. The TOA scores quantify the overall attitude toward teamwork communication and co-ordination.

***Subjects and measures***

The questionnaire was distributed to a sample of 223 maintenance operators employed in the same Company B exposed one year before to the AMAS 2000 version. The sample comprised 144 Technicians (mechanics and aircraft engineers), 26 Supervisors and 53 Support staff mainly from Materials/Logistics, Quality, Engineering and Planning functions. 145 participants were employed in Hangar maintenance teams, 63 in Support teams (Materials/Logistics, Quality, Planning, Engineering) and a smaller group of 15 allocated to Line maintenance teams. According to the available hangars and bays of work a set of nine different work teams were identified: Hangar 1, 2, 3, 4, 5, 6-Bay1, 6-Bay1A, 6-Bay 2 and 6-Centre Bay. Participants’ current job experience ranged from no experience to 41 years with a mean of 7.7 years (sd=8.3). Respondents experience in the company ranged from none to 40 years with an average of 12.1 years (sd=11.6).

For the TB scale, all respondents were asked to describe on a 3-point Likert scale ranging from *true* (coded as 3), *uncertain* (coded as 2) to *false* (coded as 1) if the items are true descriptions of their teamwork behaviour. In the OS scale, the measure of external support received by the team, participants were asked to indicate, on a 5-points Likert scale ranging from *never* (coded as 1) to *always* (coded as 5), how often the items are true descriptions of their work environment in terms of support systems for operational activities. Finally, respondents completed the TOA scale on a 5-point Likert scale anchored by *strongly disagree* (coded as 1) and *strongly* *agree* (coded as 5), in order to evaluate team attitudes preference.

* + 1. **MANOVAs, correlation and multiple regressions**

##### ***Factor structure, validity and reliability of AMAS-2001***

The TB, OS and TOA scales showed good psychometric properties with adequate internal reliability levels. The factor structures among the three scales showed good interpretability, parsimony and simple structure. Items of the TB scale loaded on a single overall factor. OS and TOA measures both converged towards a three factors structure. Notably the factorial structure of TOA confirmed once again previous findings on the construct validity of the measure.

Factorial compositions, psychometric properties and internal reliabilities of all AMAS 2001 scales are described in Annex 5F.

***Use of weighted averages for TOA and OS***

Single composite scores, in the form of weighted averages, were calculated for OS and TOA. Scores of both scale factors were standardized and then given weights reflecting their theoretical importance to obtain single average ratings. In TOA scale, *Teamwork communication and co-ordination* factor was given more importance than *Recognition of stressor effects* factor and *Sharing command responsibility* factor: weights of 1.5, 1, and 1 respectively. In OS scale, *Tools and parts availability* and *Manpower and information availability* factor were given more importance than *Quality support and assistance* factor: weights of 1.5, 1.5, and 1 respectively. TB scale was not weighted.

***One-way MANOVA: Hangar, Line and Support teams***

Team membership effect across hangar, line and support teams was tested in a multivariate analysis of variance with OS, TB and TOA measures as dependent measures. Omnibus MANOVA was followed up by Roy-Bargman stepdown Fs to test unique contribution by each univariate F separately. Order of entry of the three scales in stepdown analysis favoured external support over internal teamwork and ultimately teamwork attitude dispositions: OS, TB and TOA. The rationale for all MANOVA procedures is described in section 5.4.1.

SPSS MANOVA Syntax and GLM procedure were used for this analysis. Total N of 223 was screened for assumptions and adjusted accordingly: plausible range values, presence of within-cell univariate and multivariate outliers (p<.001), missing values, assumptions of multivariate normality, homogeneity of variance-covariance matrices, linearity and multicollinearity. No serious violation was noted. One case was a multivariate outlier and was dropped from subsequent analysis reducing N to 222.

Adopting Roy’s Largest Root criterion, the multivariate main effect for Team was statistically significant, Team F(3, 218)=2.641, p=.05, Roy’s=.036. The strength of association was poor, partial η2=.04. It is to note that the very same multivariate effect was not significant according to the other available multivariate criteria: Pillai’s trace (*V*),Wilks’s lambda(Λ) or Hotelling’s trace (*T2*).

However, as suggested by Field (2005), Roy’s root could be the criterion of choice, as it becomes the most powerful test when group differences concentrate mainly on the first *variate*. This criterion will take account of only the eigenvalues (ratio of explained versus unexplained variance) for the first variate to calculate the multivariate significance test. And, in the present analysis, a follow-up discriminant analysis showed that significant team differences were mostly concentrated on the first of the two available variates indeed (first variate: 75.5% variance explained; eigenvalue=.036). Overall, the multivariate result is thus presented with some caution and interpretations would be limited to findings of the following stepdown Fs.

Results of Stepdown Fs and univariate Fs are summarized in Table 5-9 below. The total experimentwise error rate was kept to .05 by apportionment of alpha as shown in the last column of Table 5-9. Of the three AMAS measures, only the TB scale contributed significantly to the overall omnibus MANOVA: TB, stepdown F(2, 218)=3.03, p=.05, partial η2 =.03. This effect was significant although above the experimentwise error rate, p<.02. The other two scales, OS and TOA, did not contribute significantly to the multivariate effect. In particular, post hoc contrasts on the TB scale compared hangar teams against line and support teams respectively.

**Table 59 - Stepdown F of Team (Support vs Hangar vs Line teams)**

| **IV** | **DV** | **Univariate F** | **Df** | **Stepdown F** | **Df** | **α** |
| --- | --- | --- | --- | --- | --- | --- |
| Team | OS  TB  TOA | 1.25  3.03a  0.76 | 2/219  2/219  2/219 | 1.25  3.03\*  0.89 | 2/219  2/218  2/217 | .02  .02  .01 |

asignificance level cannot be evaluated but would reach p=.05 in univariate context

\*p=.05. Experimetwise error rate of p<.02 is not satisfied.

Familywise alpha error rate was kept at .05 by a Bonferroni adjustment of 05/2=.025 per comparison. Results revealed that hangar teams (adjusted M=2.83, SE=.02) reported better teamwork performance than support groups (adjusted M=2.76, SE=.02), t(205)=2.44, p<.025. No performance difference was found between hangar and line teams (adjusted M=2.80, SE=.05), t(157)=0.71, p>.05.

The overall findings resembled, to a certain degree, the AMAS results obtained in the same company over the previous year 2000: team attitude differences across groups (support versus hangar teams) did not correspond to significant performance differences. The present AMAS 2001 survey showed that better team performance by hangar teams (versus support teams) was not accompanied by superior attitudes toward teamwork. Again, attitudes towards teamwork did not reflect team performance levels *and vice-versa*.

***Multiple regression: external support and team attitudes predicting teamwork performance***

Is knowledge on external support proficiency and teamwork attitudes useful to predict internal teamwork performance? What is their unique and individual contribution to prediction of teamwork performance?

One multivariate outlier was removed from the original N=223 after screening of residuals to check for assumptions. A standard multiple regression was performed on a final N=222. Thus, a model-building approach was favoured. In particular, with no specific model or theory on *external support effects*, each predictor was assessed as entered last in the regression equation, and its unique and single importance to prediction was tested accordingly.

Table 5-10 below displays (un-)standardised beta weights (B, *β*), unique squared semi-partial correlations (sri2), R for regression, R2 and adjusted R2. R for regression was significant, R=.25, F(2, 219)=7.02, p=.001, with R2 at .06. Significance of regression coefficients and sri2 were assessed through *t* statistics, which were evaluated against 219 *df*. The OS scale showed to be a significant predictor of the TB measure, *β=*0.246, p<.001. Instead, TOA scale did not contribute significantly to prediction of the same criterion, *β=*0.037, p>.05.

Notably, the OS scale, as measure of external support, uniquely accounted for 6% of the total variance in team performance proficiency (sri2=.06, p<.001). Person’s r correlation between TB and OS scale, *r*=.24, p<.01, corroborated such findings on regression coefficients. The TOA measure, uniquely, did not account for any variance in TB scale (sri2=.00).

**Table 510 - Standard multiple regression of OS and TOA scale on TB scale**

| **Predictors** | **B** | ***β*** | **sri2**  (unique) |  | **R** | **R2** | **R2**  (adjusted) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| OS  TOA | 0.062\*  0.013 | 0.246  0.037 | .06  .00 |  | .25\*\* | .06a | .05 |
|  |  |  |  |  |  |  |  |

\*p<.001; \*\*p=.001

aunique variability =.06; shared variability =.00

The positive relationship between OS and TB scales suggests, arguably, that the more effective the external support the better the teamwork behaviour, as reported *internally* by the team.

Also, this condition is very much in line with a model of maintenance performance as it was hypothesised previously in Chapter 3: technical performance of work teams in hangar may depend more on *external* support systems than on *internal* team attitudes, dispositions and behaviours.

***Multiple regression: team, technology and supports predicting technical performance***

As discussed in the introduction of the chapter, positive teamwork performance and favourable attitudes are frequently *associated* to a concept of higher operational performance and safety levels. Past research indicated such a positive relationship (Taylor and Christensen, 1998). Nevertheless, this argumentation is still under debate and conclusive findings are still needed (Patankar and Taylor, 2004a). For example, in the present work, a dedicated MANOVA performed over the AMAS-2000 measures failed to evidence such a relationship.

The argument is that other variables come into play and *moderate* the relationships between teamwork, attitudes and technical performance. As highlighted in the previous section above, the external support proficiency is likely to *affect* technical performance levels. Also, the technical demand, as technology effort imposed on the check operation, may be another determinant of operational performance. To date, the effect of these two variables on the technical performances is unknown.

In this framework, the key research question addressed is: What is the relative importance of team dimensions in predicting technical performance of maintenance operations when measures of technology effort and external support proficiency are added to prediction? What is the relationship and contribution of such variables all together?

***Unit of analysis and technology dimensions***

In order to test these hypotheses, a series of technology and technical performance indicators were monitored over a number of 28 hangar teams. These indicators are fully described in Table 5-11. Members of the available hangar teams were also respondents of the present AMAS 2001 survey. Each operational team was performing check operations over the same period of distribution and collection of the AMAS survey: June and July 2001. Thus, averaged ratings per each team on OS, TB, TOA scales together with the technical performance ratings were tested for potential relationships.

***Multiple regression models applied***

Overall, applying a model-testing procedure, two separate sequential multiple regressions were performed on a total N=28 teams. Regression models tested if team behaviour performance and teamwork attitudes significantly add to prediction of either check Recoverability or Downtime, after external support and technology dimension are accounted for (controlled statistically). Thus, order of entry of variables for both regression models was: Technology Effort, OS, TB and TOA scales.

Presence of univariate and multivariate outliers, as well as normality, linearity and homoscedasticity of residuals was checked upon. Two multivariate outliers were detected and appropriately dropped from further analysis, leaving a final adjusted data sample of N=26 for both regressions.

**Table 511 - Technology and Technical performance variables**

| **Technology Effort** – Technical dimension of a maintenance check operation  Hangar maintenance visits vary in technology demands and technical configurations required to perform check operations. For instance, smaller checks (called A checks) generally require less complex supports, scaffolding, smaller work orders and supplies, and less manpower efforts than larger or more complex check operations (called C checks). This technical dimension of a maintenance check operation, termed here as Technology Effort index, was modelled as linear combination of the type of check (A versus C), total spent hours (log-transformed) and total material costs (log-transformed) employed in the full operation. |
| --- |
| **Recoverability** – Ratio of planned versus actual manpower used per check operation  Check performance efficiency is measured by comparing actual versus planned expenditures in human resources by the contract: this ratio of planned versus actual team manpower used is a very common business performance indicator. This performance indicator is a common means to control the evolution of a maintenance operation. In particular the more the recoverability figure is below one, the more the team overspent manpower. The higher the figure above one, the better the efficiency and profitability/revenue for the check. This clearly translates in terms of actual man-hours spent in the operation. |
| **Downtime** – Ratio of planned versus actual time spent on the check operation  Time to complete a maintenance check operation on the aircraft is another important performance efficiency indicator. Any check operation is expected to release the aircraft according to a planned delivery date, or even to shorten the planned delivery time. Clearly, any check operation that will be completed on time or in a shorter turnaround time will be highly regarded by the customer. Instead, unscheduled delays ingenerate direct and indirect costs, penalties as well as reduce customer satisfaction. |

Table 5-12 below presents the matrix of full correlations across all variables. A pure statistical look at the correlations revealed some straightforward results: teamwork attitudes (TOA scale) and team behaviour (TB scale) did not correlate significantly with Recoverability, *r*=-.15, p>.05; *r*=-.01, p>.05 respectively. Team behaviour was also not correlated with Downtime, *r*=-.11, p>.05. Higher attitudes were positively associated to longer Downtimes, *r*=.41, p<.05.

On the opposite, both Recoverability and Downtime were significantly associated to the technology effort, *r*=-.65, p<.01 and *r*=.81, p<.01 respectively; and, mostly important, *to the proficiency of external support for teams carrying out the check operations* (OS scale), *r*=.45, p<.05; r=-.80, p<.01 respectively. Notably, teamwork attitudes and teamwork performance were not significantly associated, *r*=.31, p>.05.

**Table 512 - Inter-correlations of AMAS-2001 scales, Recoverability, Downtime and Technology Effort**

| **Measures** | | *Tech performances*  *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | *AMAS-2001 measures*  *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | Recov. | Down-time | Tech. eff. | OS scale | | TB scale | TOA scale |  | |
|  | | | | | | | | | | |
| *Tech performances* | Recoverability  Downtime  Tech. effort | ---  -.63\*\*  -.65\*\* | ---  .81\*\* | --- |  | |  |  |  | |
| *AMAS-2001 measures* | OS scale  TB scale  TOA scale | .45\*  -.01  -.15 | -.80\*\*  -.11  .41\* | -.76\*\*  .16  -.48\* | ---  .44\*  -.44\* | | ---  .31 | --- |  | |
| N=26 | | | | | | | | | | |

\*P<.05, \*\*P<.01

Multiple regression results are presented in Table 5-13. Unique and incremental values of beta weights (B), standardized beta weights (*β*), squared semi-partial correlations (sri2), R and R2 and adjusted R2 at the last step, Block 4, are displayed for each of the two regression models separately.

With Recoverability as criterion, the regression model was significant at the end of each step. At the end of Block 4, with all variable in the equation, R=.69, F(4, 21)=4.74, p<.01, and R2=.47. Almost half of the variability in Recoverability is predicted by the regression model.

Notably, at the end of Block 1, the single entry of Technology effort index accounted for all of the significant incremental variance in Recoverability, R2 = sri2 =.43, F(1, 24)=17.89, p<.001. Sequential addition of OS, TB and TOA scales in the model did not significantly improve prediction of Recoverability: sri2 =.01, F(1, 23)=0.23, p>.05; sri2 =.00, F(1, 22)=0.07, p>.05; sri2 =.04, F(1, 21)=1.58, p>.05 for OS, TB and TOA respectively.

Although the OS scale did not contribute significantly to regression, it should be noted that its full correlation with Recoverability was indeed significant, *r*=.45, p<.05 (see Table 5-12). Apparently, an important and significant positive relationship between OS scale and Recoverability appears to be mediated by the relationship between Technology effort, TB scale, TOA scale and Recoverability.

**Table 513 - Sequential multiple regressions of Technology effort, OS, TB, and TOA scales on Recoverability and Downtime**

| **Step** | **Predictors** | **B** | ***β*** | **sri2**  (incremental) | **R** | **R2** | **R2**  (adjusted) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *Recoverability*  Block 4 | Technology effort  OS scale  TB scale  TOA scale | -0.459\*  0.026  -0.375  1.030 | -0.736  0.076  -0.141  0.286 | .43\*\*  .01  .00  .04 | .69\*\* | .47 | .37 |
| *Downtime*  Block 4 | Technology effort  OS scale  TB scale  TOA scale | 0.514  -0.553\*\*  1.514  -1.246 | 0.356  -0.698  0.244  -0.149 | .66\*\*  .08\*  .01  .01 | .87\*\* | .75 | .71 |
|  |  |  |  |  |  |  |  |

\*p<.05; \*\*p<.01

Overall, bivariate correlations and regression results on Recoverability criterion confirmed that the *measures of team attitudes and teamwork performance did not reveal to be significant predictors of Recoverability levels, that is, the real technical performance of a check operation.* This finding, if corroborated by further research, would be quite in conflict with different models theorising on the operational effects of team performance in hangar maintenance.

Correlation and regression findings revealed also that *the more the external support is proficient, the better the check Recoverability*, butas the technology efforts increase (i.e., more complex checks and technological resources) the check performances will decrease.Apparently other external dimensions come into play and have much leverage on operational performance systems.

Sequential regression for Downtime criterion was also significant at the end of each step. In Table 5-13 is reported the last step, Block 4. With all the variables in the equation, R=.87, F(4, 21)=16.09, p<.001, and R2=.75. The R2 indicates that 75% of the variability in check operation Downtime is predicted by the variables in the model.

At the end of Block 1, most of the predicted Downtime variance is accounted for by the single entry of the Technology effort index, R2 = sri2 =.66, F(1, 24)=45.69, p<.001. Interestingly, addition of OS scale at Block 2, contributed to prediction of Downtime as well: sri2 =.08, F(1, 23)=6.55, p<.05. TB and TOA scales at their subsequent entry points did not reliably increment R2: sri2 =.01, F(1, 22)=0.97, p>.05; sri2 =.01, F(1, 21)=0.92, p>.05 at Block 3 and 4 respectively.

Following on from the results above, it appears that the length of Downtime duration is predicted by knowledge on the technological effort and external support received during the check operations. As expected, more complex and heavier check operations (more Technology effort) will lead more likely to longer check completion times (Downtime). But also, and more interesting from a theoretical point of view, external performance predicts Downtime performance of a check operation. That is, *effective external supports will reduce check completion times*. This result also parallels the significant positive correlation found between external supports and Recoverability criterion, shown in Table 5-12. And again, similar to findings with Recoverability criterion, team *performance and attitudes measures did not predict Downtime.*

Overall, both regression results provided a new potential interpretive model to the question of team performance and behaviour for aviation hangar maintenance teams: internal teamwork skills and attitudes disposition are at least *indeterminate* if not clearly *unreliable* predictors to account for actual technical performances of check operations. It was shown that if the model of team analysis contains and accounts for variables other than teamwork dimensions such as external processes, support and technological variability, then the model becomes reliably more sensitive to prediction.

Apparently, comprehension of hangar maintenance teams seems to require more explanations of their surrounding processes and relative impact. These *externalities* seem to reveal that outcomes of a check operation are less and less controllable and manageable from the work team itself.

## **Discussion and conclusion**

A summary with the overall AMAS patterns of results is in Table 5-14 here below. The table reports the validity criteria to verify the *attitudes-behaviour-performance* model and their level of satisfaction as tested by the AMAS measures across different samples and delivery times. The expected relationships between favourable team attitudes and behaviours, the concurrent validity, as well as prediction of operational performance, the predictive validity, were not confirmed either.

**Table 514 - Overview of AMAS results by discriminatory, concurrent and predictive validity**

|  |  | **Validity** | | |
| --- | --- | --- | --- | --- |
| **Survey – time** | **Company/Organisation** | **Discriminant**  (team attitude and behaviour differences across groupings) | **Concurrent**  (team attitude and behaviour correlations) | **Predictive**  (team attitude and behaviour predicting team performance) |
|  |  | *MANOVA* | *Correlation* | *Multiple regression* |
| AMAS-1998 | Company A | *Yes* | *No* |  |
| AMAS-2000 | Company B | *Yes* | *No* | *No\** |
| AMAS-2001 | Company B | *Yes* | *No* | *No* |
|  |  |  |  |  |

\*tested by a one-way MANOVA

Results did not match the model’s expected relationships. Other dimensions and variables seem to play a more influential and sensitive role in performance. Discriminant validity was instead confirmed across all AMAS applications. Team attitudes and behaviours differentiate across several grouping variables and demographic data. A more detailed review follows.

* + 1. **Discrimination by team situations, not performance**

The AMAS measures showed to discriminate by different groupings, companies and across different time periods. MANOVA tests revealed significant main and interaction effects as reported in Table 5-3, 5-4, 5-7 and 5-9. In the 1998 AMAS survey, positive teamwork attitudes and teamwork behaviours were higher in hangar teams than in line maintenance crews. Respect to their supervisors, technicians favoured a more conformist style in teamwork and lower dispositions towards sharing command responsibilities. Age reflected also differences in levels of collaborative style.

In the AMAS 2000 version, support teams showed better attitudes than hangar teams. This however did not translate in better perceived teamwork performance by the same support groups. Support team operations are likely more predictable and self-contained than the highly fluctuating operations of operational work teams in hangar. And, as already suggested, *this context* in turn may trigger more positive attitudes for collaboration, co-ordination and communication. Finally, in AMAS 2001, hangar and support teams showed different teamwork performance levels. A result, again, not accompanied by expected attitude differences between the two types of teams.

Notably, the interesting finding here may lay behind the fact that teamwork behaviours, attitudes and styles were discriminated by type of team, job role, grade and age, but *not* technical performance levels. For instance, in the AMAS 2000 version, teamwork attitudes, styles and teamwork performance were not significantly different for operational teams grouped by opposite technical performance levels. All the results above may favour the idea that difference in teamwork capabilities mirrors work situations, not performance capabilities. Theoretically, such findings seem to favour a *situational view of teamwork* where the emphasis could be more on skills situations for teamwork, or more generally team situations, rather than individual characteristics, traits or abilities about teamwork.

* + 1. **Lack of concurrent and predictive validity**

AMAS results in 1998, 2000 and 2001 failed to reveal significant correlations between favourable teamwork attitudes and team behaviours. For instance, in AMAS 1998, Table 5-5 showed that the PCP scale, an indirect measure of teamwork performance, did not significantly correlate with any of the teamwork attitude and style factors (TOA and CS scales respectively). A very similar finding is reported in Table 5-12 for the AMAS 2001 version. Teamwork behaviour measures (the TB scale) revealed no significant association with teamwork attitudes (the TOA scale). In general, the hypothesized attitude-behaviour relationship was not supported, reflecting a certain lack of concurrent validity.

On the same line of results, the predictive capacity of the AMAS measures revealed that team behaviour levels and attitude dispositions did not reliably predict any team’s technical performance: a one-way MANOVA in 2000 and all regression analyses in 2001 clearly showed a substantial lack of predictive power of such internal team dimensions upon Recoverability and Downtime indicators (Table 5-13). The hypothesised model of positive teamwork attitudes leading to positive teamwork behaviours which, in turn, will likely favour higher safety or technical performances is not tenable. In fact, for hangar teams, at least, it does represent a neat over-simplification of the reality. Simply, teamwork levels and attitudes did not contribute to prediction of check performance.

* + 1. **Leverage of support systems and technology**

Although this lack of predictive capacity by internal team dimensions over performance, the analysis carried out with the AMAS 2001 introduced also a new conceptual argument. That is, work teams performing check operations in hangar maintenance seem to be intrinsically connected to the role of external support systems and technologies, whose performances (not directly controllable by work teams) will affect and moderate the final check performance levels. Following this logic, the 2001 survey measured team dispositions, behaviours and performances controlling for the level of external supports and technology dimensions of the very check operations. The introduction of the Operational Support (OS) scale and Technology effort index provided a predictive capacity not found amongst the other measures of AMAS. The significant correlations between these new measures and technical performances (Table 5-12), as well as their significant contribution to prediction of Recoverability and Downtime in multiple regressions for 2001 (Table 5-13) paved the way to a new strong research hypothesis:

For teams highly dependent on the context, the proficiency of external systems and surrounding environments have more leverage on technical performance than the very internal team dispositions, attitudes and teamwork behaviours. Hangar maintenance teams seem to reflect such condition. In empirical terms, it is the process surrounding the team on the check operation that has more leverage on the system. It is the organisation of the environment (support service and technology of process) embedding the work team that could explain the major proportion of variance in operational performance, not the internal properties of the team. For work groups highly dependent on the context the primary focus of a team analysis might rather be the embedding system around the group, not even the team itself. Thus, there might be a need to understand better what team members do in real maintenance tasks as function of their immediate or distal operational environment and what kind of teamwork capabilities are in place when dealing with the effects of external systems’ performances: the externalities. This argument will be addressed in the next chapter.

**Chapter 6**

**Observation of real maintenance teams**

“*… But if it starts like normal at the beginning of the shift there’s enough time to finish the work even with the tests, the operational and functional tests* ***we*** *do.* ***We*** *couldn’t do them because the airplane is in C-check; there are a lot of things, works, still on the airplane and it’s not the only thing* ***we*** *do…*” (aircraft maintenance team leader, 2001, pers. comm., 18 July).

# **Observation of real maintenance teams**

The analysis presented here is about teamwork for *zonal teams*, the analysis of other team levels and events is discussed elsewhere. Focus of this naturalistic qualitative-based study is on maintenance tasks operations relying on teamwork within and across aircraft zones. The analysis aimed at modelling teamwork events, knowledge, skills, and team behaviours that shape daily team practices in real hangar situations. Overall, a team process model is suggested.

## **Teamwork tasks in aircraft zones**

The team events represented in this section are based on multiple sources of evidence collected across three European maintenance organisations, here called A, B and C respectively and participating to the EU funded research project called AITRAM (2002). All reported task observations are centred on their actual implication about teamwork within or across aircraft zones. Overall, the analysis will help define a new process model for aircraft maintenance teams.

The maintenance team activities and relative assignments were studied during daily aircraft maintenance visits in hangar or, where relevant, in line environments too. Different source of information were considered:

* direct observation of task operation
* video-recording of teamwork
* notes and short interviews with personnel
* review of technical documentation

Five formal maintenance tasks were considered for observation in each of the three maintenance organisations:

1. Front wheel strut seal replacement A330-200 (company B)
2. Wheel Change A319 (company B)
3. Transit check A330 (company A, B and C)
4. Engine Hydraulic Pump Replacement A330 (company A)
5. Integrated Drive Generator removal/installation A320 (company B)

Observations were carried out by a team of four analysts (including the writer) and consisted of sustained engagement with the technician(s) and supervisors as the task was being completed. Technicians were informed of the purpose of the research beforehand. All observations were carried out in as unobtrusive a fashion as possible.

All attempts were made to get rich descriptions per each task operation, with all behaviours noted down. Clarification was obtained, when required, from shift leaders or trainers. This was an important aspect of the observation as it meant that ambiguities could be cleared up and that misinterpretations were not made due to a lack of appropriate knowledge on the part of researchers.

The outputs of each researcher’s observations were then collated and summaries of each task were developed. These collated analyses provided a general task classification description. All team related findings and teamwork issues are reported below.

* + 1. **Task 1: Front wheel strut seal replacement A330-200**

The removal and installation of a front wheel strut seal is a task that is not frequently carried out and the opportunity to gain experience in the task is limited. The landing gear of an A330-200 aircraft type is quite a complex system, requiring a good understanding of it for the removal and installation.

An informed understanding of the front wheel system is necessary in order to diagnose the exact nature of the problem with the faulty strut. Some operational experience would have been an advantage, as would task-specific procedural knowledge.

Abilities to comprehend schematics are of pivotal importance as there is constant reference to maintenance manuals in which schematic diagrams feature heavily. In addition to this, basic technical skills would be required.

The task required some considerable strength and agility in order to lift the wheel and access some recesses in the fuselage. The physical effort required at some times was considerable, especially in removing some larger components, as shown in Figure 6-1 and 6-2. It is conceivable that some aspects of the task would be impossible to perform by someone of diminutive stature.

#### **Teamwork events**

Neither the shift leader nor his team had completed this task before and as such this lack of operational experience may have forced reliance on other abilities such as schematic comprehension, external supports, other services, etc.

Overall roughly 8 technicians of various grades were involved in this task. Two shifts worked on the task, with an overlap period of three hours whereby both shifts worked on the task. Given the large numbers of personnel working on the task at any one time, some prior experience of working in a team would be necessary.

There was a shift leader, but his exercise of leadership was not obvious. There was an informal allocation of roles, which perhaps were dictated by experience and knowledge. Informal task leadership changed frequently with apparently no verbal indication of the change – a different technician would take the initiative while the others supported him with tools, supports, etc. This was particularly the case when the team encountered a difficulty and several team members took a turn at solving it.

The only sign of tension in the group was at one point when an older technician with little experience of this task had to yield task leadership to a younger technician from another team who had been “borrowed” because of his relevant expertise. But this tension was only non-verbally expressed and momentary, the older technician quickly adopting an assisting role. The team members worked quite closely, as their actions were quite interdependent.

The team itself changed during the course of the task. Initially only two or three were working on the task, one of whom was also assisting with a different task on the same aircraft; others joined as the task demands became higher, and ultimately, when the group were having difficulty, two more experienced technicians were borrowed from another aircraft.

Communication levels were quite high – primarily during the diagnosis stage, although lots of verbal interaction took place throughout the task. This is unsurprising given the lack of experience of most of the team. The team worked on the same localised part of the aircraft for the most part, although some team members were at other locations on the same aircraft for some periods of time. The team was very cohesive and all seemed to be working towards a common goal.



**Figure 62 - Teamwork for front wheel strut seal replacment A330-200 (strut removal)**

This team worked well together to carry out the task and solve the problems that it raised. However, it is easy to imagine difficulties arising if the leader was being overly autocratic, or team members disagreeing about how to carryout the task, particularly given their lack of experience. The task was quite stressful for the team when they could not work out how to perform a particular sub-task and had to call in “experts”.

#### **Summary**

This was a team task, requiring good teamwork, communication and appropriate leadership. The work group worked well, but it is easy to imagine how the task could generate serious difficulties in the team.

The difficulties they encountered in the task required good group problem solving – discussing the problems, proposing solutions, different people taking the initiative, and eventually conceding the need for outside help. There was plenty of time for the shift hand-over, the overlap in shifts allowing the new shift to be fully involved in the task before it was left to them.

Very important for a definition about teamwork processes was the presence of a varying and adapting task leadership. Informal allocation of group roles and a change in the team membership was quite evident: the team set up for the task was not the one completing it. Incoming team members were temporarily from other zones and teams (tasks assignments) of the same aircraft, others directly from another aircraft check operation. The team structure *adapted* to the unexpected lack of operational competence very easily. As expected, verbal communication remained very high throughout the entire task that was completed in two work shifts.

* + 1. **Task 2: Wheel Change A319**

The wheel change task for the A319 aircraft type does not demand huge amounts of understanding and knowledge about sub-systems, equipment and components from the technicians. Wheels do not interface with many complex systems (other than the brakes) and as such precludes the need for additional knowledge. But task specific procedural knowledge is required, as well as an understanding of the wheel components.

General technical experience does not appear to be important, but experience in doing this particular task is. The observed team of two technicians did the task very quickly and efficiently, but they were very experienced, and it is likely that technicians doing the task for the first few times would be much slower. The zonal team for this wheel change task is shown in Figure 6-3.

This task was performed in line maintenance, but the same task is carried out in hangar settings exactly the same way, as it is shown in Figure 6-4. In this case more technicians were required.



Technical skills such as loosening bolts, using wrenches, etc. are required in order to remove and replace the wheel. Over and above these no specialised skills are required to complete the task. Strength and physical effort are not required on a large basis. The requirement for these abilities is limited to removing tight-fitting bolts.



#### **Teamwork events**

Ordinarily team issues would not apply to a wheel change, as one technician working alone would usually perform the task. By its nature the task is not dependent upon team co-ordination, but can be completed in a more timely fashion when performed by more than one technician. Depending upon *staffing levels* and allocation of resources, situations do arise when two (or more) technicians would perform a wheel change. This is the case in the wheel change that was observed and reported here (Figure 6-3 and 6-4 above).

Team member functions were allocated at the beginning of the task. The role allocations were such that one technician, called tech 1, performed the task while the other, tech 2, anticipated the tools required for the task and supported tech 1 when required. With regard to co-ordination it was apparent that the tech 1 made decisions. There was an element of interdependence in terms of the tech 1’s reliance upon tech 2 for parts, and tools and support.

Verbal communication did not play a large role in the task, as the technicians were able to *anticipate* the other’s actions and requirements thereby precluding the need for verbal requests. Task division also limited the need for verbal communication – tech 1 doing all the manual tasks, organising and retrieving the parts that he took off and put back on the wheel. There was reliance upon gestures and other non-verbal communication. The team dynamics were very strong; the technicians were cohesive and completed the task very efficiently. Since the observation started after the task had commenced, there was possibly some discussion of the task and the division of labour before the observation started. Also, the fact that *all the parts and tools were available to hand limited the need for communication*.

#### **Summary**

This job could be an individual or two-person task. Teamwork may be not necessary, but having a duo (as in this case) or a team of three to co-ordinating the change task would increase operational performance and efficiency. No team membership changes occurred at any time; *no interruptions* from other zones as well.

Team co-ordination and communication would be required more with inexperienced technicians and with less than ideal circumstances like unavailable parts, multi-tasking, etc. Verbal communication shows to be related to some degree to capacity to *anticipate* one anothers’ actions or *intentions*. It is evident that efficiency shown by the team is dependent on parts availability, support, knowledge on the operational practices, and *lack of external effects*. Simply the team showed less explicit behaviour (i.e., less explicit communication) and reduced teamwork efforts overall.

* + 1. **Task 3: Transit Check A330**

The following description of a typical transit check is based on observations made in line maintenance, not in hangar contexts. Nevertheless this operation is revealing for cross-zonal and cross-group dependencies emerging in maintenance teamwork contexts. Typically, a single technician will perform a transit check on the A330 aircraft fleet. However, on some occasions where staffing levels allow it is possible that more than one technician will perform a transit check on an A330. Two technicians performed the A330 transit check that was observed.

#### **Teamwork events**

Two technicians were involved in the task. One based on the fuselage of the aircraft (‘exterior technician’) and one based in the cockpit (‘interior technician’). Each of the technicians had clearly defined tasks to perform in the zone. For the most part these tasks were independent of each other. As such within an individual technician’s remit each one was free to organise his own activity, as shown in Figure 6-5. 

**Figure 65 - “Exteriror technician” for Transit Check A330 (“interior” technician is in the cockpit)**

Communication between the two technicians was conducted via walkie-talkie and face-to face. They also had to communicate with the flight crew, cabin crew, refuelling, ground handling and the parts store. The technician plays a leadership role in the assigned task – with authority to instruct refuelling, ground-handling, cabin crew and flight crew. This leadership role often is not very obvious, but on occasion requires firm decisions and instructions, and can lead to conflict across different work teams.

In particular there can be tension between the leadership roles of the maintenance technician and the flight crew (i.e., pilots). In this sense it should be considered that the *team* consists not only of close work team colleagues but also of *ancillary workers* with whom interaction is less frequent (e.g., cabin crew, refuelling, ground handling groups, etc.). An example of the dynamic line maintenance environment and interactions is depicted in Figure 6-6 and 6-7.







#### **Summary**

While the transit check is generally carried out by an individual rather than a team, communication and co-ordination are required with a number of other personnel and groups. *Cross team co-ordination is fundamental* to maintain a smooth operation across several overlapping functions and work units.

The leadership demands of the task are typically not evident, but can be very demanding with irregular occurrences and/or time pressure. Notably, here the concept of teamwork must be considered in the context of other teamwork requirements and thus for enlarged team situations awareness becomes essential to maintain effectiveness and safe operations.

* + 1. **Task 4: Engine Hydraulic Pump Replacement A330**

The task of replacing a hydraulic engine pump is both safety and efficiency critical. The aircraft could not operate safely without the repair. Given that the task observed was not scheduled and non-routine it was efficiency critical.

The main aspects relating to this task observation is about the need for a high level of understanding and additional knowledge. These two characteristics were closely tied to experience. The diagnosis of the problem was a demanding one in terms of understanding, as the cause of the leak which necessitated the pump change was not immediately obvious. It was necessary for the zonal team to be able to understand the way in which the system works and to rectify the situation accordingly. The task did not demand much in terms of technical skill. Basic removal and installation skills were all that was required. There was some physical effort involved in the task owing to a difficult physical work environment.

#### **Teamwork events**

A team of two technicians completed this task. The team comprised a senior technician and a junior one who was still learning the job. A further *two* individuals who seemed to be in supervisory roles provided some advice when required. The allocation of team member functions was quite strict. The senior technician performed the majority of the work with the junior technician in a support role. The actions of each of the technicians were quite interdependent, and they coordinated their activity to a large extent. This *co-ordination focused on goals and physical operations*, with decisions being made exclusively by the senior technician (with occasional consultation with the supervisory personnel). This indicated a clear and obvious leadership structure within the team.

#### **Summary**

The technicians relied heavily on verbal communication, which emphasised the diagnostic nature of the operation, requiring team problem solving and explicit problem sharing. The team boundaries were kept flexible with two members in a supervisory/support role. Leadership and team management was clearly assigned to the senior technician.

The most important factors in this teamwork event pertain to the *availability of tools and parts*. The prompt execution of the task relies heavily on such resources availability. Involvement with documentation was minimal.

* + 1. **Task 5: Integrated Drive Generator removal/installation A320**

The Integrated Drive Generator (IDG) is a part of the engine. The IDG provides a 115/200 VAC, 3-phase, 400 Hz AC supply. The inspection/check of the IDG is included in the standard weekly check in line maintenance. The removal/installation of the IDG is usually an unscheduled task. If a problem is detected, then sometimes it is necessary to replace the entire IDG. From the point of view of a work team, the removal/installation of the IDG is a non routine task. This task is both safety and efficiency critical. Normally, it takes at least 3 hours employing two or three practiced technicians.

#### **Teamwork events**

An engine team of four carried out the full IDG removal and replacement task on a A320 aircraft type. The work group is shown in action in Figure 6-8. The activity lasted eight hours. The work team *varied in membership* from time to time. Apparently, this was not perceived dysfunctional for co-ordination and task management. Team changes were dictated mostly by situational variables and operational constraints. Such variability, to a certain degree, was *expected due to the length of the operation*.

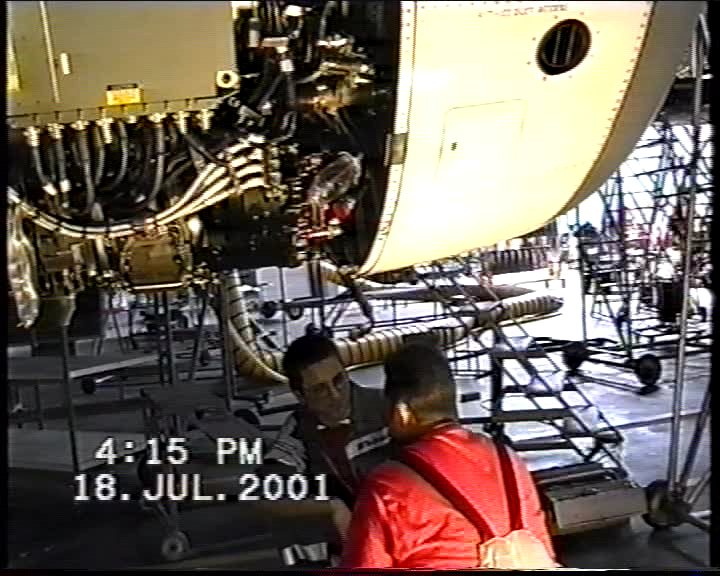
The lead technician (expert on the task) was present and in charge of the operation all the time. He performed the majority of safety critical operations with junior technicians in a support role. Easy removals or replacement of fittings, supports, or simple cables were performed individually by younger members.



Observation revealed how the team, moved physically across three different areas: tooling/stores area, engine and cockpit zones. Notably all supports (e.g., spare parts, expandable materials and equipment) were always available on demand. Most of the teamwork activity was observed in the engine zone. Informal briefing activities, as shown in Figure 6-9, were noted between various team members. This activity favoured team intervention, shared awareness, allocation of roles and task assignment.

Task co-ordination among team members was mediated by interventions of the lead technician and by the use of formal procedures. Use of aircraft maintenance manuals was prominent as the task is non routine and unscheduled.

Reliance on standard procedures by all members forced the team towards more explicit verbal communication facilitating better shared situation awareness and group decision making. Also, explicit verbal communication was always higher during critical phases of work where the procedures could not remove ambiguity in the actions to follow.



**Figure 69 - Team briefing activitiy during IDG removal/installation A320**

No operational conflict or co-ordination effort with other teams was noted. This fact, together with the adequate external supports limited the observation of potential team crises. One may wonder whether if teamwork is really a difficult *work practice* if external support performances were always performing proficiently as in this particular case. After eight hours activity, the team closed-up and disbanded.

#### **Summary**

Overall, members of this team were assigned to work together for a quite complex task, perfectly aware to disband at the close-up of the operation. This group is the most likely team configuration expected to work in an aircraft zone with a life-span membership of few hours. To note, teamwork appeared *almost effortless*. This was very likely due to a highly supporting and enabling external environment.

Behaviours in the observed team seemed to rely on a basic form of knowledge shared by the hangar environment community rather than a characteristic knowledge of the team. Also, group behaviours appeared to be highly *automatic*, *driven by situations known in operational terms,* difficult to separate in single models of “pure” communication, co-ordination, or leadership acts. It is clear that teams of this type do engage in full operational scenarios, larger than the group itself, and do not reproduce simple models of teamwork.

## **Zonal teams: common patterns of behaviour**

Some propositions emerge out of all task observations and relevant findings above. Quite clearly, zonal teams coordinate and perform their activities by *sharing expectations* on group actions, task features and work situations. Apparently, expectations are based on a socially distributed knowledge about the context and team. Team members seem all to be subject to constant forms of *adaptation* to ever changing task conditions (e.g., possible time and commercial pressure, availability of tooling and support, operation conflicts, delays, etc.). They anticipate needs for the task and teamwork accordingly. An i*mplicit co-ordination activity* allow zonal teams, under high workload, to maintain performance by relying on “implicit” co-ordination strategies, because opportunity for overt communication is restricted in such circumstances. *Capacity to predict* behaviour and needs of others is critical to all the zonal teams observed.

Also, the observed sample of hangar teams did show low/moderate teamwork efforts. Such teams, apparently, have already formed a *concept* and a stable theory about teams. To a large degree, effective team behaviour in hangar is highly *automatic* *and tacit.* Effective and efficient teams reduce teamwork activity to a minimal effort: teamwork becomes an implicit and tacit assumption across members *by practice*.

It is clear that it takes time to master such team capability and translate it into an effortless/quasi-automatic group behaviour for various team levels and configurations. Nevertheless, team skills seem to be a resource that is developed and maintained in order to work as effective social units.

Team skills in hangar are *socially developed* and evolve by commitments and requirements to perform together. This process is generated *daily* within each zonal team, across zones, for the entire project team, across projects and all external support groups. It is a tacit agreement to learn to stay in the same place and time and make an effort to work together.

However, out of all task observations it transpires that zonal teams do not *replicate* simple models of teamwork; it is instead the context that *suggests* what model of teamwork is required according to the situation: *the team does not know what teamwork is required at the beginning of the work shift*.

Finally, zonal teams in hangar maintenance have shown to be likely non-intact systems, sometimes unpredictable in the form they may assume. A certain degree of team manpower flow is evident. Team membership could vary depending on teamwork needs, operational constraints and unscheduled work peaks. Basically, task observations revealed how different zonal teams *emerged* out of formal teams allocation and task assignments.

* + 1. **Team skills isolation and decomposition**

As the real team scenarios demonstrated, many different types of teamwork skills can not be easily separated or isolated from each other without loosing their meaning. For instance, certain feedback communication behaviours may be expression of a decision making skill, which, in turn and *from a different perspective,* could be one very single aspect of a much global expression of a team co-ordination behaviour. There is no *certainty* to which teamwork skill, or combination of team capabilities, a behavioural act may actually be referring to. Different situations, or more likely the same but evolving situation, may call for the very same behaviour, but for very different changing competence demands and functions.

Therefore isolating teamwork skills by decomposing them into communication, co-ordination, co-operation or decision making competencies may appear a straightforward and reasonable *operation* in theoretical terms. Nevertheless, once such decomposition is carried out, information on the meaning and goals of the total teamwork activity may be easily lost as the context, the actual work setting, is removed from its representation.

This rationale, overall, corroborates hypotheses about *skill situations for teamwork* rather than a more comfortable view about individual skills possession. A skill has no meaning in itself and therefore a situation is required to “disambiguate” its function and role. Thus, it is the integration and combination of a diversity of behaviours with situational and operational aspects that should be modelled as teamwork elements of a team, *not* their decomposition and isolation.

* + 1. **A situational view of teamwork**

Zonal teams and their activities are embedded within a context and are situationally driven. One of the simplest and clear aspects characterising a maintenance team in hangar is the constant presence of other work groups surrounding it. The context of a hangar team is made of both several other groups working on the same aircraft or supporting it, and other full project teams working on other aircraft in the same or in other hangars.

Conceptually, findings from the five team tasks observations above, as well as survey results from previous Chapter 5 seem all to favour a *situational view of teamwork*. The emphasis is more on skills situations calling for teamwork, or more generally team situations, rather than individual characteristics, traits or abilities about teamwork.

Overall, the following interpretive model, here termed *situational teamwork,* could explain why certain task operations that suddenly and unexpectedly change in demands and conditions are dealt with by clear and viable changes in teamwork behaviors accordingly, without loss of control. This was observed in Task 5 (*Integrated Drive Generator removal/installation A320*): team behaviours were mostly driven by situations *known in operational terms* and changed, evolved, accordingly.

In particular, this concept applies to the infinite numbers of potential scenarios that could not be managed if team members would simply adapt and apply formal standard operating procedures or models of teamwork behaviors. Clearly, a form of teamwork based on situations, a situational teamwork, could be formalized further:

*The condition in which members and technologies of a team keep on recognising the existence of past, present and future teamwork demands within a series of events in a work context, and respond continuously according to those demands, is by definition a condition of situational teamwork. This concept is situational in the sense that different individuals may see and respond to different teamwork demands, but will keep on responding to the changing and evolving situations of teamwork. That will produce continuous adaptations of individal responses to other individual responses. Convergence of behaviour is expected as adaptations will reduce due to natural reduction in variability of teamwork demands and situations.*

This is at the base of the proposed situational teamwork model.

* + 1. **Team practice**

Overall, any member learns some habits of thought, behaviour and interprets the context formulating an implicit theory on teamwork: some intentions and actions are not only supposed to happen, but are expected and accepted, a *team practice* of work.

It is apparent that context and unpredictable situations are not passive elements but active and interactive elements entering completely into the team practice; the context has an active relation with participants. It is shaped and assimilated as part of the overall activity.

#### **Team practice and formal procedures**

It is assumed that the overall set of formal rules and procedures defining *acceptable* actions and modes to perform tasks cannot account for or contain all possible *acceptable* combinations of actions available to teams. Tasks and procedures will inevitably become unmanageable as they could grow exponentially as the groups increase in size or processes in complexity and combinations. In particular, rules and procedures are based on foreseen standard scenarios (standard operating situations and conditions) which are always heavy simplifications of the reality. Actual hangar operational scenarios contain an infinite number of events that any work group has to deal with by creating/inventing and evolving a much larger combination of best practices, teamwork behaviours than those ones pre-defined by rules and procedures which regulate them. As this non-designed set of behaviours become available, as learned team practices, then they *may* be used both when requirements for action are not accounted for by procedures, as well as wherever formal procedures need interpretation to apply a team behaviour.

These team practices can overcome limitations of rules and norms to account for real work situations and unforeseen working conditions. In essence, the team practice becomes the driving norm which makes sense of the collective situation.

#### **Team knowledge, practices and operational scenarios**

The team knowledge is what members of an organised work team will recognise and remember of a team practice. This condition requires at least logging some experience and activity together, that is to spend some time together to develop some memory of the events. And this was clearly the case for all the team’s task observed. It is the distributed representation comprising values, norms, beliefs and expected behaviour *with reference* *of a shared team concept.* If this concept is not explicitly attached to any particular team, then this knowledge value has no specific target but it nevertheless becomes a general and shared interpretation on what teamwork is in the context of a community of work: the hangar community.

This team knowledge is thus *practiced* and evolves over time by situated team actions. It can be described in term of different categories or domains which always reflect how collective activities respond to operational demands, which is a daily *operational scenario*, a complex but real life situation. In fact teams at any level in the hangar organisation do not simply engage in set of tasks but mange full scale scenarios, and *remember them*.

* + 1. **Formal and emergent teams**

Apparently, hangar as well as line maintenance flow of activities contain two different forms of teams: formal versus emergent teams. The former describes a team that is documented in the standard operation procedures, a formal daily job assignment. Instead, the latter form of team is generally not documented in the company schedules, operations and daily task assignments. It emerges by the temporary combination and encounter (often triggered by unexpected workload fluctuations) of different and separated individuals coming from *other* teams. For example, in the observations of Task 1 above (*Front wheel strut seal replacement A330-200*), the formal team rapidly evolved into an emergent team. Different *incoming* “experts” participated to the task assignment and thus were part of an *extended* group. Other members, moved temporarily to other work zones to provide supports elsewhere. In general, a *trace* of this emergent team activity is the additional, unplanned, quantity of man-hours reported under the rubric overheads, overtime and services.

Other emergent teams are instead the more common result of a certain flow of temporary activities which happen from time to time in the form of meetings, briefings and debriefing activities. Supervisory teams, pre-input planning teams, concerted support and service groups are frequently involved in such forms of team emergency.

Overall, emergent teams exert a relevant role in all work operations. Notably, most of team research interventions in aircraft maintenance focus on formal teams and disregard the preparation, flexible design, organisation and possible configurations for such emergent team forms.

* + 1. **Intact vs non-intact team**

Another very important property of hangar teams is about their boundaries. In a continuum, it is possible to have intact teams on the one end and non-intact teams on the other end. The latter define a continuous change of team membership. This has a specific effect on the developments of a reliable team memory and practice. Continuous change in membership may lead to more variability and flexibility in the long run. More knowledge base on the way team members interact and organise their performances. However, anticipation of individual behaviour and automatic ways of responding to each others’ inputs and outputs could be easily lost as members do not get together quite regularly. Team practices risk being too generic mechanisms. For non-intact teams such hangar work units, it would be stronger and favourable the use of standard procedures, more active, explicit and continuous monitoring and formal communication of each other’s behaviour to maintain team practices. But, such approach would be ideal for standard situations and operational scenarios, that is, normal planned situations that in hangar are almost never the case.

## **The team process model**

From a team modelling perspective it is useful to consider how to organise all the team related findings emerged (or implied) so far. Description of team events, occurrences and relation with outcomes is a necessary step towards coherent model building. In this sense, it is suggested that any team event would be associated to its outcome, or performance, by assuming the presence of a very simple model of team process:

*a team process is the joint occurrence of team practices and operational scenarios, conditions which generate a team outcome*.

The team process model can be represented by what is here called *condition tree,* shown in Figure 6-10 below. Each node in the tree-like structure is a condition necessary (but no sufficient) to obtain or generate another consequent condition until the top event (or top outcome) is obtained. The top event is the team outcome. This outcome represents a composite performance value of team practice and operational scenarios altogether.

The top event is determined by the concurrency of team practices and a real condition of work to carry out assigned tasks *accordingly*, an operational scenario. The team practice is present conditionally to the jointly occurrence of some form of team configurations (e.g., intact vs non-intact team), a *global* team behaviour (e.g., expression of an organisation of indivisible team skills) and a memory based on a socially distributed team knowledge (e.g., experiences, expectations, norms as well as attitude dispositions).

Operational scenarios for work teams represent instead the actual conditions/constraints to perform all task assignments. These scenarios are given by the embedding work process and configuration (e.g., multiple workflow process) together with all contained performances of other groups. According to previous Chapter 3, these are external performances, called *team externalities*, not directly managed or controllable by the work team under investigation. To note that the hypothesis is that team externalities in hangar maintenance have a potential strong leverage on work teams. This view is also corroborated by the survey results presented in Chapter 5.

The team process model is clearly based on a situational view of teamwork as the context (operational scenario) heavily shapes and constraints any actual team practice. Also, as any tree-like structure this model can be formalised and measured so as that the probability values at any lower nodes could determine the probability values of higher nodes towards the top event.



Team behaviours, knowledge and configurations are conditions for team practices which are represented together with operational scenarios as conditions for team outcomes. Team outcome is the representation of practices and scenarios occurring together.

* + 1. **Beyond zonal teams**

The case studies presented in this chapter focussed on one single level: assessment of internal team processes for *zonal teams*. However, as suggested in the first chapter, such level should be linked to other levels of team analysis for completeness and causal explanations. Integration between single teams throughout organisational processes is defined by the following three propositions:

1. *In aircraft maintenance, the individual team competence is a function of the context of application, that is, a complete maintenance operation. It is a highly situational competence.*
2. *The level of team and teamwork performance required into a maintenance operation is dependent on those other operators, work teams, units and contexts which make single teams dependent by the external processes*
3. *If an individual team is to be assessed then its external relationships should complete the analysis*

Specifically, the work in the next Chapter 7 and 8 addresses the issue of auditing large work processes, diagnosing co-ordination, dysfunctions and relations across work teams. The team process model presented here above will thus be reviewed as part of a wider encompassing framework of reference. This enlarged model will contain both context and motivation of organisations to conceive and deploy work teams in the system. Such wider analytic scheme can then become a useful road-map to inform *where* to locate or attribute causality about hangar maintenance work team events.

**Chapter 7**

**Interactions and co-ordination across teams**

“Co-ordination is the *expected* covariance between two or more events” (anonymous).

# **Interactions and co-ordination across teams**

When taken *singularly*, zonal, supervisory or support teams in hangar maintenance are not accountable for total operation performances as well as their individual proficiency overall. As suggested in previous chapters (e.g., from task observations to survey results) one key relevant aspect is *context dependency*, the process surrounding zonal teams and their co-ordination requirement.

The understanding of such contextual dependence is critical. For instance, comprehension of the *why* and *where* different work teams fail in performance and productivity beyond individual team members’ inefficiencies is paramount.

Overall, interaction and co-ordination dysfunctions across work groups, units and other segments in the maintenance check process are studied thoroughly in this chapter. Such team related issues are central elements to the comprehension and understanding of the organisation of multiple team performances in hangar.

## **Why co-ordination?**

As previously described in Chapter 4,maintenance teams operating live on the aircraft manage continuous exchanges of human and technical resources with the external environment, which is composed of other teams, individuals, departments or units (Endsley and Robertson, 2000). Specifically, the management of *external* inputs, the team's outputs and their *timely co-ordination* proved to be a large determinant to team performance, and group maintenance (Taylor and Christensen, 1998).

* + 1. **Need of co-ordination for hangar operations**

A generic model of hangar maintenance check operation is depicted in Figure 7-1 below. Every box is a model of individual or multiple teams. Each one of them assumes a *critical* role internally to a flow of events, the workflow of a check operation. High integration and cross-team co-ordination are then critical elements as well. They reveal the level of interdependence demanded across several teams, functions and all supports for check operations (e.g., from engineering to planning). This system requires high levels of *lateral organisation* as mechanism to control across functional boundaries and groups (Galbraith, 1994).

Actually, most of the organisational issues involving co-ordination pinpoint problems of functional/departmental integration and not just single group dysfunctions. As reported by Shepherd et al. (1991, p. 29): “W*here strong functional chains existed, communications between AMPs* [aviation maintenance personnel] *in the separate departments were often limited. Stores, shop, and toolrooms were sometimes seen, or were reported, to act unsympathetically or unsupportively to maintenance’s need for parts, components or tools*….*Separate reporting structures were usually found to create struggles for power and authority among departments (e.g., maintenance, supply, shops, and planning). Such conflicts are resolved in a variety of ways, but they usually result in one department gaining a degree of control over the other*”.

In such operational scenarios, hangar work teams performing on the aircraft as well as support groups from engineering to planning will always demand strong organisation (Taylor, 1990).



## **The analysis of co-ordination systems**

Although the presence of several critical teamwork issues in aviation maintenance is clear, integration and co-ordiantion systems do not appear as main variables in human factors and performance analysis of teams. Specifically, little research focussed on the impact of *larger systems of teams in the context of other work teams*. Focus remained too frequently on internal team variables (Baranzini et al., 2001; Taylor and Robertson, 1995).

Notably, the analysis conducted in the ADAMS 2 Project (ADAMS 2, 2004) uncovered that even when *co-ordination* between and across different teams and departments is recognised and perceived as a determinant for organisational performance, yet no specific measure or process to verify its impact is in place.

In this perspective, a methodology called Co-ordination Audit Methodology (CAM) (Baranzini and Cromie, 2002) has been developed to verify impact of co-ordination dysfunctions specific to work processes containing large cross-team interdependencies and cross-departmental relations. In particular the objective to design an instrument to audit co-ordination has been driven by the following propositions:

1. The analysis of maintenance activities and their organisation can be considered as a problem of systems of teams/groups in reciprocal interaction. This interaction should be efficient/effective and should be co-ordinated and monitored over time.
2. The auditing of co-ordination and its mechanisms within and between teams or larger work groups can be considered an activity to *prevent*, *detect* or *recover* from dysfunctions of the organisational system, which may be endangering system performance efficiency, productivity and safety.
3. Audits and diagnoses of co-ordination systems have not been fully considered nor envisaged as organisational technologies or planned interventions even though *human factors research and investigations in maintenance environments often highlight co-ordination and communication deficiencies*.

﻿ The following sections will describe the new co-ordination audit. First, a model of co-ordination, underlying CAM, is proposed together with the concept of co-ordination dysfunctions and relative estimated impact on performance. Finally, two case studies on a CAM application conducted in two different European maintenance companies will be presented and the results commented upon.

* + 1. **A model of team co-ordination**

Co-ordination systems are present in any business containing some form of division of labour and their functions in complex work settings is unquestionably a key factor in organisational control and performance (Galbraith, 1994). A key aspect to address the problem of co-ordination is to identify a model, but firstly having an operational definition of co-ordination is necessary. The following is given:

*Co-ordination as a property* designates the presence effective interactions*. Co-ordination as a process* is the activity directed to maintain those interactionsavailable: timed, sequenced and reliable. Overall, co-ordination can be referred to as the probability that an interaction is reliable, dependable and available under specified conditions and operating time. It is the capacity to maintain an *expected* interaction.

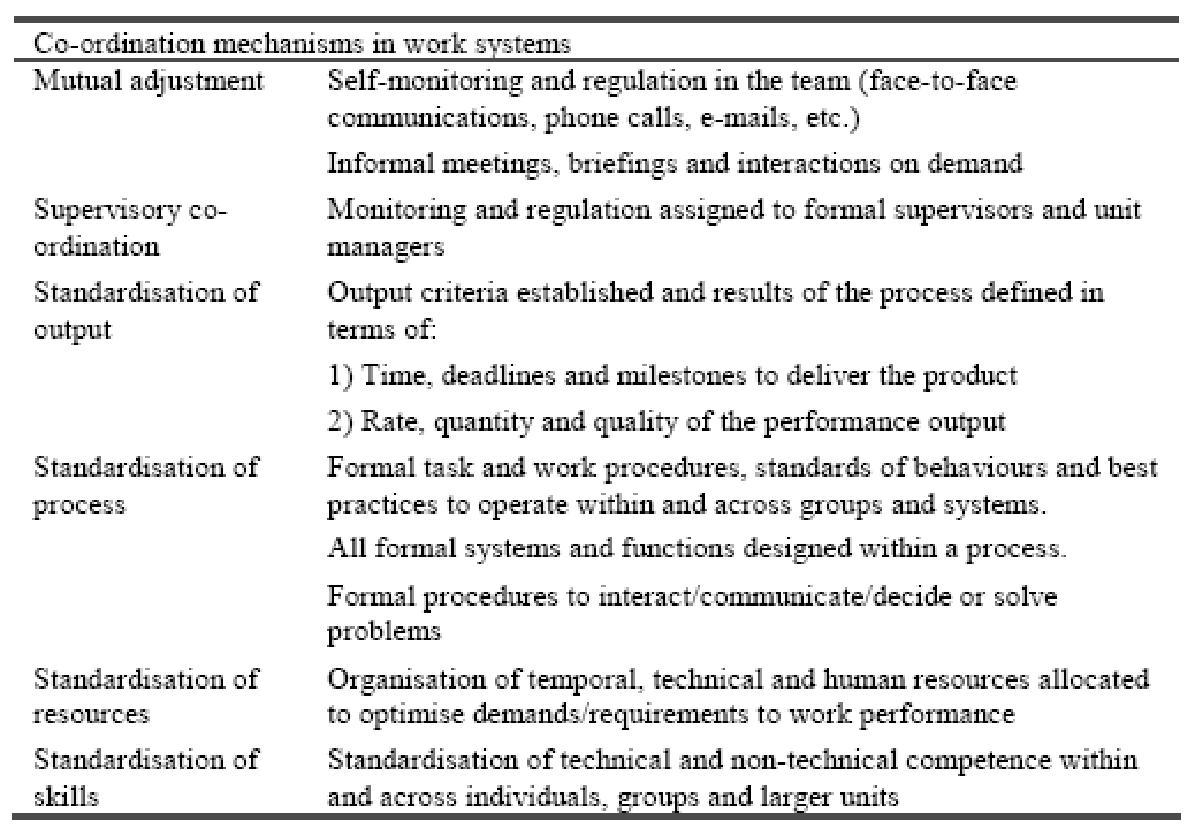
Most of the literature discussing the problem of *co-ordination as a process* refers toa number of *co-ordination mechanisms,* by which the interactions across groups willbe timed, sequenced and calibrated (Galbraith, 1977; Mintzberg, 1993). A summary of these key co-ordination mechanisms is reported in Table 7-1.

The mechanisms of *Mutual adjustment* and *Supervisory co-ordination* are all human activities to monitor/assess and control/regulate behaviours of interacting work groups. In Mutual adjustment the control of co-ordination is left *within* the group. In Supervisory co-ordination, on the contrary, the monitoring and regulating functions are delegated to an *external agent*, generally a supervisor or team leader. This mechanism is often applied whenever the resources to monitor and regulate a number of teams/groups exceed each individual team/group’s capacity and resources.

*Standardisation of output, process, resources*, and *skills* are four other types of co-ordination mechanisms which refer to built-in solutions to keep the intra- and cross-group relationships timed, sequenced and well organised by the application of procedural and operational standards. These co-ordination mechanisms are built into the task/workflow. Co-ordination is “embedded” in the tasks across groups. Such mechanisms may be favourable when supervision costs or quantity of teams and groups within a workflow is too large to be effectively co-ordinated by managers, supervisors or by the groups themselves.

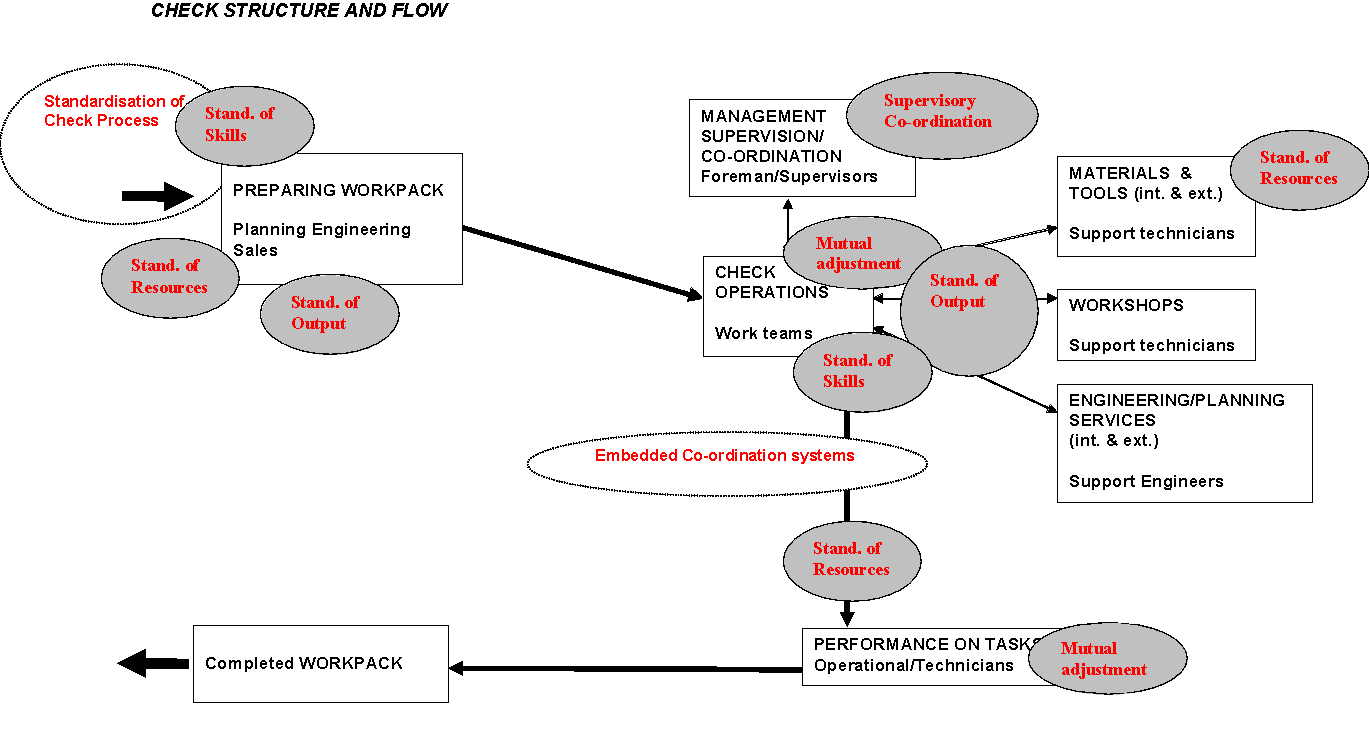
Overall, mapping co-ordination mechanisms in a work process can provide a clear roadmap to understand what actual co-ordination system is in place for multiple work teams. Ultimately, this could lead to more tailored and finer-grained interventions on what might be changed or improved if certain co-ordination dysfunctions may occur in the system. An example of co-ordination map for maintenance check operations is reported in Figure 7-2 (the complete analysis is reported in Annex 7B).

**Table 71 - General co-ordiantion mechanisms (source: Baranzini and Cacciabue, 2006)**



* + 1. **Co-ordination dysfunctions**

Any effect of a disrupted co-ordination mechanism is a co-ordination dysfunction identifiable as a teamwork and task-work interaction failure. Likely, the consequence of such co-ordination dysfunctions could then result in estimable technical performance failures. A set of *co-ordination dysfunctions* representing such specific dysfunctional behaviour in teamwork and task-work interactions has been developed in the CAM application (see list of CAM co-ordination dysfunctions in Annex 7A).



**Figure 72 - Co-ordination mechanisms mapped onto a check maintenance process in hangar**

Examples of co-ordination dysfunctions are:

* It is difficult to assess and control the activities across crews allocated to different zones
* We frequently wait for too long periods before receiving the input to run smoothly our activity
* It is difficult to maintain effective interaction/exchange of task activities within or across teams
* We frequently lack sufficient manpower to work together proficiently
* During our crew activity, it seems we do not share standard practices to work together and co-ordinate activities

The frequency or criticality of such co-ordination dysfunctions can be tested or observed in actual hangar operations. Mostly important, their relation with certain co-ordination structures may be verified accordingly. For instance, a co-ordination dysfunction identified as *lack of proper manpower* (fourth bullet above) could lead to further investigations on what main underlying *co-ordination mechanism* was supposed to regulate manpower allocation. This could be identified in certain functions of supervisory co-ordination. Such a finding could then lead to more tailored interventions on *who* and *what* is involved in supervisory co-ordination without affecting or altering the structure of other co-ordination structures.

* + 1. **Impact of *co-ordination dysfunctions***

Together with a finer-grained model of dysfunctions, the analysis of what is the technical impact of such dysfunctions is paramount. That is, the analysis of co-ordination dysfunctions should be considered in relation to technical performance levels: *within a work system, no co-ordination dysfunction is operationally relevant if its impact on the performance of that system is not estimable*.

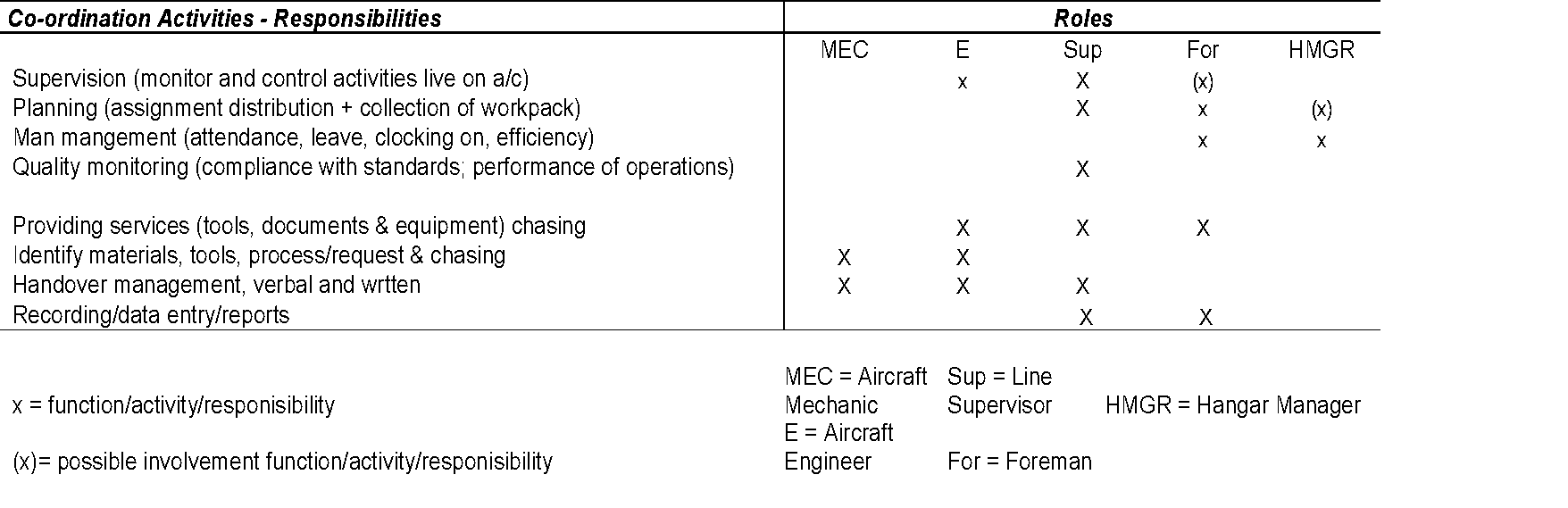
It is assumed that co-ordination dysfunctions need a reference in technical terms in order to be considered critical or relevant. That is, any co-ordination dysfunction generating a technical performance failure is more likely to be subject to verification (audit) because it has actual business performance effects as well as teamwork and human factors implications. Examples of generic performance failures that might be the result of co-ordination dysfunctions are reported below:

* Task delays
* Task repetitions
* Re-works

However, if one could reliably assess a relation between co-ordination dysfunctions and performance effects, the problem of quantifying its actual cost still remains a modelling problem. In fact, empirical data are not easily available on the actual *dimensions* or *importance* of such performance failures such as task delays, interruptions, backlogs, etc: there are frequently no empirical data on the type and real costs of such operational inefficiencies, and this, indirectly, may lead to under-specify the actual impact of co-ordination on technical performance.

In this perspective, a different approach can be applied to avoid such “methodological barrier”. This is done by estimating the effectiveness and efficiency of those operational activities, which are *instantiations* of co-ordination mechanisms assigned to human operators. An example of co-ordination activities for hangar teamwork is shown in Table 7-2.

**Table 72 - Example of co-ordination activities allocated to different job roles (source: Baranzini and Cacciabue, 2006)**



Notably, the information about these different co-ordination activities can then be analysed in terms of *time resources* spent on each activity to operate effectively.

* + 1. **The *Co-ordination Index***

At this stage, given that it is possible to measure an average time spent on specific co-ordination behaviours as described in Table 7-2, then an estimation procedure can be applied to quantify *the ineffective time spent* by the human operators in performing co-ordination activities, which fail to prevent co-ordination dysfunctions to happen.

This conceptual model is based on the following rationale applicable to any work system based on human operators allocated to specified co-ordinative activities:

a. The operators’ daily time (m/hrs) is spent on different activities. Some of these activities *are* *instantiations* of co-ordination mechanisms (i.e., supervision, handover management) supposed to prevent co-ordination dysfunctions to happen.

b. Following on from this, the occurrence of a performance failure (i.e., task delay) *accounted for* by the presence of a co-ordination dysfunction will represent an *ineffective use* of the time allocated to those co-ordination activities supposed to prevent such co-ordination dysfunction to occur: a cost of m/hrs ineffectively spent.

From this set of assumptions, it is possible to formulate a mathematical proportion in order to quantify the daily work time spent *ineffectively* by those operators dealing with a set of co-ordination tasks that are supposed to prevent the presence of co-ordination dysfunctions. This proportion is the *Co-ordination Index*:

*Effective Co-ordination Time : Ideal Performance*

*=*

*Ineffective Co-ordination Time : Residual Performance Failure*

Where,

*Effective Co-ordination Time* = total daily time spent on a set of co-ordination activities expected to prevent co-ordination dysfunctions to occur

*Ideal Performance* = 100% successful prevention of co-ordination dysfunctions that could lead to performance failures

*Ineffective Co-ordination Time* = proportion of the total daily time spent on a set of co-ordination activities that results ineffectively spent

*Residual Performance Failure* = % of performance failures caused by co-ordination dysfunctions unsuccessfully prevented

The *Co-ordination Index* defines that the time spent on a co-ordination activity is dedicated to prevent the occurrence of a certain co-ordination dysfunction that, in turn, may cause a performance failure to happen. Therefore, the presence of that co-ordination dysfunction represents an *ineffective use of the time spent on co-ordination*.

The *Co-ordination Index* can then be calculated as follows:



In particular, the index defines that if an operator spends a certain amount of time on some co-ordination activities (i.e., supervision) and these activities fail on what they are supposed to accomplish in that timeframe (prevention of co-ordination dysfunctions), then it is possible to say that the operator is *not effective* in the time allocated to operate such activities.

The index does not verify if the operator was competent or proficient in that set of co-ordination activities but simply that within that overall timeframe there was a certain amount of ineffective time spent. The operator *probably* needs better capacity in the timeframe allocated to perform such functions or, on the opposite he/she may require additional time in order to perform more effectively.

## **CAM application in two maintenance companies**

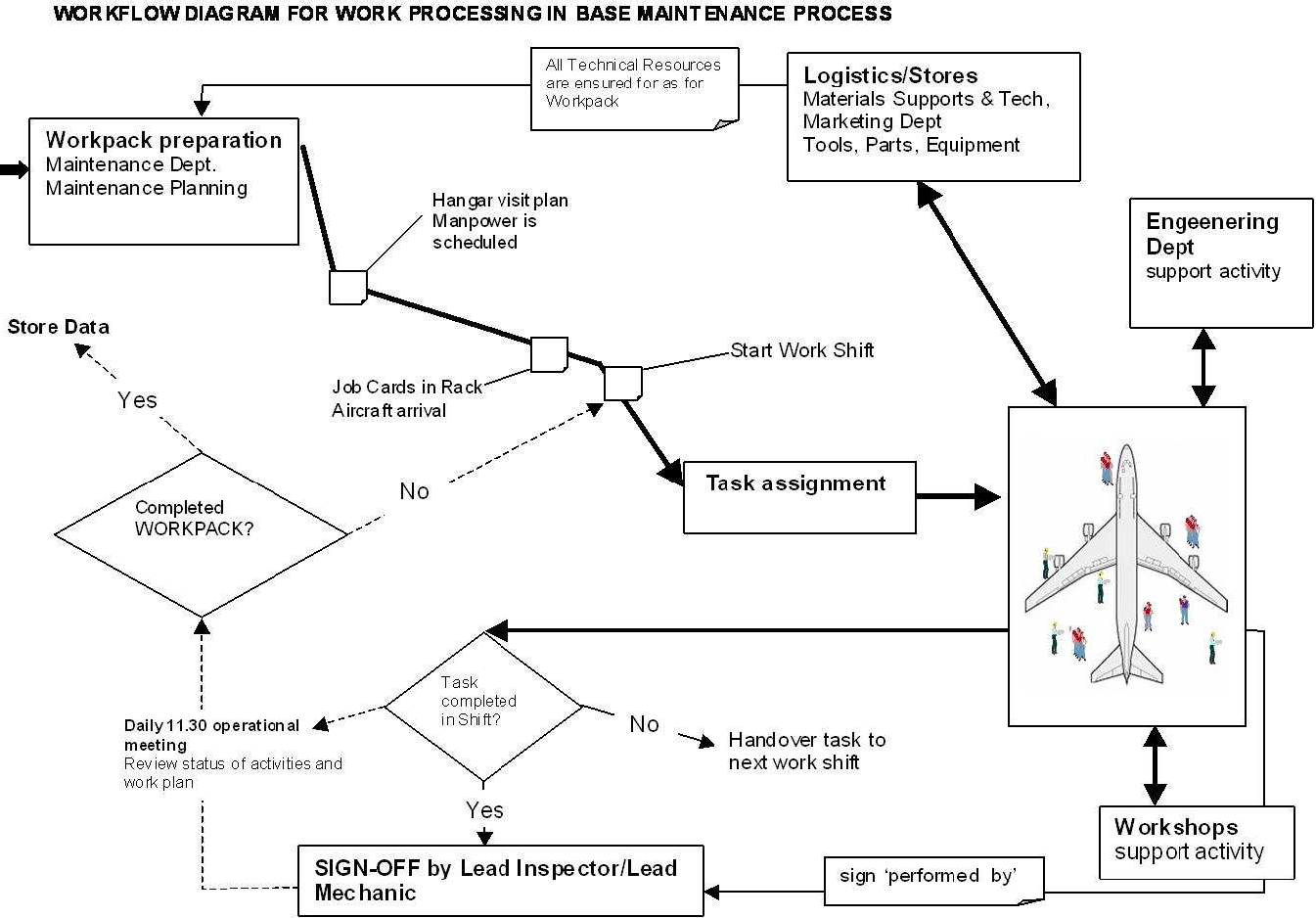
Two European maintenance companies, here called company A and B, participated in the analysis of their internal co-ordination systems between 2003 and 2004 (ADAMS 2, 2004). The framework of reference for the overall investigation was the application of the CAM methodology. The audit method was fully based on the models described in the previous sections above. The results of the CAM application presented here focus on:

a. Selection of the *target*

b. Identification of *co-ordination dysfunctions*

c. Quantification of impact of *co-ordination dysfunctions*

The maintenance check process in hangar operations was the selected target for the CAM audit in both companies. In both cases it was further decided to focus directly on the co-ordination systems acting upon the work teams performing the maintenance tasks on the aircraft. The workflow description of the selected check maintenance process is reported in Figure 7-3.



**Figure 73 - Maintenance check process selected for the CAM audit (source: Baranzini and Cacciabue, 2006)**

The application of formal checklists, called CAM checklists (see Annex 7A), provided the analysis of relevant co-ordination dysfunctions as well as their major concentration and impact in the process. In total, 18 CAM checklists out of 25 and 20 out of 26 were collected successfully in company A and B respectively. The overall samples of participants, 18 and 20 from company A and B respectively, were composed by team supervisors, technicians and support staff.

The overall results are shown in Table 7-3 and 7-4 for the two companies respectively. The results provided a differentiation both for 1) types of co-ordination dysfunctions detected and areas where such dysfunctions were mostly concentrated (first column of Table 7-3 and 7-4), and 2) the % of technical performance failures associated with the co-ordination dysfunctions (second column in Table 7-3 and 7-4).

**Table 73 - Company A (source: Baranzini and Cacciabue, 2006)**

| **Company A** | **Daily Performance failures due to Co-ordination Dysfunctions** (estimated daily % occurrence averaged across Co-ordination Dysfunction/s) | | | |
| --- | --- | --- | --- | --- |
| Daily Co-ordination Dysfunctions  (Average>=3; 3= daily frequent) | Task Delays | Task interruptions | Overtime  (not planned) | % Overspent resources  (bgt, m/p, service) |
| *1st Work Condition*  1\_It is difficult to monitor the status of other individuals or group activities  5\_It is difficult to maintain effective interaction/exchange of task activities within or across teams  10\_There is poor integration and teamwork across crew members | 13.7% | n/a | n/a | n/a |

*1st Work Condition:* Team members completion of Task Cards (at end of check, within and across zones, managing complex rectifications)

**Table 74 - Company B (source: Baranzini and Cacciabue, 2006)**

| **Company B** | **Daily Performance failures due to Co-ordination Dysfunctions** (estimated daily % occurrence averaged across Co-ordination Dysfunction/s) | | | |
| --- | --- | --- | --- | --- |
| Daily Co-ordination Dysfunctions  (Average>=3; 3= daily frequent) | Operation/Task Delays | Unexpected rework (i.e., perform a repair twice) | Unexpected re-assignment of work | Additional Overtime |
| *1st Work Condition*  1. It is difficult/problematic to monitor the status of other individuals or group activities  3. When 'we' (my team) can start/continue the activity we are delayed by other work units or teams  13. Man/power resources are poor/inadequate within or across groups  17. There are poor/inefficient standard work practices to work together and mange shared activities  *2nd Work Condition*  2. It is difficult/problematic to promptly adapt our team's tasks and operations to unexpected events | 25% | 25% | 17.5% | 27.5% |

*1st Work Condition:* Interactions within/between WORK TEAMS

*2nd Work Condition:* Interactions between WORK TEAMS and Engineering

The first indicator (i.e., Daily Co-ordination Dysfunction) was measured by the CAM checklist and it represents the averaged most frequent co-ordination dysfunctions occurring daily according to the samples of respondents in the two companies. The second indicator (i.e., Daily Performance failures due to Co-ordination Dysfunctions)was rated by sub-samples of 12 respondents within each company’s sample respectively. The sub-samples of respondents were asked to estimate the actual daily % of technical failures (i.e., Task delays) caused by the most frequent co-ordination dysfunctions as previously rated in the CAM checklist (Note: in Table 7-3 and 7-4 the % of technical (performance) failures were averaged across co-ordination dysfunctions).

Clearly both companies suffer from the presence of a number of different co-ordination dysfunctions. Mostly, they appear at task operation levels within and between operational teams.

Furthermore, results per each company revealed how such dysfunctions together were associated to an estimated daily % occurrence of generic performance failures (i.e., task delays, interruptions, rework, etc.). Overall, the CAM application differentiated between companies in terms of presence of dysfunctions, location and estimated technical performance impact.

* + 1. **Quantification of impact of co-ordination dysfunctions**

The data above on the estimated effect on performance (e.g., task delays) were then used to measure the *Co-ordination Index*. This was calculated separately for each daily % of performance failure together with a measure of the daily average time spent within a work team on a chosen set of co-ordination activities.

The result of the *Co-ordination Index* is the proportion of daily m/hrs lost, ineffectively used, over the total m/hrs spent on the set of co-ordination activities. The overall results are reported in Table 7-5 for company A and Table 7-6 for company B.

For both Table 7-5 and 7-6 the first column shows a set of co-ordination activities and a daily average time spent per co-ordination activity as estimated by samples of 23 and 35 zonal/supervisory team leads in company A and B separately. The second column shows the set of co-ordination dysfunctions causing specific performance failures. These are reported in the third column. Finally, the fourth column provides the computation of the *Co-ordination Index*.

**Table 75 - Estimated *Co-ordination Index* for company A (source: Baranzini and Cacciabue, 2006)**

| **Co-ordination activity**  (averaged daily m/hrs spent x Work Team) | **Co-ordination Dysfunction**  (in 1st Work Condition)\* | **Performance failure**  (daily % occurrence caused by critical Co-ordination Dysfunction/s) | ***Co-ordination Index***  (M/hrs lost due to Co-ordination Dysfunctions) |
| --- | --- | --- | --- |
| 1. Supervision (120 min.) 2. Planning (60 min.) 3. Handover management (20 min.) 4. Recording/data entry/reports (30 min.)   daily time spent: 230 min. (in 8-hrs shift) | *1st Work Condition*  1\_It is difficult to monitor the status of other individuals or group activities  5\_It is difficult to maintain effective interaction/exchange of task activities within or across teams  10\_There is poor integration and  teamwork across crew members | 13.7% Task Delays | | 230 X 13.7 | = 31 min | | --- | --- | | 100\*\* | |

\* 1st Work Condition: Team members completion of Task Cards (end of check, within/across zones, managing complex rectifications)

\*\* 100% effectiveness is assumed on the total time spent daily on the Co-ordination activities

**Table 76 - Estimated *Co-ordination Index* for company B (source: Baranzini and Cacciabue, 2006)**

| **Co-ordination activity**  (averaged daily m/hrs spent x Work Team) | **Co-ordination Dysfunction**  (in 1st/2nd Work Conditions)\* | **Performance failure**  (daily % occurrence caused by critical Co-ordination Dysfunction/s) | ***Co-ordination Index***  (M/hrs lost due to Co-ordination Dysfunctions) |
| --- | --- | --- | --- |
| 1. Man/power planning and control (20 min.) 2. Man Management (35 min.) 3. Supervision (80 min.) 4. Planning (30 min.) 5. Providing services (60 min.) 6. Identify materials, tools (30 min.) 7. Follow up of materials & services (30 min.) 8. Handover management (30 min.) 9. Recording, data entry, reports (30 min.)   daily time spent: 345 min. (in 8-hrs shift) | *1st Work Condition*  1. It is difficult/problematic to monitor the status of other individuals or group activities  3. When 'we' (my team) can start/continue the activity we are delayed by other work units or teams  13. Man/power resources are poor/inadequate within or across groups  17. There are poor/inefficient standard work practices to work together and mange shared activities  *2nd Work Condition*  2. It is difficult/problematic to promptly adapt our team's tasks and operations to unexpected events | 25% Operation/Task Delays | | 345 X 25 | = 86 min | | --- | --- | | 100\*\* | |
| 25% Unexpected rework (i.e., perform a repair twice) | | 345 X 25 | = 86 min | | --- | --- | | 100 | |
| 17.5% Unexpected re-assignment of work | | 345 X 17.5 | = 60 min | | --- | --- | | 100 | |
| 27.5% Additional Overtime | | 345 X 27.5 | = 94 min | | --- | --- | | 100 |   **Total Average Time lost:**  **81 min** |

\* 1st Work Condition: Interactions within/between WORK TEAMS

2nd Work Condition: Interactions between WORK TEAMS and Engineering during the Check operations

\*\* 100% effectiveness is assumed on the total time spent daily on the Co-ordination activities

Looking at the overall results, it is clear that the failure to control the occurrence of specific co-ordination dysfunctions and their associated performance impact has a cost, in m/hrs.

The work teams in both companies are wasting some relevant working time during their daily maintenance operations. Overall, the average daily m/hrs lost by a single work team in company A is of 31 minutes and of 1 hour and 21 minutes for company B. In both cases, the inability to prevent co-ordination discrepancies does have a quantifiable cost. This cost is associated to the weakness of the co-ordination systems in place in both organisations.

* + 1. **Interaction deficiencies behind co-ordination dysfunctions**

The level of efficiency/effectiveness of the *interactions* across different teams is considered a direct determinant of the identified co-ordination dysfunctions. The interaction deficiencies of company A are reported here below.

In particular, the term *interaction* refers either to the process of communication (exchange of information) or to the activities of teamwork to *perform* an operation, or to *co-ordinate* that operation.

In the present case study the potential *problems of interaction* across Crew mangers (CrMs), Aircraft Engineers (AEs) and Aircraft Maintenace Engineers (AMEs) have been assessed focussing on certain operations of a check process containing the following critical co-ordination dysfunctions (see Table 7-3 above):

1. Difficult monitoring of individual/zonal team activities (e.g., within and across zones, end of check, across trades)
2. Difficult exchange of task activities within and across zonal teams (sequencing activities, multi-trade/multi-zone task activities)
3. Poor integration/teamwork across crew members (preferential one-to-one informal communication, and poor team orientation with new and/or external trades)

In general, these three main co-ordination dysfunctions seem to be associated to a number of interaction deficiencies as reported in Table 7-7. This table represents and contains the narrative structure useful to identify maintenance team conflicts.

The overall set of behaviours representing those interaction deficiencies (third column of Table 7-7) have been documented by different sources of information (last column) during the overall CAM application in company A, in particular:

1. CAM checklist (Annex 7-A, section on the *possible causes*)
2. Structured observations and notes taken during real check operations
3. Interviews conducted over the entire period of investigation (20 work days)
4. Technical documents managed during all check activities

The interactions deficiencies addressed show a number of commonalities which deserve careful attention. In particular, the interaction deficiencies all together, and independently by the specific co-ordination problems which they refer to, seem to represent a pattern of common *characteristics or factors present in the actual team structure*. These commonalities are reported in Table 7-8.

Overall, the nine major characteristics reported in Table 7-8 should all be considered as a complex of interlinked elements, and could not be simply separated and treated as independent aspects. But certainly, these characteristics shape the way the relationships, interactions and roles across the grades are managed. This means that the interaction deficiencies can be described, but should be carefully interpreted in the light of such characteristics actually present into the team structure. Also, the interaction deficiencies reported in Table 7-7 have been uncovered in a number of actual behaviours and operational practices that can be considered as true informal norms to operate at the individual as well as team level which, to a certain degree, would be replacing standard operation procedures.

Evidently, some of these behaviours can be *interpreted* as deviations from operational best practices (as defined by the organisation) based on *shared* working styles, dispositions, or habits, generally considered in applied human factors research as highly resistant to change. This becomes especially true when the following variables are consolidated or crystallised into normal behaviour in hangar:

1. The request to follow formal procedures or practices are given, but these procedures were never tested enough to assess and verify their viability and reliability
2. There is a growing number of older and more experienced personnel, independently of the grade or role, which are highly valued but not monitored: the attitude “*they-know-how-to-do-it-at-best”* is unchallenged
3. There is a quantity of operational but informal practices and formal procedures with a long history which were never monitored over time
4. The core group operating in line (zonal teams) is functionally and operationally separated by the support and managerial units (large scale organisations)
5. The introduction of solutions or changes in the company are not communicated or discussed extensively before their implementation

Overall, a hypothesised issue is emerging beyond interaction and co-ordination problems (especially beyond zonal team levels of analysis): the interaction deficiencies identified can be partially considered as a *by-product* of negative boundary conditions of work and limiting organisational/contextual factors; there is a *true pervasive influence of upstream processes*.

Apparently this involves a need for highly flexible work systems. As one zonal team supervisor of company A stated: *supervisors and technicians may consider that the non-application of standard practices to work together and co-ordinate activities is an asset for the company, not a weakness: the flexibility, and high interdependency across most of the trades, grades and job roles require flexible standards and adaptable procedures in order to balance performance targets and the cost of a check; agile systems are needed* (team supervisor from company A, 2003, pers. comm., 18 July).

**Table 77 - Co-ordiantion dysfunction and interactions deficiencies in company A**

| **Area of Check** | **Critical Co-ordination dysfunction** | **Interactions deficiencies across CrMs-Aes-AMEs**  legenda:  CrMs-AEs = CrMs interact with AEs  CrMs-(AEs, AMEs) = CrMs interact with both Aes and AMEs  CrMs-AEs-AMEs= reciprocal interaction across all Grades  CrMs or AEs or AMEs = role/responsibility aspects per individual Grade | **Source** |
| --- | --- | --- | --- |
|
| Team members completion of Task Cards:   1. During end of Check (across trades, Avio and others, function tests) 2. Within and across zones 3. Managing AOGs, MODs, 4. Managing complex Rectifications | 1\_It is difficult to monitor the status of other individuals or group activities | *AMEs*  The AMEs signing ‘done by’ on a task card does not necessarily mean that he/she performed that task. This event can be due to time or commercial pressure on CrMs to clear the task cards. However, this events reveal an insufficient monitoring and supervision of the activity accomplished, as well the person involved.  *CrMs-(AEs, AMEs)*  Supervisory competence and behaviours are not standardised. This reflects a different and individual way by CrMs to receive or gather information from AEs and AMEs: Different CrMs monitor AEs and AMEs activities differently.  *CrMs-CrMs*  The 8.30 meeting may be manged to know share information on what has been done so far and less on what is actually needed or critical: the focus on Customers risks to reduce time to solve actual problems across CrMs  *CrMs-CrMs*  There is at least one hangar (H1) where CrMs do not have formal communications to team briefing and debriefing at the beginning of early shifts.  *AEs-CrMs*  An estimated small proportion of AEs do not used to sign-off their own Task Cards or others’ Task Cards even when required so.  *CrMs-AEs-CrMs*  CrMs and AEs monitor the status of activities considering their own zones implications. There is less communication to manage them together. The priorities are different at the end of Check: conflicts on who has priorities are always managed reactively. | CAM/  Interviews    CAM/  Interviews  Observations/  Interviews  Interviews  Interviews  Interviews/  CAM/  Observations |
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**(Table 7-7 cont.)**

| **Area of Check** | **Critical Co-ordination dysfunction** | **Interactions deficiencies across CrMs-Aes-AMEs**  legenda:  CrMs-AEs = CrMs interact with AEs  CrMs-(AEs, AMEs) = CrMs interact with both Aes and AMEs  CrMs-AEs-AMEs= reciprocal interaction across all Grades  CrMs or AEs or AMEs = role/responsibility aspects per individual Grade | **Source** |
| --- | --- | --- | --- |
|
|  |  | *CrM-AEs-AMEs*  There are not standard shared practices to supervision and monitoring (by CrMs) of AEs and AMEs task activities and problems    *CrMs-AEs*  CrMs and AEs rely on informal communication to daily (routine non routine) operations  to maintain co-ordination: this informality fix contingent problems but risks to go undetected by other CrMs or entire teams  *CrMs-(AEs, AMEs)*  Monitoring by CrMs can be ineffective before and during 8.30 meeting (30/45 min of lack of supervision on tasks live on a/c) . This is also because CrMs AEs and AMEs do not have any formal team briefing at the beginning of shift: all is driven by reading Task Cards or informal discussion on demand. | Interviews    Observations  Observations/  Interviews |
|
|  |

**(Table 7-7 cont.)**

| **Area of Check** | **Critical Co-ordination dysfunction** | **Interactions deficiencies across CrMs-Aes-AMEs**  legenda:  CrMs-AEs = CrMs interact with AEs/AMEs  CrMs-(AEs, AMEs) = CrMs interact with both AEs and AMEs  CrMs-AEs-AMEs= reciprocal interaction across all Grades  CrMs or AEs or AMEs = role/responsibility aspects per individual Grade | **Source** |
| --- | --- | --- | --- |
|
| Team members completion of Task Cards:   1. During end of Check (across trades, Avio and others, function tests) 2. Within and across zones 3. Managing AOGs, MODs, 4. Managing complex Rectifications | 5\_It is difficult to maintain effective interaction/exchange of task activities within or across teams | *CrMs or AEs*  CrMs considers Visaer not user friendly: it requires too much time to enter or retrieve  data. The actual problem is the speed to entering and retrieving data  *CrMs-CrMs*  The format of 8.30 meeting and information sharing across CrMs can be improved to reduce time of meeting and meeting efficiency  *CrMs-AEs*  Manpower is not always planned adequately: understaffed zones (AEs or AMEs) will cause longer delays to Complete Tasks and force CrMs to move from Supervisory role to operation role: this will increment the capability to moitor asses operations.  *AEs-AEs or AMEs-AMEs*  During the completion of tasks requiring more than a shift, the handover of tasks is not detailed enough without a formal debriefing between the outgoing and incoming AEs or AMEs. This seems to happen also for reassignments and re-allocation of personnel across bays on the same shift due to unavailable personnel or trades required elsewhere. The same type of problem can appear also for multi-trade or multi-zone task cards operations.  *CrMs-(AEs, AMEs)*  AEs and AMEs do not consistently clock to task cards. This could endanger the efficiency  of CrMs to assess and control the exchanges between task activities accurately and  operations within and across teams.  *CrMs or AEs*  The CrMs and the AEs manage paperwork (task cards) not consistently: entering  information, returning and distribution seems not to follow a standard. This leads to  difficulties to track progress of activities and task cards assignments to new incoming  personnel. | Interviews/ Observations  Observation/  Interviews  Observations  CAM  CAM  CAM/  Interviews |
|  |  |
|
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|

**(Table 7-7 cont.)**

| **Area of Check** | **Critical Co-ordination dysfunction** | **Interactions deficiencies across CrMs-Aes-AMEs**  legenda:  CrMs-AEs = CrMs interact with AEs  CrMs-(AEs, AMEs) = CrMs interact with both Aes and AMEs  CrMs-AEs-AMEs= reciprocal interaction across all Grades  CrMs or AEs or AMEs = role/responsibility aspects per individual Grade | **Source** |
| --- | --- | --- | --- |
|
|  |  | *CrMs-CrMs-AEs-AMEs*  Even though not frequent, the lack of communication across CrMs can cause rework for AMEs: removing/fitting twice panels because of AEs-avio requires an activity and AMEs were not informed.  *AEs*  A part of AEs could feel free to decide what/when to operate specific job assignments, especially when the experience/age of AEs respect to that of CrMs is inversely related: this will generally endanger shift activities or between-shifts exchanges of operations | CAM    Interviews/  CAM |
|  |
|  |  |

**(Table 7-7 cont.)**

| **Area of Check** | **Critical Co-ordination dysfunction** | **Interactions deficiencies across CrMs-Aes-AMEs**  legenda:  CrMs-AEs = CrMs interact with AEs  CrMs-(AEs, AMEs) = CrMs interact with both Aes and AMEs  CrMs-AEs-AMEs= reciprocal interaction across all Grades  CrMs or AEs or AMEs = role/responsibility aspects per individual Grade | **Source** |
| --- | --- | --- | --- |
|
|  |  | *CrMs-CrMs between two early shifts*  The shift handover across CrMs is is generally not based on formal meetings: CrMs do not frequently discuss during the overlapping time across shifts  *CrMs-(AEs, AMEs)*  CrMs and AEs and AMEs can be ineffective to organise across a/c zones or during task re-allocation: information/decision can be easily lost because it is frequently shared between personnel on an informal basis of exchange: other units or new/incoming AMEs, AEs or even CrMs could be misguided and unaware or could loose time to understand what to do and logic  *CrMs-(AEs, AMEs)*  The time spent by CrMs to monitor activities intensifies when the AEs or AMEs come from other groups or are contractors because of the lack of knowledge and confidence on skill levels of new personnel. The level of trust or confidence should be re-established to an optimal level, but requires time which could not be available especially when new personnel is present for short tasks operations.  *CrMs-AEs-AMEs*  The nature of teamwork within and across zones is based more on interpersonal relations and knowledge than on task-requirements: this, in turn may create resistance to work area movements and reallocation to new teams when required. Also, the level of collaboration and co-operation across different groups or different trades is based on interpersonal relationships and knowledge.  *AEs-AMEs*  The way to interact across AEs and AMEs is informal communication and informal leadership. Notably, the AEs play a relevant role acting as link between the first level of line management (CrMs) and the workforce (AMEs). It is apparent that the more experienced and older AEs do not follow or do not have any specific standard to interact with AMEs. In the context of regulations and role responsibilities it is clear that enforcing AEs group to monitor and become responsible of others work activities do not follow neither training nor guidance on how to accomplish such a role. | Observations  Observations/  CAM      Observations/  Interviews  Observations/  Interviews    Interviews/  Observations |
| Team members completion of Task Cards:   1. During end of Check (across trades, Avio and others, function tests) 2. Within and across zones 3. Managing AOGs, MODs, 4. Managing complex Rectifications | 10\_There is poor integration and teamwork across crew members |
|  |  |
|  |  |
|  |  |
|  |  |

**(Table 7-7 cont.)**

| **Area of Check** | **Critical Co-ordination dysfunction** | **Interactions deficiencies across CrMs-Aes-AMEs**  legenda:  CrMs-AEs = CrMs interact with AEs  CrMs-(AEs, AMEs) = CrMs interact with both Aes and AMEs  CrMs-AEs-AMEs= reciprocal interaction across all Grades  CrMs or AEs or AMEs = role/responsibility aspects per individual Grade | **Source** |
| --- | --- | --- | --- |
|
|  |  | *CrMs-AEs-AMEs*  The interactions between CrMs, AEs and AMEs (generally mediated across CrMs) across zones provides information on what task activity will affect which team but the communication do not provide information on each other priorities, objectives and procedures: this limited exchange of information cannot provide effective teamwork and co-operation across zones live on a/c.  *AEs-AMEs*  Task interruptions for unexpected events (additional interfering task) and for tasks requiring the handover to another shift may require high and effective communication and information exchange across AEs and AMEs. This communication is filtered across CrMs which are not always prepared to manage effective team briefing and debriefing across the incoming and outgoing AEs and AMEs | CAM    Observations/  Interviews |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

**Table 78 - Common interaction characteristics and key factors present in hangar teams - CAM application in company A**

| 1. *Informal* ways to communicate, adjust and gather team situation awareness to control activities |
| --- |
| 1. *Personal* ways to manage communication in team replacing a *known* or an *unknown* operational standard |
| 1. *Level of knowledge* and mutual confidence/trust across the grades |
| 1. *Experience* and previous job *background* of the individual grade |
| 1. *Different* interpretation between teams of standard work practices |
| 1. *Information sharing* across personnel re-assigned or re-allocated |
| 1. *Role ambiguity* between expert or experienced maintenance engineers and maintenance team leaders |
| 1. *Ownership-*based teamwork instead of *Task-based* teamwork |
| 1. *Variability of* Team composition and membership |

* + 1. **Which co-ordinations mechanisms are most preferred?**

Out of data collection and in-field observations in company A the following co-ordination mechanisms can be considered the most likely ones employed for hangar check operations.

Overall, the two co-ordination mechanisms stand out:

* *Supervisory co-ordination* and *mutual adjustment* are the key co-ordination mechanisms driving most team operations. Standard processes, resources and practices which may support co-ordination patterns across several units vary depending on the situation. Variance in workload peaks disrupts any partially ordered plan of co-ordination.
* CrMs AEs and AMEs (Check Managers also) are frequently having to make local adjustments to solve their immediate problems. These local fixes do not take into account the wider context and may often create wider disturbances in the system.
* Mutual adjustment, based on interpersonal relationships, is used to co-ordinate activity but this is a less *traceable* way to organise and co-ordinate work by other team members or units involved in the same activity.
* In general, there is preference to teamwork based on team members’ mutual knowledge and good interpersonal relations than basic task-oriented teamwork.

CrMs ande AEs (when required) find difficult to monitor the status of activities within or across zones, trades and eventual changing manpower. This is particularly problematic in the sequence of activities at the end of checks.

As a consequence of monitoring deficiencies, teams find difficult to manage the *integration* of task activities, especially when the activities require different trades and, in particular, when team members interact and co-ordinate one another and the various external support units (i.e., tools/materials stores, backshops, etc.).

* + 1. **Need to expand views on the process**

Clearly, co-ordination and interactions of multiple zonal, supervisory as well as support teams (full project team/s) reveal a complexity that can only be understood by assessing the organisation of performances within the entire work processes, and the next chapter is about such analysis. It is clear that the understanding of co-ordination problems across companies requires a better detail of the maintenance operations. In particular, the check process and its organisation becomes a critical step to address the complexity of teamwork and co-ordination issues in hangar maintenance.

Interaction and co-ordination are safety and performance sensitive items and cannot be underestimated. An important Australian aircraft maintenance survey (Hobbs, 2001) revealed that as a much as the 12 per cent of all safety related occurrences featured co-ordination and teamwork problems. Quoting Reason and Hobbs (2003, p. 105): “A breakdown in coordination is one of the most common circumstances leading to incidents. In many cases, coordination breaks down when people make unspoken assumptions about a job, without actually communicating with each other to confirm the situation”. The same Authors suggest the presence of co-ordination hazards in rushed shift handovers, lack of communication, working with unfamiliar people.

**Chapter 8**

**The organisation of team performances**

“*The opposite may be closer to the truth: The best way to get individuals to behave well in a group is to do a good job of setting up and supporting the group itself* ” (Hackman, 2002, p. 38).

# **The organisation of team performances**

From the previous chapters it is becoming clear that co-ordination and teamwork levels required to effective team activities can be understood in terms of the organisation of an entire check operation. Nevertheless roles and team functions within a process require some clarifications as it follows throughout the next sections of this chapter.

## **A model of a check process for project teams**

The check process model presented below has been developed from interviews with personnel, check observations in hangar and talk-through techniques applied during in-field research carried out across several European maintenance organisations and airline maintenance divisions like FLS Aerospace, KLM Engineering, SAS, ADRIA AIRWAYS, ATITECH, Easyjet, Air Europe, Sabena, SRTechnics, TEAM Aerlingus, Volare Airlines, British Airways. Site visits occurred between 1996 and 2005 and were sponsored under three large EU funded research Projects: ADAMS (1996), AITRAM (2002) and ADAMS 2 (2004).

* + 1. **Check process commonalities**

Overall, the check process model below does not represent any single specific work organisation or structure. On the opposite it would subsume some basic check process events common to most aviation maintenance and repair organisations in medium/large size hangar settings:

1. A business contract is agreed between a customer (e.g., airline company) and the repair organisation (e.g., maintenance company). This contract would generally refer to a specification of technical services, an aircraft’s hangar visit for a check operation or, more frequently, a cycle/programme of fleet checks for the customer. Agreements are taken about man-hours to spend, toolings, materials required and delivery times for the aircraft. In essence, technical and human resources are planned. This is agreed with the hangar personnel. Customers require quality, punctuality and no-additional expenses.
2. A set of pre-check meetings are organised by the check managers, supervisors and various types of planners assigned to the check operation: the full check project and preliminary schedule (i.e., *when* and *who* does what) is decided upon. Ideally, the operational teams should receive the complete work-pack 4/6 weeks prior to the commencement of a check.
3. Supervisory and zonal teams are pre-assigned *per* maintenance repair or inspection demand. More appropriately this process comes under the name *skilling the aircraft*. Put simply the total man-power available is distributed across the various aircraft areas or zones. Personnel will perform into smaller groups as dedicated zonal work teams over a pre-specified hangar visit period.
4. Hangar and support facilities are set up, prepared and organised. The work-pack (the complete check project programme) is decomposed into job cards for the individual technicians. The check resources configuration is completed.
5. At the aircraft arrival, supervisors, inspectors and technicians are already assigned into zonal teams distributed across 7-8 major aircraft zones (see Figure 4-2 in Chapter 4). Any zonal work team greets the aircraft and perform their scheduled operations for the day (requisitioning necessary equipment/material/tooling/job cards as for the schedule):

*Technical task performances*

* 1. strip/access/location to parts of aircraft as by maintenance programme
  2. configure aircraft for operation (activate or deactivate systems, power and circuit breakers, install safety tags, warnings)
  3. inspections to parts (to confirm job cards work and to detect unscheduled repairs/corrosions)
  4. routine tasks according to job cards: removal and repair of parts if necessary (this may require to send parts to the shops for overhaul)
  5. non routine tasks (raised by inspections)
  6. modifications or special maintenance programs (corrosion programs)
  7. daily completion of documentation for the tasks at hand
  8. reassembly and close-up of task as by job cards
  9. reconfigure a/c to operations
  10. operational/functional tests
  11. close up of tasks, sign off of job cards

*Resource management tasks*

* 1. identify, gather and manage use of documentation per task/operations (job-cards, maintenance manuals, engineering orders, safety bulletins, etc.)
  2. identify, procure and manage the use of scaffolding items (in co-ordination with stores/materials/logistics)
  3. identify, requisition, procure and manage use of tools (special and non special), equipment and materials for the tasks (in co-ordination with stores/materials)
  4. report special conditions

*Teamwork communication/co-ordination tasks*

* 1. define and communicate task assignments and configure the work team (organise individual technicians and tasks) for separate operations and expected timing (supervisor)
  2. monitor the status of operations, problems and dependencies within single as well as across zones
  3. inform on new action/decision and communicate with peers and technicians within and across zones (supervisor)
  4. reciprocal co-ordination and communications between separate tasks performed in the same or different zones (i.e., timing and sequencing across sub-tasks)
  5. reciprocal co-ordination and communication for a single task performed by more individuals in the same zone (or across zones, i.e., towing and jacking the aircraft)
  6. shift-handover communication and co-ordination of the process
  7. co-operative and co-ordinative efforts in physical tasks
  8. organise and sequence task operations within the zone of activity (of the single work team) in order to minimise interruptions and delays for other tasks, teams and zones of aircarft
  9. communicate technical problems, requests and estimates on the status of activities in the zone to the supervisors
  10. communcate supply delays, facilities and resource unavailable to supervisors

1. Overall, all daily task operations performed are monitored constantly. In particular the use of resources (human/technical) are monitored and controlled against a planned check programme expenditure (actual daily spent versus planned man-hours).
2. The operational conformities and deviations are controlled and minimised by co-ordinating all the team effort by constantly *reconfiguring* (re-scheduling) team resources (man-power availability) to match work- and task-load fluctuations as well as unexpected arisings. This is done by re-organising the different team performances and schedules and re-regulating the sequence of operations to adapt the plans to the new events and workload demands. This teamwork effort is performed by the constant daily *organisation of team performances*:
   1. identify task and operational assignments and configure any work team to meet the operations demands and constraints
   2. daily informal face-to-face meeting with the supervisory and zonal teams (team leaders and technicians)
   3. daily operational meetings to verify and co-ordinate all scheduled and unscheduled work activity
   4. daily customer meetings and communications to inform and decide (with customers agreements) about critical items
   5. communications with planners, material co-ordinators, sales unit and vendors about technical/economical information on parts, materials, and all supply orders to control supply system and associated delays
   6. communications about project team reconfigurations (necessary to match unexpected workload demands) and team flexibility (use of overtime, contractors and people transfers across different zones or check operations)
   7. Queries for/from engineering, quality or other technical services
3. The check operations records (e.g., technical documentation, job cards, man-power usage sheets), are scanned and archived for later analysis. The aircraft technical log-books are updated.
4. As the check is completed the Certificate of Release of Service (CRS) is signed off by the check managers and the aircraft is released.
5. A final de-briefing meeting (at least in some companies) is arranged by the main parties involved (i.e., hangar/check managers, engineering, planning, sales and contractors) to discuss the aircraft visit performance.
6. Customers will provide feedback or may fill out a customer satisfaction survey for later review on the part of the maintenance operator.

From this verbal model above, it can be argued that there is no such a thing like an *aggregate single team’s task.* In fact, hangar teamwork activity is not contained in a single unit or group.

In hangar, teamwork events are distributed in the process and are moved along different time horizons and process segments. It is a business project where teamwork is not simply the activity to work together to perform an operational task but it is also an activity distributed in the mechanisms of a process of several other work teams. Commonality and convergence of multiple team objectives is given only by the logic of the work flow and the work process.

A workflow diagram of the check process is described in Figure 8-1 below. The picture overlaps the distribution of the three basic teams composing the overall project team with the workflow of check process events.

As it was anticipated in the previous chapters, the practices of several operational teams are not just a single individual team effort or *solution*. It is instead a wider system’s *reaction* containing the project team in the context of even larger and certainly more complex processes. It is this larger context that can shape the overall performance of project teams.



## **Managing the project team (case studies)**

In order to understand what kind of team dynamics may emerge in a check process, a series of four operational meetings observations, eight short case studies and a set of e-mail transactions were recorded at a large and representative maintenance organisation participating at the EU funded ADAMS 2 Project (ADAMS 2, 2004). All observations were performed by the writer in the offices of zonal team supervisors and operations managers leading project teams on a daily basis.

* + 1. **Office activity about project teams**

Participation in the *work life* in hangar offices allowed an understanding of how, why and when support and supervisory teams get organised to monitor and organise zonal teams’ performances. The supervisory activity was observed directly during specific operational meetings held every morning around 8.00am. Such operational meetings start with the first work-shift and serve the purpose to update, keep informed and co-ordinate all zonal team supervisors about decision, actions, supplies and resources for all zonal teams’ operations. Support team activities were evaluated indirectly at any interface with the other two teams performing the check.

The actual presence of the researcher was clarified and explained to all crew before any direct work observation. This reduced the potential of a biasing effect. Observations were performed in 2003.

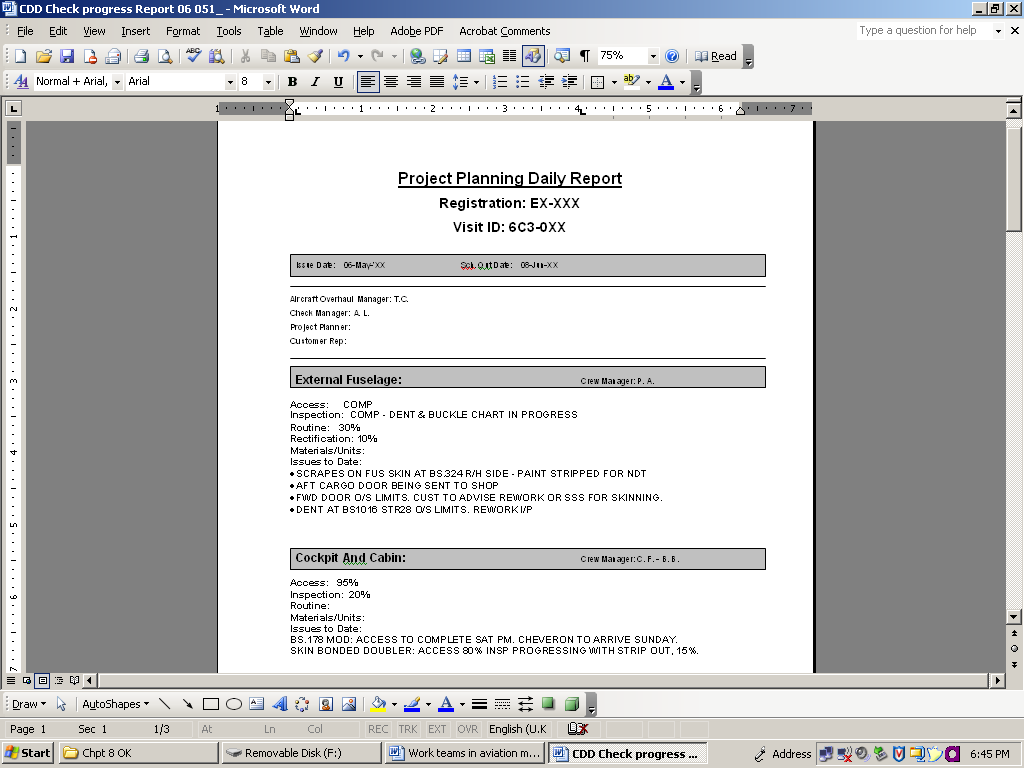
#### **Observation 1 - De-briefing about operations in office**

Ten supervisors, two check managers, one quality and a material co-ordinator attended the morning meeting at 8.30 am. It ended at 8.45am. The meeting was dedicated to inform and update all supervisors and check mangers with necessary information about the status of the operations (zonal teams’ activities). One of the two check managers informed all participants of *changes in manpower* by the day (more personnel at disposal). Then he went through each zonal activity asking for updates about the operations to each assigned zonal supervisor (i.e., zonal team leader). No specific problems were evidenced overall and finally *estimates* were provided about time to compete operations in each one of the zones of the aircraft.

At the end of the meeting the check managers provided additional information and notes on man-power needs and daily problems with some supplies and *expected* delays.

#### **Observation 2 – Last day of a check**

Ten supervisors, two check managers, one quality and a material co-ordinator and two planners attended the morning meeting at 8.00am and it lasted one hour. The meeting was held for the last day of a complete check operation. The senior check manager started directly to review the status of all aircraft operations. He inquired about the situation on the “under-floor” zone of the aircraft. The involved zonal supervisor reviewed the project planning daily report and his written notes. An example of project planning daily report is shown below in Figure 8-2.



**Figure 82 - Example of Project Planning Daily Report**

The check manager asked if that zonal activity could be closed by 2.00pm that day. The supervisor asked for more time to finish the zonal operation. Notably, all other zonal supervisors *considered* how their own zones would have been affected by that potential delay. *No one wants to be cause of further delays in closing up the operation*.

#### **Observation 3 – Supervisors discuss about tasks relations**

A total of twelve personnel participated to the operations meeting at 8.30am. The check manager in charge of the project team operations went through all aircraft zones and reviewed them thoroughly with the help of the respective supervisors. Sub-activities, supplies, technical or operational problems, *manpower needs* and services were checked upon for consistency.

During every zonal review the interested supervisor affected by a delay was noted. Priority to their zonal activity was based on: type of dependence and sequence between operations, type of supply and necessary workshop activity and *timing*.

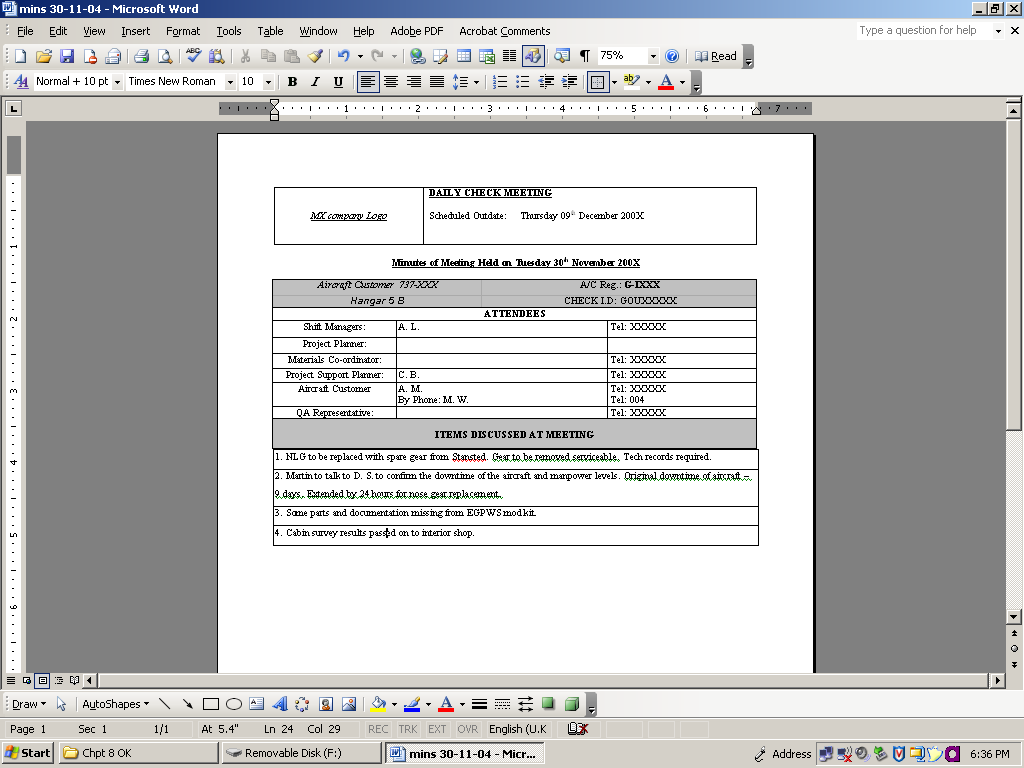
All supervisors took notes about the other zones statuses and constraints. They discussed together to assess optimal sequencing for the different activities, especially *cross-zones interactions*. Several questions by the check managers were directed towards *issues or delays on the part of materials, tools, parts, and supplies*.

At the end of the operations meeting, the check manager asked for any new possible operational problem to consider and thanked all participants. The meeting ended at 9.30am.

#### **Observation 4 – prediction and anticipation between supervisors**

An hour operations meeting (8.30am-9.30am) was held by a leading check manager. Ten supervisors, a live planner, a billing/sales and a quality representative attended it. The check manager went through the minutes of the last meeting to verify agreements taken with the aircraft customers. An example of minutes of the meeting is given in Figure 8-3 below. Additionally the check manager received verbal feedback on the status of work per each operational item by the relevant supervisors, as well as information about the *manpower* status across zones. He asked planners and interested team leads for *estimates* on time-to-finish for various activities, status of supply orders, shipping times as well as *predictions about delays*.

Every supervisor in charge of a zone *potentially affected by other zones* inquired about the time-to-finish for the operation on that external zone in order to free or adapt his/her zone according to such constraints.



**Figure 83 - Example of minutes of Daily Check meeting**

* + 1. **Findings**

From a preliminary review of these morning operations meetings, some simple findings emerge overall. These are presented below.

#### **Capacity to estimate task close-ups degrades in minutes**

It seems to be physically impossible for check managers and supervisors to monitor the status of all activities across all aircraft zones over the same period of time*. At any shift of supervision in one zone, the status of previous operations may have changed unpredictably, and concurrently to other zonal changes. Early operations meetings among supervisors, planners and check mangers are fundamental to prepare and schedule operations in sufficient detail. But undoubtedly, check managers have to rely on estimates of team leads (i.e., supervisors) assigned to specific aircraft zones. Such estimates apparently seem to degrade very rapidly.*

#### **Zonal team objectives and contexts**

In a very basic sense, the mission of any specific zonal work team is based on executing a single portion of a very large, and supposedly orchestrated, operation shared by multiple work groups. But, the original scheduled (and planned) daily objectives are not guiding the main patterns of activities for the entire course of actions of any full project team. In fact, context, unplanned or unforeseen events and conditions create new demands or *disturbances to the schedule* which in turn, generate new *situational* and temporary objectivesthat are instrumental to reach the original, planned ones. This actual daily context (of several work teams) generates work situations where the performance events are always more than those expected and planned originally: the context itself imports and generates new work for any team at any given time.

#### **Control of team manpower and resources flows**

Maintenance teams work across shifts, team membership can change every shift. Controlling such flexibility is mostly in the hands of the check managers and their supervisors.

Optimal and systematic manpower flows and regulation for efficient or effective team performances is based on *concurrency in scheduling team configurations across zones, bays and sometimes even hangar groups.* Unfortunately decisions about scheduling manpower and resource flows are not shared beyond individual operations meetings within each bay (e.g., a single aircraft operation) and across shifts.

#### **Reporting documentation**

The reporting systems and documentation used at the morning meetings appear to vary depending on the project team involved. Differences in such *practices* seem to vary even more per hangar or bays of work: each project team is a pool of practices with its own unwritten norms and rules of behaviour. The types of documentation used entail, for instance, man-power charts, operational status reports, work orders, supply status reports, and different planning or engineering orders. For instance, documenting the man-power status may assume the form of a spreadsheet as previously shown in Table 4-1 of Chapter 4. Across project teams, this form of documentation could easily change in layout and structure. This might suggest that the information demands in one area are reported and possibly examined differently across units or bays. In this company, document standardisation is most likely lacking.

* + 1. **Common daily teamwork deficiencies**

A number of *stories*, unwanted events, were recorded during the same in-filed activity above. These are simple cases of common deficiencies reported by technicians, supervisors and managers encountered by the writer after the 08.00am operations meeting. The following simple case studies are examples of *common boundary conditions, constraints and teamwork difficulties* occurring rather frequently in the maintenance company. Obviously, these simple cases do not necessarily represent common organisational failure conditions in hangar settings, they cannot be generalised at present. However, they represent real working conditions which deserve more understanding to unravel teamwork constraints in hangar maintenance operations.

#### **Case 1 – Cockpit maintenance tasks required**

1. Some scheduled tasks for the cockpit team were stopped because of a late detection of a hole of 2 cm of diameter in the external fuselage, just over the cockpit. Such a *snag* required immediate repair.
2. This unexpected stoppage required to cut additional parts of the cockpit interiors (panels in the cockpit) in order to reach and fix the damage (the external hole in the fuselage).
3. The metal cutting work required two sheet-metal workers to have it fixed. The workers were available *at least one day after* the identification of the damage. A hole of 2 cm of diameter delayed all the cockpit team’s tasks scheduled for about 2 days.

#### **Case 2 – Sudden transfers of personnel**

1. During the check operation more than 30 personnel (technicians and team supervisors) were moved out of the check in a single day, *for unspecified higher work priority*.
2. This event drastically stopped and heavily delayed the entire project team operation.

#### **Case 3 – Request of man-power**

1. A check manager required six different technicians (with three different specialties) to the manager of the hangar. This request to assemble the project team was done at least a week before the starting of the check operation.
2. The six personnel arrived to complete the project team *two weeks later after the starting of the operations*.
3. The check manager and the *entire* project team had to heavily adapt and rearrange efforts and configurations to sustain the work.

#### **Case 4 – Withdraw of man-hours**

1. *During* a C-check operation the *planning* department required the check managers to reduce by 900 man-hours the project team operation (on average, this daily activity generates 450 man-hours). This is approximately 8-10 technicians a week for two weeks.
2. This unforeseen request constrained all schedules set up in advance by the team with a heavy additional effort to maintain the deadline and performance by employing less manpower than that necessary to complete the check.
3. The final check recoverability (i.e., man-hours billed versus spent) was affected negatively.

#### **Case 5 – Parts orders inefficiencies disrupt zonal teams**

1. The Aircraft On Grounds (AOGs) in this company represent orders of parts or components that are required immediately for the aircraft. They are necessary items to release the aircraft from the maintenance visit in hangar.
2. Notably the expected turnaround time to collect these AOGs ranges between few hours and a day. But, *in several occasions*, the estimated average time to receive an AOG for the aircraft is about two or three days, or even more delay.
3. Notably, such delayed AOGs generate very serious disruptions for the team operations across the interested zone and other interdependent zonal teams. The zonal team may be configured to operate on the aircraft but there may be not parts to replace and reinstall as they result delayed AOGs.

#### **Case 6 – Supplied wrong parts**

1. A Nose Landing Gear component was ordered as AOG.
2. The project team received the component two days later (optimal lead time is one day).
3. The component was not that one expected: the supply consisted of two special components for the two Main Landing Gears.
4. The zonal team assigned to the correct order was disbanded and a new order was posted.

#### **Case 7 – man-power assignments**

1. A check manager had some technicians that were not working in the check when another hangar wanted them.
2. He did not release them because he did not want to lose good staff. He wanted *to maintain a stable project team*. The check manager would send less skilled staff if he had to send someone.
3. Check managers are reluctant to let personnel go to other teams because they don’t want to lose good personnel for their own project team.

#### **Case 8 – A zonal team delay**

1. A cabin team got job cards and went to do the work. The material to perform the job was not there and the team had to wait for it, but when they arrived they still could not do it because of the following issues: some electrical wiring had to be finished first, and some structural work had to be done also.
2. *The cabin team had to wait for 2 weeks* until the previous issues were solved before. Meanwhile, they were just sitting around waiting. Eventually they were able to do the work.

* + 1. **Findings**

The simple cases above reported by technicians, supervisors and check managers after the morning operations meetings are straightforward. All cases somehow do evidence *a need to adapt to workflow fluctuations and contention of peaks for resources*, *human resources required to teamwork activity*. Problems seem to be triggered by a clear *need for flexibility and re-configuration* from zonal to supervisory teams. For instance, Case 3 above shows how team leaders need maximum freedom to re-schedule certain team configurations and operations when unexpected external delays impose prompt responses.

As it is described in Case 7, conditions of “fire-fighting” generates work practices that may limit proficiency of the organisation overall. In order to keep organised what seems more and more a condition of pooled human and technical resources the team leaders may tend to keep man-power (personnel) in the team, even when not required, despite the fact that other project teams may really need it.

Another clear finding is evidenced by Cases 5, 6 and 8. They all refer to effects of external factors upon internal team performances: *the likelihood of external issues augments the probability of conflicts and delays for zonal teams.* It is quite evident how *supervisory and zonal teams working live on the aircraft are subject to constraints not controllable locally, as they are too dependent by all support units proficiency*.

* + 1. **Team transactions, planning and configurations**

In order to verify how communication and transactions occur between supervisory teams and the support groups, a series of e-mail communications mostly between check managers, supervisors and external supports are reported and analysed here below. The following real e-mail transactions were taken between May 2005 and December 2005 in the same company exposed to the same studies described here above. All names and contextual information is removed or changed accordingly to protect the source. Three transactions involved the writer.

#### **Team change of configuration and flexibility**

*From: H. K. (Planner)*

*Sent: Friday, December 02, 2005 4:01 PM*

*To: 18 Team Supervisors,*

*Cc: 1 Project Planner; 4 Hangar Managers; 1 Aircraft Overhaul Manager*

*Subject: Manpower Distribution week 10th Dec*

Attached please find the Manpower assigned for week 10th Dec. to: <<Team 1>> <<Team 2>> <<Team 3>> <<Team 4>> <<Team 5>> <<Team 6>>.

Management have decided that there is no requirement for contractors on site next week, as the available manpower from Hangar 6 Bay 2 has been distributed to the remaining checks.

Please advise all Contractors currently assigned to you that they will not be required.

#### **An example of unplanned man-power flow effects**

*From: C,T (Hangar Manager)*

*Sent: 28 October 2005 10:38*

*To: 1 Hangar Manager; 18 Team Supervisors*

*Cc: 1 Planner*

*Subject: FW: A330 Landing Gear Team*

Gentlemen

This is the landing gear team (see attachment) selected for the A330 work in hangar *x* next week. It will be headed up by T. L.. and C. Q. over early and late shifts. I realise that taking manpower off any C check causes problems but ask for your full co-operation in dealing with this very tough challenge. Please have a look at the list and confirm that all the people listed are available. If I don't hear from you I will take it that all are available.

T.C.

Hangar Manager

<Attachment with the team for the A330 in hangar *X* next week>

Reply by a Check Manager:

*From: D C (Check Manager)*

*Sent: 28 October 2005 13:28*

*To: 2 Hangar Managers; 10 Team Supervisors*

*Cc: 1 Planner*

*Subject: RE: A330 Landing Gear Team*

T.,

I do not see anywhere, the trade off agreed for the transfer of manpower from Hangar 6. For instance, M. C. and W. F. for the two supervisors and 2 replacement mechanics for our 2?

Regards

C. D.

Check Manager

Hangar 6 Bay 2

Reply by the Hangar Manager:

*From: C. T. (Hangar Manager)*

*Sent: Friday, October 28, 2005 3:12 PM*

*To: C. D.; 1 Hangar Manager; 10 Team Supervisors*

*Cc: 1 Planner*

*Subject: RE: A330 Landing Gear Team*

C.

As I said this type of job upsets every C check. The Lion's share of the manpower in this case is taken from the upper hangars. M. C. and W. F. replace M. D. and C. R. but unfortunately we do not have mechanics to swap. D. S. <Hangar Manager> and I agreed on the arrangements.

We both at different times discussed the issue with T. B., H. M., M. D. and J. W. The success of this operation depends on full co-operation. So far thankfully all check managers have registered their

complaints and then committed.

T. C.

Hangar Manager

#### **A question about planning software**

*From: Baranzini Daniele (Researcher)*

*Sent: 09 June 2005 09:00*

*To: L. A. (Check Manager)*

*Subject: RE:*

T., a question:

Is there any system to help planners (in planning cells or support planners). I mean..., and independently by the company? Do you know if there are softwares or other systems to help planners to schedule with you the resources operations and priorities?

I know the existence of project master plans, Gantt charts, and the replacement charts that you generally use to verify who is in and who is out the check day-by-day.

Ciao!

Reply by the Check Manager:

*From: L. A. (Check Manager)*

*Sent: Thursday, June 09, 2005 11:21 AM*

*To: 'Baranzini Daniele' (Researcher)*

*Subject:*

Hi Daniele

We have a planning department that consists of a Dept Head, 12 Planners and also 12 support planners. The Gantt chart is drawn up front the out date back to the arrival date of the aircraft and the check manager fills in the blanks i.e. each task schedule.

We also have an Operations Planning Manager B.B. He draws the plans for each hangar approx. 1 week in advance of the check. There are MS Projects on each planners support planner and check manager PC to assist with the plan there is no other software involved.

Ciao

#### **Planning in advance**

*From: N. K. (Planner)*

*Sent:*

*To: D. D. (Planner)*

*Subject:*

Hi D.,

Next Sunday 28th of Nov. Ryan air XW XXX 737-800 aircraft will come into Hangar 5. The aircraft requires a stabilizer modification to be carried out and this modification is the pacing item for the check. The plan is to remove both stabilizers on Monday and start the stabilizer modification Tuesday at 0700Hrs. For the mod to start on Tuesday we will need the scaffolding built on Monday evening (same as H2 in Sept /October). Will you please liaise with T. L. <Check Mangers> for timings and D. T. for design to ensure that all runs smoothly?

If there are any difficulties please let me know.

The above will be followed by a sister aircraft (XW ZZZ) with the same requirements. Current dates for XW ZZZ are aircraft-in 8th Dec. Scaffolding built evening of the 9th. XW ZZZ is due out on break up day, but target is 16th Dec.

Regards, N. K.

#### **Support for team operations**

*From: daniele.baranzini (Researcher)*

*Sent: 29 September 2005 13:41*

*To: L. A. (Check Manager)*

*Subject: Re:*

Hi T.

if you had to think of a sort of integration of different maintenance data useful to better manage your maintenance checks, what kind of data you would like to have and that may be interesting to put together?

Reply by the Check Manager:

*From: L. A. (Check Manager)*

*Sent: Friday, September 30, 2005 11:26 AM*

*To: daniele.baranzini*

*Subject:*

*Importance: High*

Hi Daniele

The answer to you're question is a simple one, the maintenance requires:

1) Good management, a proactive leader

2) Support to carry out the task

3) The tools to complete the task

The above headings do cover many things in their own right and can be broken down.

#### **Project team: personnel shortage and changes**

*Date: Mon, 9 May 2005 07:39:35 +0100*

*From: L. A. (Check Manager)*

*To: C. T. (Hangar Manager)*

*Subject: XC-CKK aircraft*

*Importance: High*

Hi T.

We have the continuing shortage of an assigned support planner, a material co-ordinator, maintenance assistant, and structural personnel.

The shortage of assistants is now affecting the progress rate of our inspection. We cannot get the areas cleaned for the outstanding inspections, i.e., cabin, freight holds, internal wings, engine pylons. The volume of structural work, as previously reported, requires structural personnel.

Since the beginning of the check we have no support planner, and material person and there are a number of components for shop 16 that stores will not accept without a purchase order normally provided by the material co-ordinator. Also we are short of mechanics as we have people gone on nights and bay 2 have some of the people assigned to this aircraft.We require a cable person as the approved man for cable manufacture on this crew is on nights and there are at least 6 control cables to be fabricated for the wings and engines.

We also have some personnel on the Tue to Sat shift team 83 and 1 team Supervisor on training

Please advise

Your Sincerely,

A. L.

#### **Project team: loaning team members**

*From: L. A. (Check Manager)*

*Date: 16 April 2005*

*To: 'Baranzini Daniele' (Researcher)*

*Subject:*

There is no assigned crew to each aircraft. *I have loaned 12 people* from SS-DDS this week to A-XXZZ and the result is that SS-DDS is further delayed as a result. We are on a slippery slope down hill.

Question by the Researcher:

*From: 'Baranzini Daniele' (Researcher)*

*Date: 16 April, 2005*

*To: L. A. (Check Manager)*

*Subject: Re*

Were you asked by the Hangar Manager to loan your guys? By the Planning team? Or you simply received a phone call by the A-XXZZ check manager asking for your help (I never understood who is in charge to take the final decision on a situation like this). Do not tell me that you are managing both checks!

Reply by the Check Manager:

*From: L. A. (Check Manager)*

*Date: 16 April, 2005*

*To: Daniele Baranzini (Researcher)*

*Subject:*

No

The Hangar Manager instructed me to give the men to the other aircraft. He is the decision maker.

* + 1. **Findings**

Maintenance teams in hangar operations require high *integration* into the larger system throughout co-ordination and synchronisation with suppliers, managers, peers, and customers. Also when the system is large and contains multiple check operations, as shown for instance in Figure 8-4, the situation for any one project team is exacerbated even more.

Notably, the real context of a hangar becomes very difficult to manage. Resources (human and technical) must be pooled together. Such integration is maintained by effective pace and timing of exchanges with other work units. *When one team falls behind it is the entire system which suffers*.

In general e-mail transactions reported previously reflect such condition: the internal capacity of teamwork is lost where the external dependencies constrain most of the production flows and when teamwork *in* the team has low-control on such *externalities*.

[](http://www.aerospace-technology.com/projects/a310-200f/index.html#a310-200f7)

**Figure 84 - Example of multiple check operation in single hangar (Available under:** [www.aerospace-technology.com/projects/a310-200f/](http://www.aerospace-technology.com/projects/a310-200f/) [**08/08/2007**]**)**

Considering a more common and academic view about teamwork one may wonder what is the real effect of setting up training and competence about *transportable* teamwork skills if most of the constraints to teamwork and team performances are *slaves* of such external complex processes. Other specific findings follow here below. Of great relevance is the fact that decisions and solutions to adapt to external systemic dysfunctions determine what teamwork capability is relevant, effective, but not necessarily acceptable.

#### **Types of requests**

Supply requests, re-planning and re-scheduling to unexpected conditions, and escalation procedures to optimise workflow changes are the most common basic requests. E-mail communications between check managers (leading the check operation and its project team) and hangar managers and planners (monitoring multiple hangars, bays and schedules) serve the purpose to *escalate problems from project team levels (e.g., single check operations)* to global organisational levels and solutions (*section 8.2.5.2*). Interestingly, *solutions seem to favour global organisational optimisations, and resist meeting requests coming from single project team levels*.

#### **Common inefficiencies and mutual adjustments**

Despite the efforts to maintain effective organisation of team performances, the sample of e-mail transactions reflects how poor responsiveness (*section 8.2.5.2* and *8.2.5.6*), unexpected requests (*section 8.2.5.1*) and, sometimes, lack of transparency (*section 8.2.5.7*) may limit the operational capacity of who leads entire project teams, that is, check managers, live planners and zonal team supervisors. Also, re-allocation of resources, mainly team members across zones or even across bays/check operations, is *negotiated* mostly by mutual adjustments between check managers and zonal team supervisors: this is a very flexible and rapid co-ordination mechanism but suffers of lack of traceability for higher levels of control (i.e., hangar managers looking for entire hangar solutions). *Sometimes hangar managers do not easily know where people are moving around*.

## **Flexible team structures**

The normal check process, as described in section 8.1.1, defines how the project team resources are planned some weeks before the aircraft visit. But, generally, it is not realistic to maintain 100% availability of any project team’s resources per any bay at *all* time across *all* available hangars: *despite massive team planning efforts in advance, under- or over-manning a check operation is more likely to happen than right-sizing it*. This is certainly a common problem of economies of scale. No plans can guarantee an active utilisation, say, of 80 technicians per project team over two or more project teams. There is not enough man-power, or too much to sustain *efficiently* the work at this level of organisation. *Flexibility* has to be built into any available team.

Following on from this, an analysis about the role of team structures, membership, flexibility and man-power flow throughout check operations was carried out and presented below. This analysis was envisaged to better assess the role of personnel mobility/flexibility within and across bays and hangars, and its potential impact on team-based systems of co-ordination.

* + 1. **Flexibility in team configuration**

A maintenance work team performing a task does not necessarily imply that the *same* team members will operate that task. This condition is quite common as the very same operation has to be extended over more than a work-shift, or even when some technicians *coming from other teams and other job assignments* are *temporarily* *re-allocated to that operation*. This latter practice, here termed *team manpower flow*, reveals to be a critical factor determining interaction and co-ordination effectiveness or efficiency for hangar teams. The request or *need* for flexible team compositions would reflect different operational practices. Thus, even small proportions of manpower flowing in an out the very same zonal teams or operations would deserve better insights and understanding.

In the present investigation, the team manpower flow issue is articulated as follows:

* Are there any unexpected internal or external flows (mobility) of manpower?
* If yes, does this exchange of manpower show a flow of personnel across different aircraft zones, bays or even hangars in order to sustain particular check demands?
* Does this exchange of team members across bays or even hangars suggest a trend or common practice in the team manpower management and control?

#### **Methods and information sources**

The team manpower flow analyses were carried out in 2003 at the same maintenance company exposed to the observations and in-field studies as above (*section 8.2*). For the limited amount of time and resources at disposal, only the following four maintenance check operations were investigated by the writer:

1. Martinair: PH-*XXX*\* 25/03/2003  18/04/2003 (Hangar 6B1)
2. My Travel: OY-*TTT*\* 23/04/2003  05/05/2003 (Hangar 6B1a)
3. Rayanair: EI-*DDD*\* 26/01/2003  04/03/2003 (Hangar 5b)
4. Volare: I-*VVVV*\* 06/05/2003  07/06/2003 (Hangar 6B1)

\* Check reference codes are hidden

The company’s worksheets containing the weekly man-hours plan and the factored man-hours spent on each one of the four checks above (i.e., actual man-hours spent both daily and weekly) were matched with information and data from spreadsheets about personnel attendance, clocking in/out per specific check and task card, and actual personnel membership to specific project team. This information provided evidence of actual daily (re-)allocation of personnel across zones, bays or even hangars, if any. In Figure 8-5, 8-7, 8-9 and 8-11 the “formal company records” represents the daily number of personnel allocated to the check operation according to the company plans.

Notably, for three out of four checks, it was even possible to collect updated (even within the same day) information on the actual presence of personnel on the check, the actual team composition, with all the information of *who* were actually coming from or going out to other bays or even hangars. This information was collected by the writer for the hangar 6 operations from specific “team composition worksheets” regularly updated by check managers every work-shift. These informal but highly important recordings represent an actual check manager’s practice (and technology) to monitor and supervise the actual team structure and configuration *on the line*. In Figure 8-5, 8-7, 8-9 and 8-11 this information is represented by the “check managers records”. Finally, Figure 8-6, 8-8, 8-10 and 8-12 show the total % of manpower flowing in and out of entire check operations from the total % of manpower deployed according to the “formal company records”.

* + 1. **Findings**

The overall results across the four checks identified specific trends in the team manpower flow as follows:

1. There is a small but constant flow of manpower *exchanged* across project teams working on different checks, operated in different bays or hangars: considering all the four checks, a range between 3% to 20.4% of the entire team manpower working on an specific check (especially aircraft engineers and contractors) is composed *temporarily* by members re-allocated to or from other teams working on other checks, coming from or going to other bays or even hangars. These results are shown in Figure 8-5, 8-6, 8-7, 8-8, 8-9, 8-10, 8-11 and 8-12.
2. The team manpower flow, considering all the four checks, ranges from 1 to 25 technicians re-allocated per day: *the manpower flow is not constant and it contains high variability*.
3. Data recorded by the formal company’s worksheets (counts of personnel) *reflects* the check managers recording practices (i.e., team composition worksheets), even though the there is not complete overlapping of the data recorded.



Notably, moderate flows of personnel within and across project teams and different checks are clearly present. However, this business strategy about teamwork management could certainly be *enhanced* by implementing dedicated



















procedures to team flows and exchanges with less reliance on interpersonal-oriented teamwork practices. This latter approach, requiring a more consolidated mutual knowledge and established interpersonal relations, is at present, the favoured team practice in the organisation under analysis.

1. The daily team manpower volume (i.e., formal company or check managers records) is significantly correlated (except for the Ryanair check) to the levels of manpower flow in and out of the same check. This finding is shown in Table 8-1. This positive correlation could imply that:
   1. The planned manpower estimates over a check are actually not responding to the real team manpower needs when required.
   2. It is a work practice across check managers, at least on these four checks, to favour *manpower robberies or donations* (i.e., borrowing or lending manpower to other teams, bays and hangars) in order to maintain certain levels of check activity.
   3. These exchanges of manpower are actually based on *mutual adjustment and interpersonal relations across project team managers* (that is, check managers) across different teams and locations. Basically, there is a preference towards informal ways to manpower control and re-allocation. This team management practice results to be the faster modality to *react* on time to highly fluctuating work demands and unexpected/unplanned tasks or operational conditions. *This is a fire-fighting approach to the manpower control*.
2. Table 8-1 shows also that personnel counts recorded by the formal company’s worksheets are correlated to the informal team composition worksheets by check managers (except for Rayanair case, as no data were available). As already reported the overlapping of such data is substantial but not complete: this aspect should require further in-depth analysis in order to address potential discrepancies related to the reliability of the actual formal data monitoring and control by the company.
3. The use of external manpower or re-assignments to other checks is one (certainly less practiced) of the mechanisms employed to *react* to manpower planning deficiency as well as daily fluctuations of work resources within and across different project teams. The other common mechanisms are:
   1. heavy use of unplanned overtime
   2. use of high numbers of contractors (on demand)
   3. misuse of overtime (‘barrier’ practice: consecutive work-shifts with no rest)

(The use of these three other mechanisms/buffers has been identified by reviewing technical documentation, communications with team leads about the four check operations)

Notably, even if the use of overtime (a. and c.) is intrinsic to the company’s business nature, when this is *misused* or *not controlled*, the results will affect negatively the level of team performance and the personnel involved.

**Table 81 - Person *r* correlations betweeen manpower flow *in or out of check,***

***formal company records and check managers records***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Manpower flow (formal company records) | Manpower flow in or out of check | Manpower flow (check managers records) | |
| **Martinair: PH** |  |  |  | N=23 |
| Manpower flow (formal company records) | \_\_ |  |  |
| Manpower flow in or out of check | .65\*\* | \_\_ |  |
| Manpower flow (check managers records) | .88\*\* | .80\*\* | \_\_ |
| **Volare: I** |  |  |  | N=28 |
| Manpower flow (formal company records) | \_\_ |  |  |
| Manpower flow in or out of check | .64\*\* | \_\_ |  |
| Manpower flow (check managers records) | .89\*\* | .68\*\* | \_\_ |
| **My Travel: OY** |  |  |  | N=10 |
| Manpower flow (formal company records) | \_\_ |  |  |
| Manpower flow in or out of check | .53 | \_\_ |  |
| Manpower flow (check managers records) | .71\* | .84\*\* | \_\_ |
| **Rayanair: EI** |  |  |  | N=15 |
| Manpower flow (formal company records) | \_\_ |  |  |
| Manpower flow in or out of check | .43 | \_\_ |  |
| Manpower flow (check managers records) | \_\_ | \_\_ | \_\_ |

\*P<.05, \*\*P<.01 (2-tailed)

Furthermore, permanent members of teams and with longer experience within the company identify contractors (b.) as *external members* and certainly less known in several respects, suggesting that confidence on the expertise and competence of such team members has to be verified and tested over time: *contract workers are an unknown quantity in relation to skill, competence, etc*. Thus, building up trust and confidence in such new members will certainly require time, but this time may be not available over a period of a few days of a check. This, considering also the preference for teamwork based on interpersonal relationships and mutual knowledge can result in a *conflict of team membership*, confidence and operational awareness. This condition may, in turn, lead to higher, unnecessary and unwanted levels of monitoring and supervision by zonal team supervisors or other team members on the contractors’ activities decisions and actions. This is also reflected in attempts to ‘hold on to’ people who are known as insurance for known and faster work results, which require less direct supervision. It is very important to note that this logic applies also to all the other trades or personnel being *temporarily re-allocated* to other work units and operations.

Overall, the continuous fluctuations of work requirements over a check do suggest that team leaders experience problems in managing even a small proportion of recurrent flexibility in the team *configuration* (e.g., team members from/to other groups). The concept called here *configuration variance* is in line with that of group's *adaptive structuration* by Poole and colleagues(Poole and Roth, 1989a, 1989b). Members should change if they do not fit to division of labor and role network requirements. This provides opportunities to modify the team's composition into a new system altogether. More easily, the manpower variance can change simply because of a work shift change. The point in any case, is that the *teams analysed were never the same* as the manpower flow regularly changed their configuration. And, apparently, the effect of a change in performance was negative.

Also, this *team configuration variance* will cost much higher levels of monitoring, co-ordination and efforts to keep team situation awareness within and across new *mixed* work teams, spread out across different zones, bays and hangars (*mixed* as they aremade up both by actual team members and new members, generally less acquainted to, or cognizant of the operational practices of other groups).

* + 1. **Predicting check performance from team flexibility**

Following on from the fact that project teams do change configurations, another question can be addressed then: *is variability of team configuration actually related to team performances?*

In order to test this question, data of 41 check operations occurred between 2002 and 2004 were analysed from the same maintenance company tested as above. Their technical performance in terms of recoverability was recorded, as well as their levels of team manpower flows. This latter measure was operationalised as % of hours which come uniquely from the core team members (i.e., a dedicated project team manpower). The remaining % of total time spent on the overall check operation is due either to *borrowing or loaning* people to other checks, that is, manpower flows *traces*. Two other measures per each check operation were monitored: the percentage of contractors and overtime employed for the operation.

#### **Multiple regression**

A standard multiple regression was applied to test if team composition (%Core team), contractors (%Contractors) and overtime (%Overtime) would jointly predict check performance levels (Recoverability) over the sampled 41 check operations. The relative contribution of each predictor was verified as well. No logical or theoretical priority was given to any predictor. An exploratory model-building approach was preferred.

Check of assumptions led to some data adjustments over the total N=41: presence of missing values, univariate and multivariate outliers, as well as normality, linearity and homoscedasticity of residuals was checked upon.

8 non-randomly missing values on the %Core team were imputed by application of a stochastic regression approach (MVA – SPSS 12 procedures). A case was deleted as it showed missing values on all three predictor variables (i.e., %Core team, Overtime, Contractors). A square root transformation was used on %Overtime to reduce positive skewness and improve normality. After adjustments, normality, linearity and homoscedasticity of residuals were appropriate. No univariate or multivariate outliers were identified. A final data sample of N=40 was used in the following analysis.

Table 8-2 below displays (un-)standardised beta weights (B, *β*), unique squared semi-partial correlations (sri2), R for regression, R2 and adjusted R2. R for regression was significant, R=.51, F(3, 36)=4.30, p<.02, with R2 at .26. Significance of regression coefficients and relative sri2 were assessed through *t* statistics, which were evaluated against 36 *df*. Very important, *team composition showed to be a significant predictor of check performance*: %Core team measure, *β=*0.406, p<.01. On the other hand, %Overtime (sq. root) as well as %Contractors measures did not contribute significantly to prediction of Recoverability: *β=*0.146, p>.05 and *β=*0.226, p>.05 respectively.

The manpower flow measure (i.e., %Core team) uniquely accounted for 16% of the total variance in the check operations recoverability (sri2=.16, p<.01). Person’s r correlation between %Core team and Recoverability scale, *r*=.43, p<.01, corroborated such findings about regression coefficients.

**Table 82 - Standard multiple regression of %Core team, %Overtime, %Contractors on Recoverability**

| **Predictors** | **B** | ***β*** | **sri2**  (unique) |  | **R** | **R2** | **R2**  (adjusted) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| %Core team  %Overtime  %Contractors | 0.004\*\*  0.036  0.007 | 0.406  0.146  0.226 | .16  .02  .05 |  | .51\* | .26a | .20 |
|  |  |  |  |  |  |  |  |

\*p<.02; \*\*p<.01

aunique variability =.16; shared variability =.10

* + 1. **Findings**

The multiple regression results show the importance of the core team configuration versus recoverability. Also, the *%Core team* is the *only* individual reliable predictor of check performance levels. *This result supports the hypothesis that borrowing people and a high level of loans is disruptive: even small changes are disruptive for such organisation of teamwork. Arguably, the more the project team is maintained stable the better the technical operation performance*. No correlation for contractors or overtime was identified.

Overall, the results presented in the last two sections (*section 8.3.2 and 8.3.3*) reflect the analysis of a relative number of checks operations within a single company. Although the business practices described so far are quite common in the hangar aviation maintenance community, generalisations should be fully resisted at this stage. More research is needed. However, it is reasonable and sensible to consider that membership of work teams and its *variance* is not a trivial aspect, and apparently it is associated to various performance levels. In the future, this factor could play a critical role in the way team manpower and structure will be managed, controlled and generated, thus, becoming new drivers to meet productivity and efficiency levels in team performance for hangar operations. This topic is now considered from an *external performance* point of view, which will be defined in the following sections as the *team externality* problem.

## **Team externalities**

A *team* *externality* is here defined as the specific performance of a system in the organisation that is not (directly) controllable by a work team which turns out to be dependent on that performance. In very simple terms, an externality is the behaviour of an external group with respect to another one. In the aviation maintenance world, it could be represented in a *support team’s performance* which responds to certain zonal or supervisory team demands.

Examples of such team externalities are:

* Provision of Kits, Parts, Equipment, Tools from Stores and Materials Units
* Delivery of work-packs, job-cards, technical manuals from Planning or Engineering
* Back-shop services – work order reports from Technical Support Units
* Engineering or Planning, Sales and Procurements, Service responsiveness
* All forms of supply chain performances

Team externalities, as external behaviours, can trigger negative or positive effects. The externality is *positive* if the affected team benefits from it. On the opposite, the externality is *negative* if the affected team cannot perform its internal processes and has to disband the technical operation (effectiveness criterion) or, more frequently, if it has to delay or adapt some of its processes by overspending technical or human resources (efficiency criterion).

It can be said that *teams with high external dependencies have low levels of tolerance to negative externalities.* In particular, teams with high context dependency perform effectively or efficiently as far as negative externalities are prevented, minimised, or contained adequately.

From an operational perspective, each project team per hangar has limited time, technical and human resources to spend effectively. The working hypothesis here is that such limited resources are all affected by the presence of negative externalities which require huge re-organisation and re-scheduling efforts on the part of the team managers. Performance is expected to worsen with higher level of negative externalities. If confirmed, this would corroborate one key hypothesis of this thesis:

*It is the organisation of the environment (support services and technology of process) embedding the work team that could explain the major proportion of variance in operational performance, not the internal properties of the team* (see Chapter 5 - *section 5.7*)

* + 1. **Predicting team performance from team externality**

A study on the externality impact on teamwork was carried out to identify if zonal and supervisory teams are really affected by such performances. The study was carried out by the writer in 2004 within the same maintenance organisation exposed to the previous analyses here above (see previous sections). A checklist to rate the presence and impact of 7 types of team externalities across different check operations was developed. An additional item recorded the number of personnel transfers from/to other operations (e.g., another measure of team manpower flow or team flexibility).

The checklist, shown in Table 8-3, was called *team checklist*. The team checklist was used to rate availability of *expected* daily supports (i.e., Special tools available for the task) and services (i.e., Engineering support response within 24 hours) as well as team zonal performances in the check operation (e.g., average % daily task completed successfully across zones). This latter measure was recorded at every end of the day shift. In particular, every day the team checklist was filled in regularly by two check managers with the help of a live planner per check operation. Overall, 6 maintenance check operations were monitored and rated accordingly.

The assignment to fill in the team checklist was to rate the presence/absence of different externalities and their relative availability levels across zonal teams (see also Table 8-3). The rating scale is shown below:

“[ ]N/A” = there is no request of that resource in any zone (i.e., Pre-draw Kits, Special Tools…)

“[ ]no” = no zone have got the resource they required   
“[ ]partial **low**” = less than half of the demanding zones have got the resources required, but not all the zones

“[ ]partial **high**” = more than half of the demanding zones have got the resources required, but not all the zones

“[ ]yes” = all zones have got the resources required

#### **Multiple regression**

Following an exploratory scheme, a standard multiple regression was applied on the team checklist variables to test if availability/reliability levels of different team externality indexes as well as a measure of team flexibility would jointly or individually predict zonal team performances measured as “Average % of daily tasks completed successfully (across zonal teams)” (see Table 8-3). Variable predictors were 1) Approved manpower (e.g., planned manpower resources), 2) Pre-draw kits (e.g., tooling kits for maintenance services), 3) Access requirements (e.g., free access to various aircraft parts), 4) Special tools, 5) Engineering support response in 24 hours, 6) A.O.G's within 24 hours (e.g., special parts due within 24 hours), 7) Job interruptions by shop, 8) Personnel transfer from/to other bay (across zones).

Being an exploratory approach, no logical or theoretical priority was given to any predictor and standard multiple regression was preferred over statistical and sequential approaches.

Check of assumptions led to some data adjustments over the total N=110 observations across 6 check operations: independence of errors, presence of missing values, univariate and multivariate outliers, as well as normality, linearity and homoscedasticity of residuals and of individual variables were checked upon.

Two cases in the criterion variable (i.e., “Average % of daily tasks completed successfully (across zonal teams)” were removed to improve normality, linearity and homoscedasticity of residuals and bivariate relations across variable predictors. Also both cases had unexpectedly low values in the criterion variable. Plausibility of such team performance values was dubious. As it was not clear if such cases were from the target population they were removed leaving a total N=108. The response *“[ ]N/A” = there is no request of that resource in any zone (i.e., Pre-draw Kits, Special Tools…)* was treated as “missing value” and its imputation was considered if necessary. In particular, four predictors (item *2), 4), 5) and 6)* in Table 8-3) had more than 5% missing cases in a non-random missing pattern. Imputation of missing values for such predictor variables was carried out according to a stochastic regression approach (MVA – SPSS 12 procedures). Variable’s mean substitution for missing cases of predictors with less than 5% missing was applied.

A square root transformation was applied to *Approved manpower*, *A.O.G's within 24 hours*, *Job interruptions by shop* and *Personnel transfer from/to other bay*. Reciprocal transformation was applied to *Access requirements*. All transformations aimed at reducing skewness, improving normality and homogeneity of variance. After adjustments, normality, linearity and homoscedasticity of residuals were achieved. No univariate or multivariate outliers were identified. The adjusted data sample of N=108 was used in the regression analysis.

Table 8-4 displays (un-)standardised beta weights (B, *β*), unique squared semi-partial correlations (sri2), R for regression, R2 and adjusted R2. R for regression was significant, R=.79, F(8, 99)=20.16, p<.001, with R2 at .62. Significance of regression coefficients and relative sri2 were assessed through *t* statistics, which were evaluated against 99 *df*. Notably, *team externalities do affect team performances*: availability of Pre-draw kits (e.g., tooling kits for maintenance services), *β=*0.370, p<.001 and Approved manpower (e.g., planned manpower resources), *β=*0.459, p<.001, were *significant predictors of zonal team performances*.

Also, and expected, *team flexibility contributed significantly to performance*: Personnel transfer from/to other bay (across zones) *degrades* performances, *β=-*0.296, p<.001. No other team externalities contributed to prediction.

Significant sri2 of *Approved manpower*, *Pre-draw kits* and *Personnel transfer from/to other bay* accounted for 12%, 9,% and 5% of variance in team performance respectively. This adds up to a .26% of unique sources in R2. The remaining .36% variability represents the amount of R2 attributable to shared variability among the three significant predictors together.

**Table 83 - Team checklist**

| **Daily Cross-Zones indicator**  Rate an average measure across all zones | | **Average all Zones results**  Average % daily task completed successfully (as per check master plan) |
| --- | --- | --- |
| 1) Approved manpower available (across-zones) | \_\_% | \_\_\_\_% |
| 2) Pre-draw kits available (across zones) | [ ]N/A [ ]no [ ]partial **low** [ ]partial **high** [ ]yes |  |
| 3) Access requirements available (across zones) | \_\_% |
| 4) Special tools available for the task (across zones) | [ ]N/A [ ]no [ ]partial **low** [ ]partial **high** [ ]yes |
| 5) Engineering support response within 24 Hrs | [ ]N/A [ ]no [ ]partial **low** [ ]partial **high** [ ]yes |
| 6)A.O.G's within 24 Hrs max time elapsed (across zones) | [ ]N/A [ ]no [ ]partial **low** [ ]partial **high** [ ]yes |
| 7)Job interruptions by shop (across zones) | \_\_% |
| 8)Personnel transfer from/to other bay (across zones) | \_\_to \_\_from (put numbers) |

legenda

“[ ]N/A” = there is no request of that resource in any zone (i.e., Pre-draw Kits, Special Tools…)

“[ ]no” = no zone have got the resource they required   
“[ ]partial **low**” = less than half of the demanding zones have got the resources required, but not all the zones

“[ ]partial **high**” = more than half of the demanding zones have got the resources required, but not all the zones

“[ ]yes” = all zones have got the resources required

**Table 84 - Standard multiple regression of team externality/flexibility indexes on zonal team performnce (Average % of daily tasks completed successfully – See Table 8-3)**

| **Predictors** | **B** | ***β*** | **sri2**  (unique) |  | **R** | **R2** | **R2**  (adjusted) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1) Approved manpower  2) Pre-draw kits  3) Access requirements  4) Special tools  5) Engineering support response(24 hrs)  6) A.O.G's within (24 hrs)  7) Job interruptions by shop  8) Personnel transfer from/to other bay | 4.554\*  0.252\*  70.787  -0.009  0.002  0.317  0.061  -4.009\* | 0.459  0.370  0.114  -0.017  0.003  0.034  0.006  -0.296 | .12  .09  .01  .00  .00  .00  .00  .05 |  | .79\* | .62a | .59 |
|  |  |  |  |  |  |  |  |

\*p<.001

aunique variability =.26; shared variability =.36

Notably, *Job interruptions by shop* correlates moderately with the criterion variable, *r*=-.23, p<.01, but it failed to contribute significantly to regression. This bivariate correlation seems to be moderated by the relationship between the criterion and all the other predictors in the regression model. With caution, it can be said that even this *externality* (shop performance) affects zonal team performances live on the aircraft: *more shop interruptions less zonal team performance achievements*.

* + 1. **Findings**

Overall, *team performance live on the check operation worsens with higher levels of negative externalities*. The impact of team externalities is rather *consistent*, and does show to affect operational (zonal/supervisory) team performances more than expected. Compared with overall results in previous Chapter 5, team externalities are giving even more leverage upon team performances than internal teamwork factors alone. Regression results (this chapter) indicate that approximately *60% of zonal team proficiency seems to be driven by external factors not controllable by the zonal or supervisory team leads or members (externalities and flexibility)*.

Within this overall percentage (see Table 8-4) of variance accounted for, availability of *Approved manpower* encompasses planning and engineering and human resource departments. This kind of externality accounted for an average daily 12% of performance variance about zonal teams (see ri2 values in Table 8-4). Instead, externalities arising out of stores and materials supports are obviously related to *Pre-draw kits* availability and workshop interruptions impacting zonal and supervisory teams on operational work. Interestingly, no prediction or bivariate relation was found for engineering responsiveness, special tools availability and A.O.G’s within 24 hours. Such externalities may be relevant, but complex relationships may lay behind these measures so that the present regression model was ineffective to reveal any clear cut relationship.

Being aware of the exploratory approach taken, it can be nevertheless argued that team externalities have, at least, as much importance and leverage as internal teamwork effects. However, the implicit logic about *when and where* any team externality will impact on teams might suggest that they would then show more leverage than teamwork levels alone. Externalities represent critical dependencies to which internal teamwork competence would not be capable to compensate for. This, again, corroborates the hypothesis suggested in this Thesis: *for highly dependent systems like operational teams in hangar maintenance it is the environment that accounts for performance more than internal team capabilities.*

Last but not least, the regression analysis showed that the hypothesis about the effects of team manpower flows (personnel transfers from/to other operations) is counterproductive. This confirms the previous case study results as discussed in *section 8.3*.

## **A new concept: Process teams**

Following on from the various case studies and results throughout this chapter some arguments can be highlighted. The efficiency and effectiveness of a maintenance operation depends on the property of the organisational system rather than on the skills and knowledge of any individual or single team. Such properties are distributed in the entire work systems which enable different work teams to operate their activities. No single operational group have complete control on its quality and performance. This also suggests that the individual performance of zonal teams in the maintenance operation is a *distributed concept*: the performance of any team operation is distributed and propagated across the performance of the other dependent teams and units.

Therefore, the individual team performances are fully combined with the external set of work systems performances: they are tightly coupled systems in a process which render hangar teams bounded events within that process, they are *process teams*. A process team model is explained throughout the following sections.

* + 1. **Complex teams need good processes**

The capacity to control team performance in hangar maintenance is revealed to be a function of how many other (external) individuals, groups or units allow any single team to control its resources to operate. Generally, hangar operational teams have no or limited control of their own resources and task inputs. Several external teams and units determine the available resources provided in forms of service support, information, technical equipment, materials, parts procurement, advice and decision. The supervisory teams have discrete control on their resources to deliver decisions and co-ordination on the operational teams, but they, in turn rely on engineering, planning and materials support and advice. These latter support teams control the informational, material and m/p resources of all the other two form of teams.

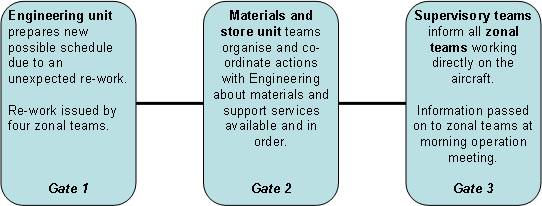
In essence, in aviation hangar maintenance the case of “pure” internal-driven team (in-)efficiency remains a special case: the impact of lack of internal co-ordination or communication within a single shift are generally compensated by the process surrounding it. Instead cross-team/units inefficiencies are more frequent and, safety or operationally sensitive to the dimension of a check operation. From this conceptual view, it is not useful anymore to discuss about work team models *alone*. It is necessary to consider teams as *elements of process segments*; they are not separable entities by a *work process visible in a workflow*. A link to normal work processes is necessary. Simply*, all maintenance teams happen to be by process*.

* + 1. **All hangar teams are *process* teams**

The variety and combination of teamwork requirements for completion of a maintenance check process in hangar encompasses different work team levels ranging from zonal to full project team efforts. As mentioned previously, one of the main characteristics of hangar teams, whichever their form or nature, is that they happen to be by process, they are *process teams* and therefore they need check processes to perform their functions. The very existence of such work teams depends on the expected workflow of a maintenance operation, a check process. Teams in hangar are like *mechanisms* that will co-ordinate a process much larger than their individual and local teamwork performances.

*A process team defines the system of team events required of a work process. A process team is a description of workflow processes in terms of teamwork requirements and capabilities*

It is to note that a process team is a teamwork capability dependent on external work process requirements. The very existence of such work teams depends on the expected workflow of a maintenance operation. Therefore a process team model in hangar is then a workflow configuration required by two or more interdependent work teams co-occurring in the process. A generic process team model is represented in Figure 8-13.



**Figure 813 - Generic *process* team model**

In particular, the picture describes in terms of segments, called gates, the presence of certain teams per specific *separable* work group function allocated from Gate 1 to Gate 3.

The process team model allows a richer understanding of *probable* causal factors and explanations for teamwork based on process demands and inherent constraints occurring at certain stages, gates, during the entire hangar maintenance check operations. Interpretations of team findings are subsumed to process events. *Without this process level*, the analysis would not pinpoint any interaction effects between process events and internal teamwork dynamics.

Overall, it is always possible to describe any team *process* (i.e., co-ordination) with reference to this *process* team model description, which may clarify leverage of internal versus external team factors and effects combined together.

#### **Useful properties of *process team models***

To summarise, some useful properties inherent in the process team model depicted in Figure 8-13 are *integration*, *traceability* and *sensitivity* factors. The three features are explained below:

*Integration*: internal team processes interpreted from an operational sequence point of view. Internal *team process* conditions (see Chapter 6, *section 6.3*) and *process team* organisation and events will be combined. For instance, assessing internal communication effects with the effect of the process already accounted for.

*Traceability*: traceability, as a system’s capability for complete tracing of team factors/events along a process is augmented. It allows better understanding of what is the effect of the work process upon performance of the team.

*Sensitivity*: together with traceability, the (partially-)ordered sequence of events imposed in a maintenance check process (as shown in Figure 8-13) may allow finer-grained analysis of causal models based on sensitivity to initial conditions. Somewhat little upstream events in a workflow could have stronger impacts and leverage on downstream events.

* + 1. **The *minimal critical order*: explanation for process teams**

Overall, the impact of team externalities and flexibility suggests how the traceability and sensitivity factors described above can really reflect causality. In particular, a new causal model based on a concept of sensitivity to initial or occurring conditions in the work process is here proposed and called *minimal critical order* of causality. The *minimal critical order* principle is a simple theoretical mechanism to satisfy a basic condition of causal orders inherent in any work process (either full sequential or parallel), provided that the process allows for upstream and downstream events. A definition of the principle of minimal critical order follows:

The *minimal critical order of causality* *defines that the widest source of dependencies (largest set of time/sequence orders) within a process will contain the minimal causal chain to comply with and generate the maximal leverage on the system*.

This requirement suggests that there is a temporal-sequential and causal order between different elements, where the elements happening upstream and before than others can propagate by dependence an identifiable class of effects downstream on the subsequent elements in the process. The application of this requirement identifies what element (process or system) demands focus first given the leverage it has on the system.

#### **Epistemological advantage of the *minimal critical order***

The principle of minimal critical order of causality implies that any causal and logical explanation of team behaviour and performance, at any level, would contain that order as a *principle of economy*. In fact, causal explanations of team performances, at one specific level of analysis, should favour explanations based on the simplest order of causality which accounted for the largest impact on the system *at that point of analysis*. Team explanations suppressing this assumption are less *parsimonious*.

In such approach this thesis is suggesting, nevertheless with extreme caution, that for teams very dependent on the embedding process, all internal teamwork attitudes, dispositions, skills and individual behaviours are less *parsimonious* explanations of team causality than processes and events happening before and external to the team. These external patterns had shown higher leverage, explanatory power and *simplicity* on team causality, and explanation. That is to say, an explanation based on the problem of a lack of team support would precede the one based on a theory about internal team attitudes or behavioural styles.

**Chapter 9**

**Spreading team risks: a business strategy?**

“*A dysfunctional work group participates with all other work groups to maintain a dysfunctional organizational system. Further, the dysfunctionality of a work group may increase the effectiveness of the organization*” (Friedlander, 1987, p. 304).

# **Spreading team risks: a business strategy?**

The focus of this chapter is about team behaviour in terms of business results at a more global level. Overall, multiple teams and processes all contribute to a business model which may *or may not* satisfy local single teamwork interests and needs. On the contrary some arguments are brought to bear a fundamental idea: local inefficiencies are a necessary price for global organisational productivity and risk distribution.

## **Check performances**

Two primary performance indicators in aircraft maintenance are the check *recoverability* and the *downtime*. The first measure provides a difference between man-hours planned and actually worked. It is a target assessed routinely at the core of all operational teams and support units, that is, the full project team man-hours. The review of this indicator is generally used as basic measure accounting for check profitability and performance efficiency from the maintenance organisation point of view. The downtime indicator instead measures the capacity to meet check project deadlines and planned on-time schedules. Clearly, this is an index very sensitive for the aircraft customers as well.

In general, the resources spent per check are instrumental to understand and verify if the check man-hours sold and billed equal out and provide the expected recoverability figure. Every time the resources spent are too high or downtime delays occur there is a case for questioning the proficiency and quality of the operations. The man-hours lost, as the actual man-hours overspent over those billed, are symptomatic of a lack of efficiency, and, the downtime delays of poor quality of service. *And, quite obviously, the project team involved in the check operation is rendered liable for such lack of services*.

To investigate such relationships, three case studies were carried out on the subject matter and presented below. As test bed, the productivity and efficiency in the years 2002/3/4 was analysed in one large north European maintenance company. The company (the same one discussed in the previous chapter) has shown to be highly representative for concurrent project team operations, across hangar/bay operations. All analyses were carried out as part of the ADAMS 2 EU funded project (ADAMS 2, 2004). The study showed the relations between technical performance figures and team factors issues.

As the reported case studies report on a single very large aviation maintenance organisation, generalisation of results is to resist. Nevertheless, the present findings match what other previous research did put in evidence across several other organisations and maintenance companies (Taylor, 1990). The present findings seem to drive also towards new considerations about business strategies and work teams’ utilisation.

* + 1. **Case Study 1: 35 *basket cases* in 2002**

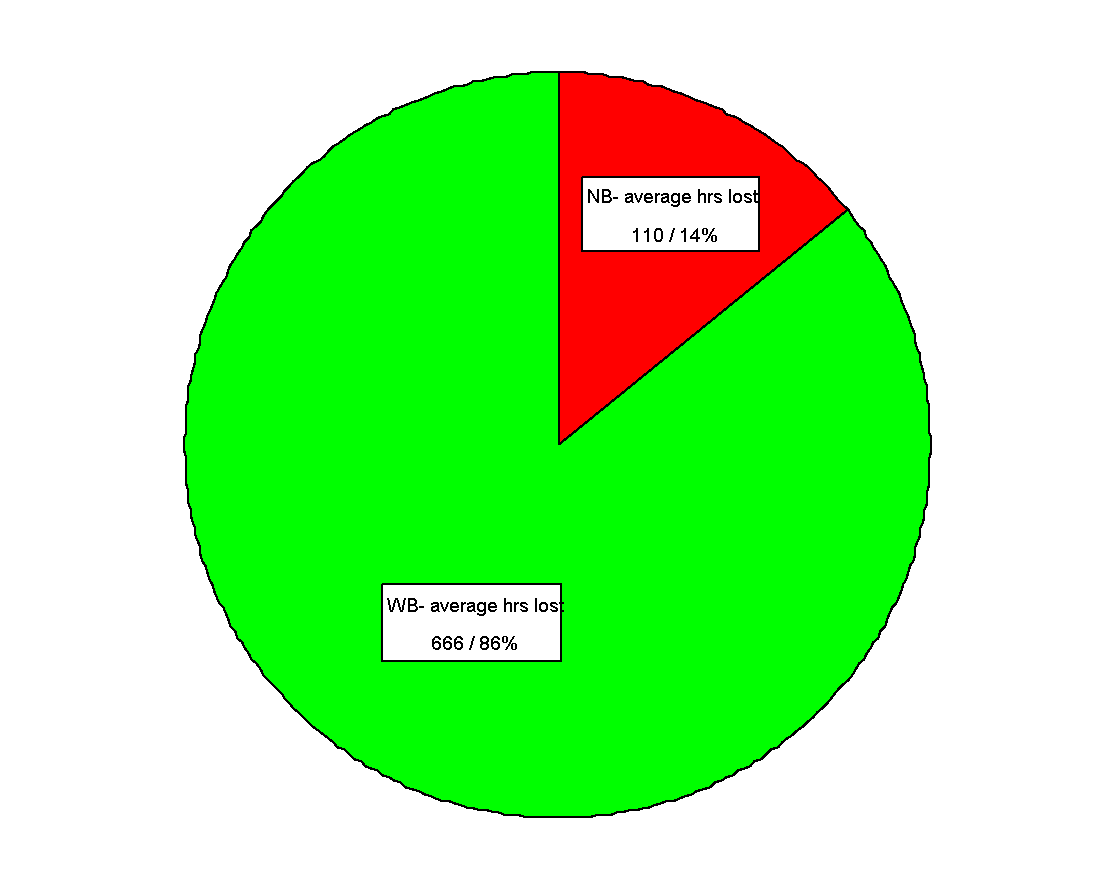
In the company under study the performance figures of a random sample of 121 check operations in 2002 provided a very peculiar result. The recoverability trend shows that the minimal break-even (minimal 100% recoverability) was obtained by only 38 checks. This is a clear loss of profitability.

Figure 9-1 shows for the same sample of 121 checks that *a large portion of overspent man-hours is contained in a minor proportion of bad checks.* These checks are defined here as *basket cases*. In particular, looking at Figure 9-1, the 29% of the total checks analysed (35 out of 121 checks) contain the 80% of the total man-hours lost. This equals to a cumulative 79.852 man-hours overspent lost over a total of 99.759 lost *in the 83 checks failing to reach the break-even*. The average man-hours lost in these 35 basket cases is 1.748 with an average recoverability of 78% and 5 days late.

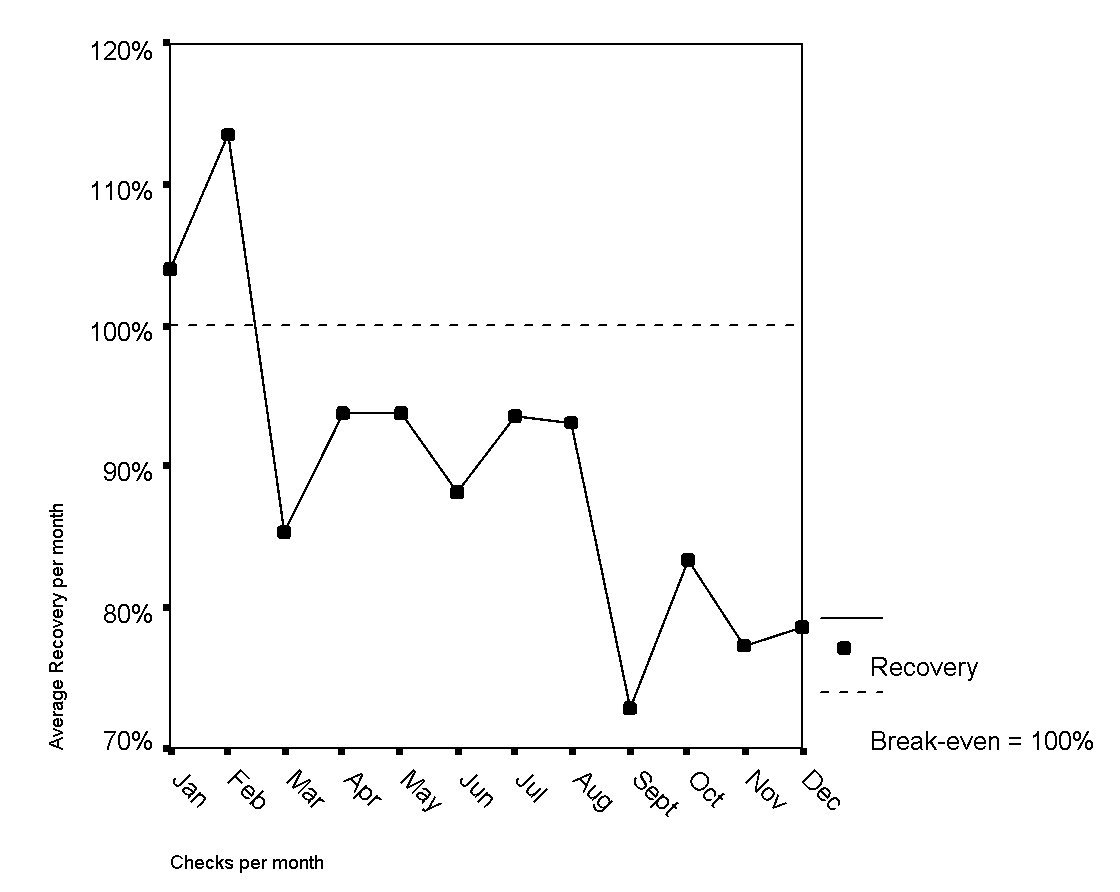
Considering all the 121 checks, the distribution of the average man-hours lost between performance on bigger (i.e., wide body) and smaller (i.e., narrow body) aircraft shows a reasonable difference. Technology and aircraft *size* makes a difference. This is shown in Figure 9-2. The planned check *dimension* is also significantly related to the final check performance in the overall sample of 121 checks: the higher the *planned* man-hours required (bigger check), the higher the man-hours overspent on the check (r = .42, p<.01).

As shown in Figure 9-3, the average monthly check recoverability showed a progressive decline throughout the year with very low check performances towards the end of the year (September and December ’02). A seasonality effect was present.



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**Figure 92 – Breakdown of 121 checks in 2002, average m/hrs lost per wide vs narrow body aircraft**

**Figure 93 – Recovery trend: Jan-Dec 2002, average recovery achieved per month**

#### **Findings**

These preliminary data suggest that very bad project team performances within a year are *concentrated*, and contain most of the man-hours lost in the sampled 121 checks.

An implication about teamwork resources is advanced: the teamwork and human factors competence and capacity contained *within* the teams is *part* of the problem explaining inefficient check performances, but could not reflect the entire problem at all. *In fact, if team competence (i.e., team members’ knowledge skills and attitudes towards teamwork) would be the main primary factor accounting for these check inefficiencies (overspent resources), those 35 very bad performances would appear more diffused and spread across the overall sample. This seems not the case*. Nevertheless, 83 over a total of 121 sampled check operations did not reach break even levels: a clear *spread* of loss of profitability is present. The hypothesis could be that there might be other factors affecting the checks operations interacting heavily with competence as previously presented across Chapter 5, 6, 7 and 8. Such factors, plausibly, do affect the level of flexibility and capacity of any operational team at another level of influence.

Furthermore, check *size* counts in terms of performance levels and proficiency displayed by the teams. This clearly indicates that organising and managing larger activities as well as human and technical resources per any single check requires higher level of monitoring, communication and co-ordination: this interaction and co-ordination control is not working well for those teams managing bigger checks, *therefore bigger teamwork elements*.

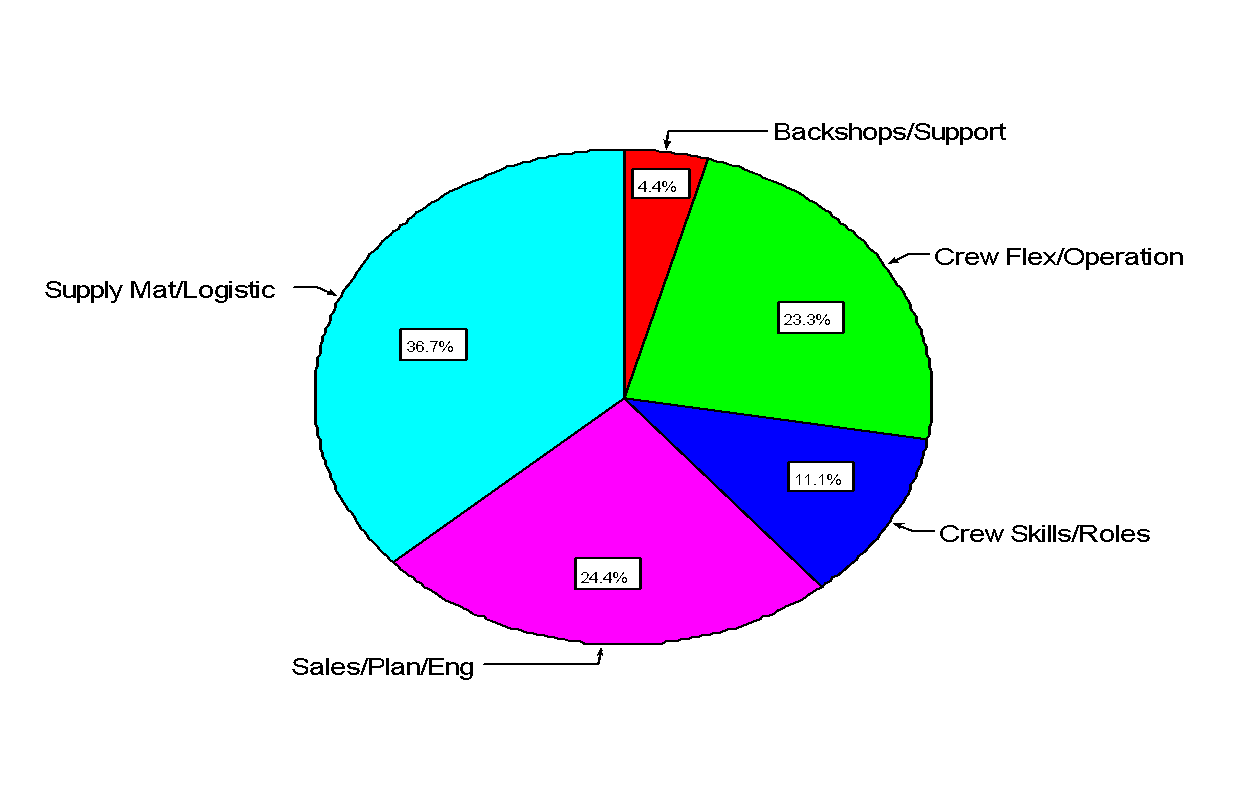
In fact, increases in size of a work system follows increases in operation-integration conflicts which result proportional to the number of interdependencies across the units. Again, the co-ordination in a check operation and the integration of its activities can be achieved only by *optimal integration and co-ordination* between teams *and* the external interdependent support units.

* + 1. **Case Study 2: Crew Factors and performance in 2003**

The main key results presented so far in Case Study 1 did put in evidence a comprehensive pattern of performance issues affecting the company’s check operations in 2002. In such perspective, an analysis on the influence of team factors upon technical performance inefficiencies was carried out. This was done by an internal company’s action, a dedicated survey, conducted at the start of 2003 to verify strengths and weaknesses in check operations and productivity. The survey is reported in Annex 9A.

This survey was organised into 24 interviews with top, middle and front-line managers of Planning, Engineering, Services, Sales and Operations. The interviews were conducted by two dedicated managers from the company’s Aircraft Overhaul division. The key objective was to elicit and highlight critical inefficiencies, potential improvements and opportunities to augment profitability and quality for the new working year 2003. But, *indirectly, these interviews contained highly valuable information on the perception of the causal factors impairing directly or indirectly operational crews and check operations altogether*. The *crew* wording here stands for joint supervisory and zonal teams (the actual operational work teams on the line) of the entire project team (which generally comprises also all support units involved in the check operations as well).

All interviews were reviewed and re-assessed by the writer with the objective to pin-point, highlight and qualitatively cluster any team factors of relevance (see Annex 9A for the full survey and grouped responses).

Figure 9-4 below shows the survey responses (in %) grouped by areas of perceived inefficiency by the interviewees. Such inefficiencies (as response items describing a perceived conflict or dysfunction) were grouped into five main areas. Notably, *these areas mirror to a large degree the concept about team externalities (see Chapter 8) and internal team dysfunctions about roles, competencies and configuration.*

**Figure 94 – Areas of inefficiency impairing check operations (company survey, Feb-2003) *NOTE: Crew stands for supervisory and zonal teams***

#### **Findings**

In particular, the percentages of responses in Figure 9-4 are distributed over three major areas of dysfunction: Supply Materials/Logistics (36.7%), Sales/Planning/Engineering (24.4%), and Crew Flexibility/Operations (23.3%). For the first two areas, the main issues raised by the interviewees were “Material verification”, “Materials: service level is unacceptable”, “Delivery cost and time delay cut out”, “No match between estimates & actuals”, “Unrealistic downtime”, “Records man-hour estimates but not tooling and materials”, “No preplanning”.

Instead, for Crew Flexibility/Operations some of the most representative issues were “Inefficient working”, “Flexibility of staff”, “Day-by-day plans” and “Under-manned vs over-manned conditions”. Such planning, flexibility and configuration factors are perfectly in line with the findings on the previous case study of 2002.

Clearly, the lack of responsiveness and efficiency of external Support and Supply units (i.e., Sales, Planning, and Engineering) have a major implication on project team productivity and performance. Secondly, Crew (project team) flexibility and operations are perceived ineffective. They are not *resilient* enough to cope with varying check demands and inefficient supply chain responses. Apparently, *team flexibility, not planning, is the primary mechanism to compensate for continuous workload fluctuations*. Unfortunately, solid team flexibility requires higher level of integration and cross functional co-ordination that is very difficult to sustain in case of *limited resources*.

As expected, Crew Skills/Roles (11.1%) is not perceived as much critical as the first three factors above. Most of team competence problems are defined as “Delegation Upwards/Downwards”, ”Use of Crew Managers/Duties” and “Role of support planner and Supervisor role not thought out fully”. Such problems are clearly more concentrated in role functions and allocations than skill levels and competence.

In line with previous findings of Chapter 5, *the present results suggest that focussing on internal zonal or supervisory team skills, training and competence may be a less sensible area to gain a real performance leap rather than, on the opposite*, to focussing on capabilities and co-ordination of all main external Support units (i.e., Supply, Estimation Planning, Engineering, Tech. Services) of a full project team structure. Verification of technical integration and co-ordination of supervisory and zonal teams (operational groups live on the check operations) with all external functions and support units is more convincing argumentation about check performance levels overall.

The role of Back-shops (4.4%) is not addressed as highly problematic area. However, Back-shops factors addressed “issue of control”, where a decentralised or “more local control” by the operational teams (supervisory and zonal teams) could be a more favourable solution. Notably, the impact of the back-shop activities over the operations depends heavily on their own supply system: most of back-shops operations depend by a proficient supply for AOGs, Rotables and Parts orders, tracing shipping statuses and obtaining deliveries on-time. *Any inconsistency in the shop-related supply will become a zonal team inconsistency*. Evidently, more research on this form of *doubly support team externality* is to be considered for future research.

Overall the results in Figure 9-4 show two important aspects:

* Some areas of perceived inefficiency have more *importance and weight* than others. And *external factors may exert more influence than the internal teamwork factors on check proficiency.*
* Whether internal or external, such factors could be *ordered by their individual occurrence in the check process*. This could provide a more reliable and accurate framework to understand *where and when* it could be more effective to recommend interventions: i.e., enhance externalities, spend on training resources or engage in team re-engineering activities. The existence of *upstream* and *downstream* factors in the process seems a key variance that can be taken into account to assess these work systems. Most important, there seems to exist a form of risk distribution throughout a work process, which apparently may fit in with the *process team model* presented in previous Chapter 8.

* + 1. **Case Study 3: team inefficiency throughout 2002, 2003 and 2004**

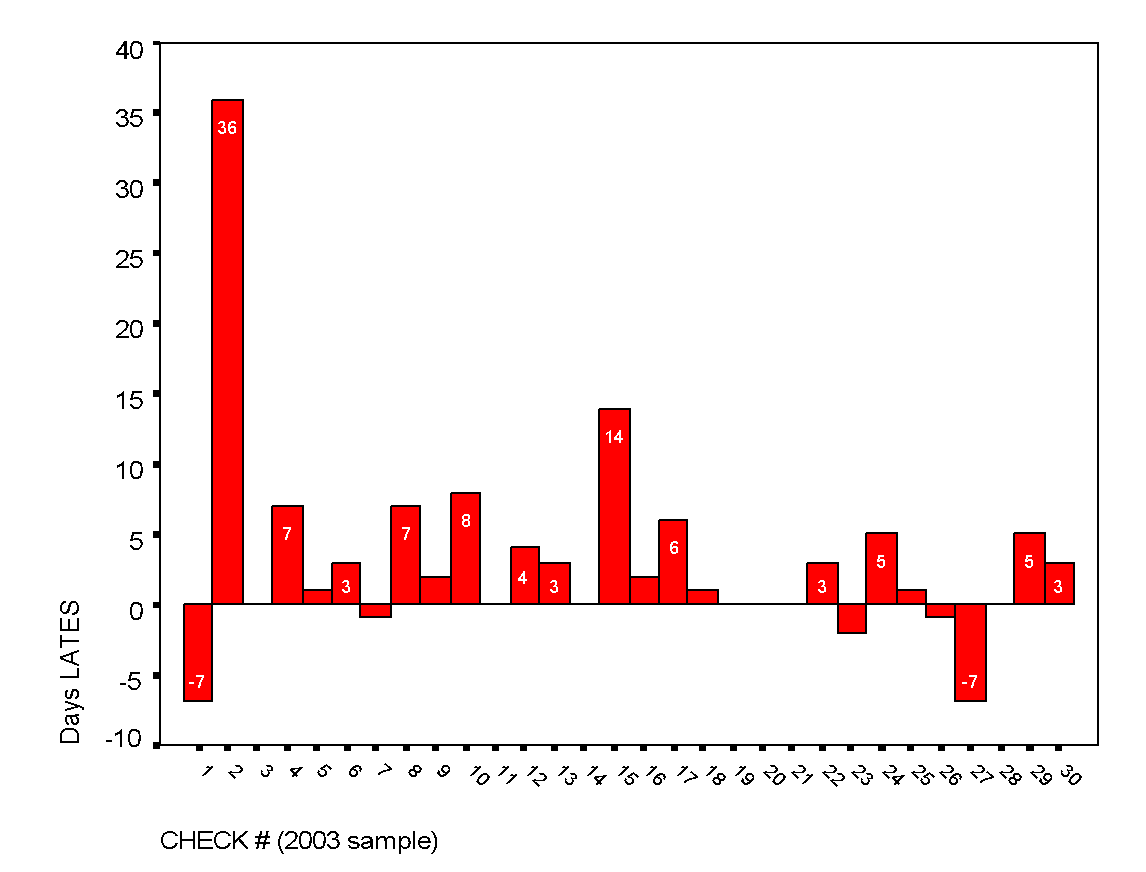
Following on from the previous analyses of check performances in 2002 a new investigation was carried out over some randomly sampled checks that were performed throughout 2002, 2003 and 2004 in the same company as above. The main objective was to determine if low levels of performance could have simply been contingent to 2002 year’s trend or, more likely, being a more *generalised and diffused* condition in the same company’s operations and teamwork. Downtime delays, unexpected man-hours variability across operations and work teams were addressed as available relevant indicators to test the levels of operational performance and teamwork.

#### **Downtime factor**

A sample of 30 checks was randomly chosen from the first three months of the working year 2003 and each check operation’s downtime (planned and actually used) was measured accordingly. Each delay according to a planned release of the aircraft from the hangar is obviously representing a negative performance. Here below are the main results:

* The downtime delays throughout the 30 checks are *consistent* in the sample. This negative trend is shown in Figure 9-5. The percentage of checks with downtime inefficiencies is still relevant: 60% of the sampled 30 checks were delayed.
* The average days late (downtime delays) in the overall 30 checks is of 3.5 days, with a high variability across the sample ranging from a minimum of one day to as much as 36 days delay.

Overall, the downtime inefficiency appears to be *distributed and spread*.

**Figure 95 – Downtime for 30 checks (first 3 months of 2003)**

#### **Unexpected man-hours variability**

The evidence of overspent resources (man-hours) in the same organisation was investigated on another random set of check operations performed between 2002 and 2003. In this case however, the analysis was finer-grained and centred on the study of the *daily* *variability* of resources allocated within each check and the flexibility deployed to control the volume of work.

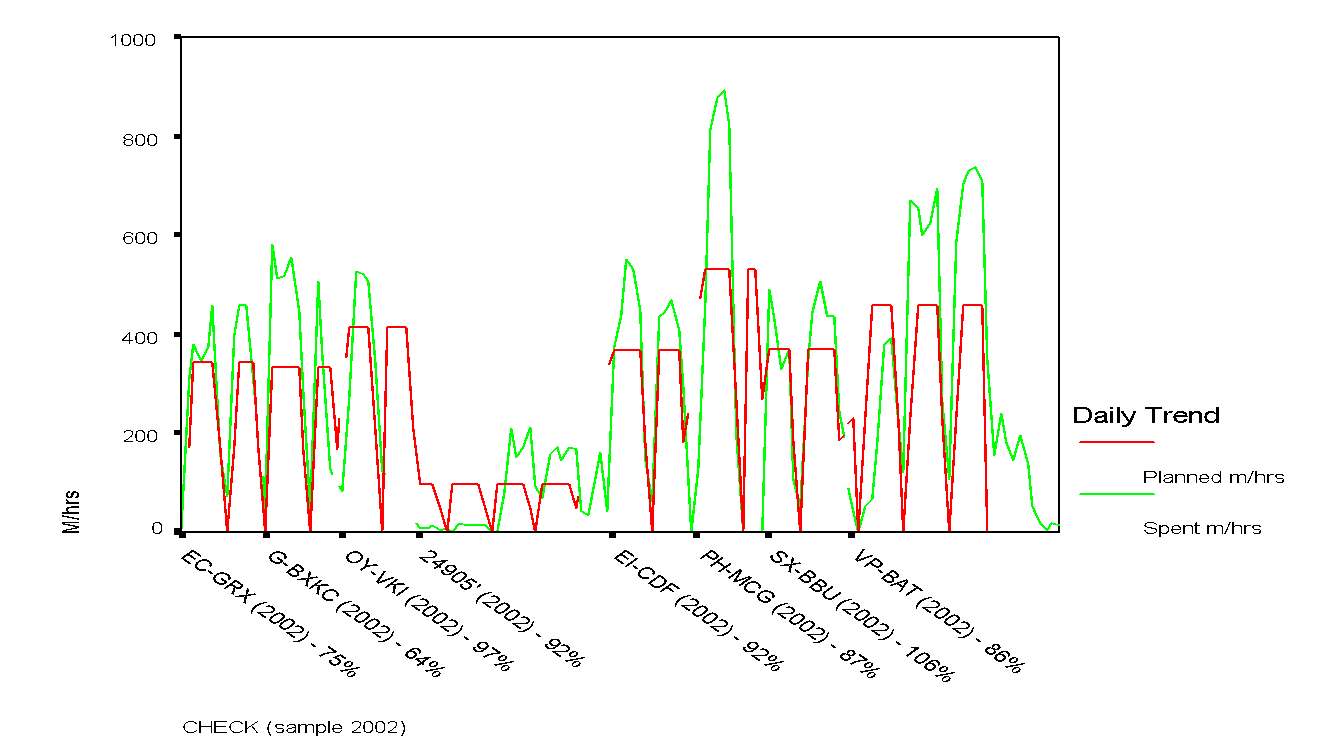
The key performance indicators utilised to this verification were the daily man-hours planned (estimated for use) and the daily man-hours actually spent (factored) per single check per day. Twelve checks were randomly chosen between 2002 and 2003. The results are shown in Figure 9-6 for 2002 and Figure 9-7 for 2003 data. Referring to both years’ results it is no doubt that check operations are not stable in human resources terms. They show a marked *twisty* trend in crew resource management.

Resource utilisation within every check and progression plan appears highly *inconsistent*, however *invariant* across the 2002 and 2003 samples:

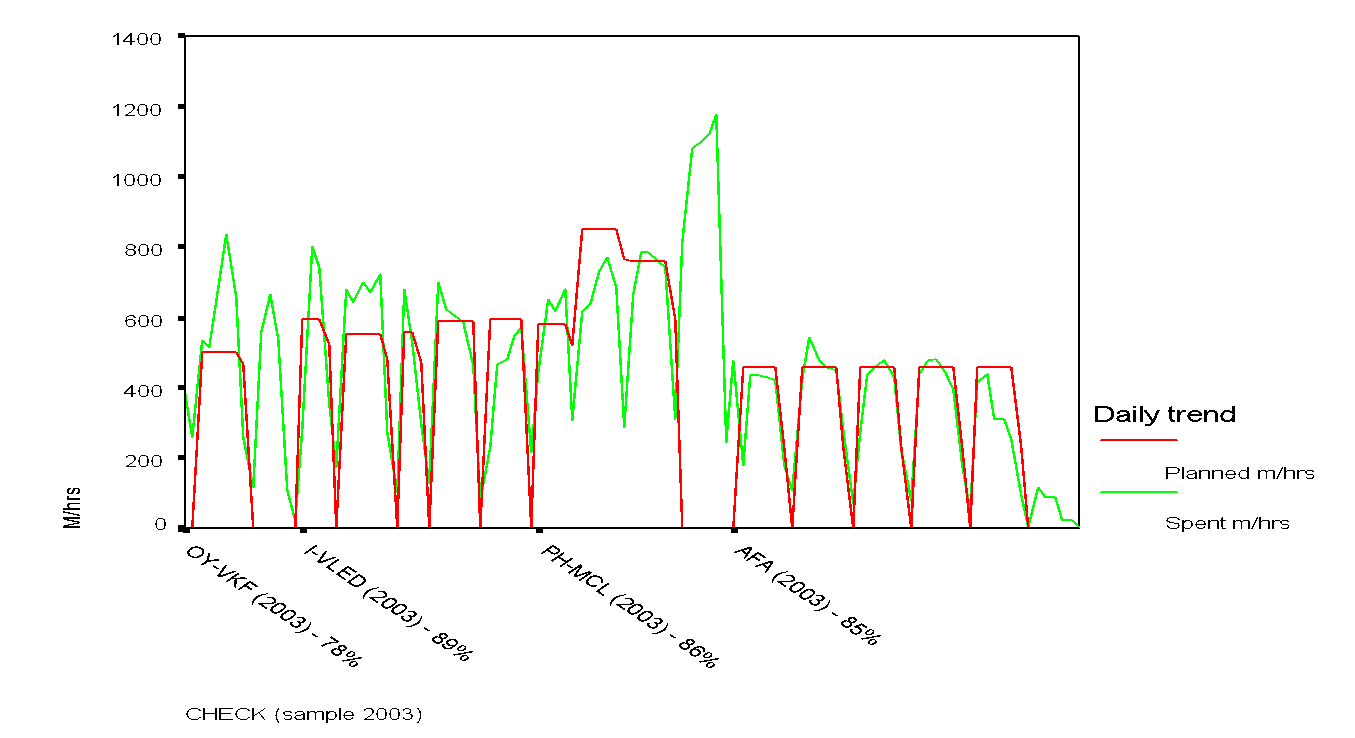
* Check operations teams (project teams) tend to manage and spend human resources independently of the estimates (planned man-hours): *The amount of man-hours spent and planned per each day or week period is almost never aligned. The planned man-hours are never reflected in the actual man-hours spent on a daily or weekly basis.*
* The different check performances show a remarkable variability over time, *but the majority of cases overspend man-hours resulting in low recoverability levels. This trend kept almost all the checks below a minimal break-even level.*

Overall, there is a trend towards ineffective planning of team member resources. *This seems a diffused condition not specific to any project team or check operation*. It appears more as a generalised condition to many teams. It could be argued that workload fluctuations and operational conditions in hangar demand high levels of flexibility which are apparently lacking, at least in this case.

Despite teams are different for every operation performed, trends in performances do not change neither in level nor direction. That seems to suggest that whatever team is in control of the operation, performance apparently is invariant.

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**Figure 96 – Trends of daily Planned versus Spent m/hrs in 8 checks of 2002 (recoverability in %)**

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**Figure 97 – Trends of daily Planned versus Spent m/hrs in 4 checks of 2003 (recoverability in %)**

Thus, other variables should be taken into consideration to account for such flattened and similar performance situation. Notably, what is *also* invariant is the set of systems around any project team. Such systems are all the support and service departments which may prove to be critical to mediate technical performance levels for project teams. If they are the only process elements that do not change *across* operations, then their performance has to be very influential on check performances overall. This is fully in line with the concept of externalities effects and findings in Case Study 2 above.

However, other arguments are considered. In fact, despite the fact that one theoretically may consider that all teams are unprepared to bring up higher performance, *all teams could be forcedly limited in their capacity in order to strategically manage limited organisational resources and shared support and service units*. Such controversial hypothesis may suggest how team risks are voluntarily distributed.

## **Overall finding: the spread of team risks**

Large systems of performance like multiple aircraft maintenance teams are expected to perform *without failing across* operations. However, the three case studies highlight how technical performance *per* check operation is profoundly affected by several deficiencies at organisation, management and support level, rather than a result of internal single-team deficiency.

Interestingly, such findings are revealing a new argument *beyond* the externalities issue. A new look at the problem of maintenance team performances and management of technical operations:

a relevant portion of teamwork and performance inconsistency at local project team levels *is* a strategy to maintain acceptable global organisational results achieved by *team* *risk distribution*.

Put simply, the system is too large to be locally resourced efficiently and effectively at any time at each team level. However, rather than having single or very few project teams outperforming among all the others by absorbing all resources available, it is possible to provide *some* resources, capacities and capabilities to all teams with the effect of *distributing risks* of moderate performances organisationally. Basically, due to an intrinsically limited pool of shared resource availability, no project team will be fully resourced and serviced, but all of them will get some resources in order to survive. This strategy would provide an organisational equilibrium by satisfying the needs of the system of the groups, units and relations, not the singles; the system of teams is satisfied not the teams themselves.

The concept of *team risks distribution* is well mirrored in the Friedlander argument here below.

* + 1. **Friedlander argument**

The findings from the case studies so far would corroborate a controversial hypothesis about *team risks distribution.* Such idea is reinforced by what it is here termed the *Friedlander’s argument* (1987, p. 304):

“*A dysfunctional work group participates with all other work groups to maintain a dysfunctional organizational system. Further, the dysfunctionality of a work group may increase the effectiveness of the organization*”

This argumentation suggests that local and global measures of team and organisational performance work on different, sometimes conflicting criteria:

1- "a work group may well operate somewhat inefficiently in order to maximise its contribution to the organisation"

2- "if each component work group operates as efficiently as it can, the organisation as a whole will probably operate inefficiently"

3-"if we get the organisation behaving as well as it can, it may be that none of the individual work groups will work optimally on their own terms"

In essence, it seems necessary to somewhat fail at local levels, at each single work group to maintain global organisational proficiency. The reason for that is the empirical evidence that in the presence of limited and pooled resources (human and technical), or insufficient planning and support capacities, all local units should adapt and sacrifice their expected performance levels so as to maintain global organisational proficiency and robustness. Every single project team cannot perform perfectly as it will end up exploiting resources which are limited. Such resources are pooled among *many* other teams: no team can be excellent as it will cost several others to fail.

Overall this is what substantially emerges across the case studies presented in this chapter. Such findings are mirroring that there is not real difficult link between teamwork and technical performance. Instead a business strategy, the team risk distribution, may lay behind this relation. A business strategy spreading the likelihood of limited team and technical failures at local levels so as to keep the total system of teams from collapsing altogether and maintaining it into a global organisational capability.

From a logistical point of view, the economy of scale imposes that production lines (teams on the operations) should relay on or be granted of certain level of support, but this support structure instead is always limited to contain the costs of the total supply.

The strategy here is that the organisation *prefers* to provide teams with faulty supports overall, rather than maximally improve support efficiency and effectiveness per single check operations: optimising organisational production by maximising spread of risk and failure locally.

Last, but not least, the more you distribute risk the harder it is to *pinpoint* the source of that risk, therefore the *responsibility/liability attached to it*.

**Chapter 10**

**New concepts for teams in hangar**

“*Organic structures are themselves expression of an ordered process, and they are only maintained in and by this process. Therefore, the primary order of organic processes must be sought in the processes themselves, not in pre-established structures*”(von Bertalanffy, 1960, p. 17).

# **New concepts for teams in hangar**

This final chapter presents the *team system* model, by which the *process team* and *team process* models (Chapter 6 and 8) are unified into a single scheme. This latter scheme (or framework) is termed here the *team multivariate frame*, and it mirrors the rationale of multiple levels of team explanations as suggested in Chapter 1. This multivariate approach is indicated as new means to model and theorize about teams in real work environments. Then, the set of work hypotheses about work teams presented in Chapter 3 are reviewed considering case studies, survey analyses and in- field research findings presented across different chapters of the Thesis. Such results will be discussed for team design and re-design purposes as well. Finally, a discussion about new emerging concepts suggested for future team research in hangar maintenance will conclude this Thesis’ work.

## **The team system model**

Previous findings in Chapter 2, 6 and 8 do evidence that aviation hangar maintenance is made of *teams*, that is, teamwork based systems for organisations that have to meet objectives for a business to control.

Following on from this, it is argued with confidence that aviation maintenance organisations do generate a team effort and *model it*. Although not explicitly all the time, there exists a *concept about teams*, followed by ideas and actions to develop and maintain *it*. Put simply, the two models about hangar work teams, the *process team and team process* (Chapter 6 and 8 respectively) *do not seem to happen by chance*.

The hypothesis is a *design criterion* about teams. Briefly, work teams require a system to preserve their existence as units within an organisational structure. This underlying model is here called the ***team system***:

The *team system* *is* the available organisational capacity which enables *process teams* to develop, perform and maintain assigned functions and goals, which in turn would favour a normal development of *team processes*. This organisational capacity should drive the transformation of a team concept into a best practice *by design*.

* + 1. **The team concept**

A model of a team system is depicted in Figure 10-1. According to this model a preliminary assumption is that work organisations (top-mangers first) should have a sound and explicit *team concept*. For instance, there must be some shared ideas about teams, their role, values, functions and possible structure.

From a design point of view, three basic requisites may be considered essential to provide such a *team concept*. First there should be *recognition* of what a team is. There must be an idea on the role of teams, their importance and elements to recognise them. A common concept should be agreed. Managers and leaders should come to terms with a simple question: *what is a team in our organisation?*

Following on from this, a system to team formation via *training and indoctrination* becomes essential to spread the presence of a team concept. Put simply, the organisation must provide means to spread and reinforce the meaning of it. Finally, the team concept requires some dedicated processes to *monitor and maintain feedback* on how the concept is understood, shared and conceived.

In fact, the team concept is never static and would change over time. Maintaining and possibly evolving a team concept is as important as its actual implementation and supervision.

* + 1. **The team programme**

The team concept is an idea, a value which needs implementation. Therefore the organisation has to implement such concept into real processes: teams are always to be rendered operational. In this sense, a planned action or program must be in place to convert the team concept into reality. Three basic requisites are of uttermost importance to provide such transformation.

First, *resources* follow needs. A dedicated process would provide any work team with appropriate human resources as well as technical means. Work teams resources are even more important for complex work systems based on heavy interdependencies.

Second, available and reliable work processes facilitating *team organisation, planning and scheduling* should be in place to facilitate team configurations and operations. Planning and scheduling are paramount to keep multiple hangar operations under control.

Third, *workflow and work processes* should fit in with team capabilities. Teamwork and performances cannot be achieved successfully if the organisation keeps work processes separated from teamwork processes.

In hangar maintenance, any team operation and subsequent performance depends by the process it is embedded with. If real workflows do not facilitate teamwork, team processes will succeed by continuous adaptations only. The implication here is that technical workflows and teamwork needs and events should be designed together.

* + 1. **Use of the team system model**

The team system model represented in Figure 10-1 is in the form of a condition-tree structure, likewise the team process model presented in Chapter 6. As any three-like structure it could be formalised and quantified so as that the probability values at any lower nodes determine the probability values of higher nodes to the top team event. Such formalisation is very useful in (re-)engineering terms. Team (re-)design efforts can be verified according to the reliability levels given at each node of the tree. So this modelling could be very practical to measure global reliability levels of a team system according to all the assumed levels combined bottom-up.

Put simply, this perspective allows using the model as a potential *auditing map* to determine major team risks in quantitative terms about a model of a system. This team system model can be tested to validate the robustness of concepts and programmes of those managers *responsible* for team designs or team deployment.

At this stage, a combination of the team system model with the previous process team and team process models can be theoretically relevant and operationally useful. It would support a multivariate approach to team explanation (i.e., combined levels explanations for the same team element - see Chapter 1). Such overall multivariate approach is presented in the next section below.



## **The team multivariate frame**

As suggested in Chapter 1 different levels of team explanation were considered: 1) high-range explanations addressing organisational requirements and plans to team presence and implementation, 2) middle-range explanations addressing the organisation of teamwork-oriented processes, and finally 3) short-range explanations addressing basic behaviour within the team and teamwork competence overall. To note, high-range explanations are generally not easy to verify or test. Instead middle- and low-range explanations are possibly tested or verified more easily and frequently (Bryman and Cramer, 2001).

This high-, middle- and low-range explanations (“theories”) are mirrored in the team system, process team and team process models respectively. Finally, the three models are merged together to define a multivariate approach, a componential view about teamwork, team events, outcomes and relative enabling systems. This new reference system is here called *team multivariate frame* and appear in Figure 10-2 below.

Certainly, the multivariate frame brings an order of analysis that varies. It does bring different perspectives based of three different team modelling frameworks, but a minimal criterion to follow is that any of the three levels of explanation derived by the models should be coherent from a logical, *sequential* and, where possible, from an empirical point of view.

For instance, reporting from Chapter 1: “…, the search for an explicit and sustainable relation across diverse levels of team explanations is not only desirable but will be considered a theory-building requirement underlined by the following argument:

*A single level of explanation for any team behaviour is less probable of verification/falsification in the absence of a measure of the relationships between this level and at least another (possibly) dependent explanatory level.*”

It is here assumed that the three levels of explanation do mirror the three team models presented in this Thesis, and, together, these models coexist and support each other to provide a richer composite meaning and interpretation to work team behaviour in aviation hangar maintenance.

* + 1. **Triangulation in the team multivariate frame**

Focussing on Figure 10-2 again, it can be said that any team analysis can be approached as *triangulation* across the three reference models. That is, any team event or outcome in a real work flow brings all the three models into full discussion and review. All the *team system* requisites and *team process* elementscan be studied *per* specific *process team* considered and co-occurring. It is an analysis and review of the actual fit between three models and the processes involved. As an example, Figure 10-2 represents the process team event “Zonal teams re-schedule daily work” that would be assessed in terms of the team system requisites and the team process elements for consistency and reliability. In this case the starting point is the process team model. But this is not fundamental. What is relevant is the study of the relationships *among two team models keeping fixed the third one as reference point*. It is a continuous triangulation among three models in multivariate approach.

* + 1. **Some implications hidden in the team multivariate frame**

Although not explicitly stated, a suggested sequence in the team multivariate frame is represented by the levels of explanation. Obviously the team system model is the key starting point. Given a team system model, the configuration of process teams is investigated. Finally any team process model can be studied at the light of the other two previous parent levels (models). Cleary some implications in the team multivariate frame follow:

1. The design and requisites are the most inner values and dispositions determining the *dna* of any work team. The *team system* is the explanation of what the organisation thinks, envisages and provides for any team event. This level is the most critical mechanism to evolve team concepts into team events. Without a reliable and consistent team system, process teams may not perform reliably and the entire team-based work system will be affected.
2. If configuration of *process teams* becomes unreliable (e.g., inefficient organisation across groups) then any single team may be affected proportionally to their level of dependency from other groups and external systems: team externalities will occur and degrade the global work process.





1. Any single work team would inherit a *team system* and a capacity of being *process team*, which in turn shape consistency and robustness of the internal *team process* (e.g., teamwork, communication, attitudes and values). Any team process analysis has to be organised around the other two explanatory and wider levels.

Overall, team process, process team and team system, will provide a multivariate and integrated view of the work team concept and its application in real work systems.

## **New hypotheses of research: a review**

Chapter 3 (*section 3.5*) highlighted six new hypotheses of research about hangar maintenance teams. These are summarised below and discussed according to the main findings of this Thesis. More in-depth conclusions per specific argument can be found at the referenced chapters.

* + 1. **Main findings**

1. *Internal team dynamics and competencies are not reliable predictors of teamwork levels and task performances for teams with very large interdependencies about the context*

The literature review about work teams in maintenance in Chapter 2 seems to corroborate such hypothesis. More important, this finding was found by all survey investigations performed and reported in Chapter 5. The AMAS surveys performed across different organisations and periods between 1998 and 2001 revealed how neither teamwork proficiency nor check operations performances are reliably predictable (i.e., MANOVA and multiple regression) by teamwork skills or attitude dispositions. The relationship seems to be conditioned and accounted for by other organisational variables.

1. *Compared to internal team attitudes and skills, impact of external systems and team configurations (e.g., technology demand, proficiency of supports, team variability) account for higher levels of variance in operational performance*

Further evidence from the AMAS survey in Chapter 5 suggests how performances of check operations depend more on the support teams and external service proficiency rather than teamwork competence of zonal teams performing hands-on maintenance. Also, previous Chapter 4 evidenced the highly dependent nature of zonal and supervisory teams by the level of support and service received. This dependence from the system-environment was suggested also in Chapter 7. High need of co-ordination systems have to be in place reliably within the entire work process of a check operation. Notably, internal team attitudes and teamwork skills become part of a larger system to take into account in order to understand and predict hangar maintenance team behaviour.

Finally, the key role of team flexibility and team externality, that is, a model of external performance influence, was evidenced in Chapter 8. Team externalities and configuration of man-power (within and across check operations) account for higher check operations performance variance than team attitudes and internal teamwork skills.

1. *The ability of individual teams to adapt to unexpected situations and events will augment effective task accomplishment but reduce sensibly team efficiency*

Observations of real teams in Chapter 6 revealed that teamwork competence is situational and adaptive team behaviour to contextual events prevails. In *Section 6.1.5.2* it is reported a common condition found in several work teams in hangar operations: “Behaviours in the observed team seemed to rely on a basic form of knowledge shared by the hangar environment community rather than a characteristic knowledge of the team. Also, group behaviours appeared to be highly *automatic*, *driven by situations known in operational terms,* difficult to separate in single models of “pure” communication, co-ordiantion, or leadership acts.”

The relationship between loss of team efficiency and adaptive team behaviour was pinpointed clearly in Chapter 8. For instance, the study of e-mail transactions between team supervisors, managers, engineering, planning, etc. showed how entire project teams must adapt and re-organise regularly to fire-fight unexpected situations (e.g., lack of man-power, tools and supports responsiveness). Apparently, such adaptation is useful to mange workflow fluctuations and unexpected events, but often it results in operational delays and underperformed maintenance service overall. Also in Chapter 8, it was pinpointed how higher levels of team flexibility and a changing team configuration (*section 8.3*) would predict lower levels of check recoverability (efficiency) and task performances accomplishments (effectiveness).

1. *Team adaptation will result in accepted team norms and practices that are generally considered routine violations of organisational procedures, norms and practices*

Chapter 6 on real work teams put in evidence that several teamwork behaviours are situational and contextual. Nevertheless, a critical finding is highlighted in *section 6.2.3.1*: “Actual hangar operational scenarios contain an infinite number of events that any work group has to deal with by creating/inventing and evolving a much larger combination of best practices, teamwork behaviours than those ones pre-defined by rules and procedures which regulate them.”

Notably, this need of adaptation may bring forward certain work practices which are obviously violations of safety-oriented procedures and practices. Examples of such maladaptive behaviour are evidenced in the case studies of Chapter 8: 1) unchallenged inadequate level of personnel to task performance, 2) unchallenged misuse of overtime by team members like consecutive work-shifts with no rest, and 3) – passive acceptance of lack of unit support efficiency and service responsiveness.

These latter findings above lack of generalisation but are suggesting how the problem of routine violations indeed originate from the management of pooled/limited resources. The acceptance of misbehaviour by single team members is likely a *by-product* of such condition. More research about this hypothesis is clearly needed.

1. *For large systems based on pooled resources (human and technical) single individual teams should become inefficient or ineffective to certain degrees in order to maintain acceptable global organisational performance. The risk of failure is distributed and shared by all local teams so as to reduce concentration of risks which favour global systems breakdowns*

Chapter 9 highlights this hypothesis where the three case studies presented seem to converge and confirm such proposition. The *local* lack of resource planning and responsiveness, *local* teamwork deficiencies and unexpected manpower variability are generalised and diffused issues, they are problems spread in the system, but notably there seems to be like a form of business strategy behind such condition. In *section 9.2* such argumentation is presented: “Put simply, the system is too large to be locally resourced efficiently and effectively at any time at each team level. However, rather than having single or very few project teams outperforming among all the others by absorbing all resources available, it is possible to provide *some* resources, capacities and capabilities to all teams with the effect of *distributing risks* of moderate performances organisationally.” Such overall findings are also fully mirrored in the Friedlander’s argument (1987, p. 304):

“*A dysfunctional work group participates with all other work groups to maintain a dysfunctional organizational system. Further, the dysfunctionality of a work group may increase the effectiveness of the organization*”

1. *Organisational resources (time, technical, and human resources) are reliable predictors of team efficiency and/or effectiveness*

All findings across Chapter 5, 6, 7, 8 and 9 mirror a common conclusion: the proficient management of organisational resources will augment team consistency and lead to higher operational performance in *aviation hangar team-based operations*. The lack of it triggers any form of coping strategies to survive. Overall, the control of the organisational resources is the basic determinant to team performance. Notably, in Chapter 9, the team system model within the team multivariate frame reflects this level of control.

## **Future team research *in hangar***

This Thesis’ work was an attempt to study by finer-grained models some basic propositions about team and teamwork in aviation hangar maintenance. Together with the direct or indirect testing of certain working hypotheses some new concepts emerged throughout the entire work. Such concepts seem to fit in with a model of teamwork occurring in highly complex work processes. These concepts are briefly reviewed here below. It is here suggested that this set of new propositions can lead the way forward to future team research in aviation hangar maintenance environments.

* + 1. **Team performance *conditions***

*All project teams, composed by zonal, supervisory and support teams become reciprocally dependent* due to multiple (functional, operational, structural) relationships imposed by the technical system be maintained, the aircraft, and by the organisation necessary to perform such co-ordinated process.

This condition of high dependency implies that any unscheduled work, unexpected tasks operations, demands, or delays in one single team may very likely propagate to other work groups via such inherent dependency. Even small unexpected arisings could be very disruptive (see Chapter 8, *section 8.2.3.1*).

This clearly suggests that performance of any work teams in a hangar is also *a distributed concept*: the performance of any team operation is distributed and propagated across the performance of the other dependent teams and units. Also, this daily evolving teamwork flows may contain also team operational failures and delays at any specific point in time which may affect and interact with other teams to generate undetected multiple failures. This may collude in a potential pattern of multiple failure interactions, where *unpredictability of the team error propagation* becomes a constant.

Following on from this, future research may re-consider the performance problem for teams very dependent by the context like the aviation hangar maintenance teams: high *performing teams* are teams put in a *condition* of high performance environments. Such view clearly mirrors some basic conclusions about the importance of supportive and enabling environments for work team performances (Hackman, 2002).

* + 1. **Team externalities**

The study of the hangar context in this work highlighted the importance of modelling external performances as elements of the team model. Such approach has been termed the *team externality* problem. As defined in Chapter 8: “A *team* *externality* is here defined as the specific performance of a system in the organisation that is not (directly) controllable by a work team which turns out to be dependent on that performance. In very simple terms, an externality is the behaviour of an external group with respect to another one”. An example of team externality for a zonal team is the Engineering and Planning responsiveness.

Findings in Chapter 8 revealed that zonal and supervisory team performances are influenced by high levels of externalities: “Regression results (this chapter) indicate that approximately *60% of zonal team proficiency seems to be driven by external factors not controllable by the zonal or supervisory team leads or members (externalities and flexibility)*…Being aware of the exploratory approach taken, it can be nevertheless argued that team externalities have, at least, as much importance and leverage as internal teamwork effects. However, the implicit logic about *when and where* any team externality will impact on teams might suggest that they would then show more leverage than teamwork levels alone. Externalities represent critical dependencies to which internal teamwork competence would not be capable to compensate for. This, again, corroborates t*he hypothesis suggested in this Thesis: for highly dependent systems like operational teams in hangar maintenance it is the environment that accounts for performance more than internal team capabilities.*”

The concept of team externalities is suggested here as clear future team research topic due to its implication about controlling the *source* of team performance and the role of the context.

* + 1. **(Teamwork) skills situations**

Teamwork factors are not frequently or easily implemented in the technical process. What a group of people manage at work is the technical process. It is un-frequent that the same group of people deliberately or actively reviews teamwork factors at the end of their work shift. Feedback on teamwork is contextual to certain situations. In particular, what seems to emerge from real hangar (zonal) team observations in Chapter 6 is clear: “…out of all task observations it transpires that zonal teams do not *replicate* simple models of teamwork; it is instead the context that *suggests* what model of teamwork is required according to the situation: *the team does not know what teamwork is required at the beginning of the work shift*.”

Also, focussing on the concept of skills decomposition (from Chapter 6): “As the real team scenarios demonstrated, many different types of teamwork skills can not be easily separated or isolated from each other without loosing their meaning. For instance, certain feedback communication behaviours may be expression of a decision making skill, which, in turn and *from a different perspective,* could be one very single aspect of a much global expression of a team co-ordination behaviour. There is not *certainty* to which teamwork skill or combination of team capabilities a behavioural act may actually be referring to. Different situations, or more likely the same but evolving situation, may call for the very same behaviour, but for very different changing competence demands and functions.

Therefore isolating teamwork skills by decomposing them into communication, co-ordination, co-operation or decision making competencies may appear a straightforward and reasonable *operation* in theoretical terms. Nevertheless, once such decomposition is carried out, information on the meaning and goals of the total teamwork activity may be easily lost as the context, the actual work setting is removed from its representation.

This rationale, overall, corroborates hypotheses about *skill situations for teamwork* rather than a more comfortable view about individual skills possession. A skill has no meaning in itself and therefore a situation is required to “disambiguate” its function and role. Thus, it is the integration and combination of a diversity of behaviours with situational and operational aspects that should be modelled as teamwork elements of a team, *not* their decomposition and isolation”.

Overall, future team research may focus on how team skills interact frequently and in un-predictable ways: for instance, it is difficult to separate a lack of communication skill by a lack of leadership skill as they are generally integrated into a unique set of situations, events and changing objectives.

* + 1. **Minimal Critical Order**

One of the fundamental questions emerging from the study of process teams in Chapter 8 is the *link* between dependence and causality.

Such relationship was operationalised into the following theoretical assumption or principle:

The *minimal critical order of causality* *defines that the widest source of dependencies (largest set of time/sequence orders) within a process will contain the minimal causal chain to comply with and generate the maximal leverage on the system*.

The principle of minimal critical order simply suggests that there is a temporal-sequential and causal order between different process elements (e.g., teamwork events, work processes and demands), where the elements happening upstream and before than others can propagate by dependence an identifiable class of effects downstream on the subsequent elements in the process. The application of this principle could identify what element (process, system or condition) would demand verification first.

In this view, the implication of this principle for project teams in aviation hangar maintenance (and their associated models) suggests that effective assessment and verification of teams and teamwork should start by the study of work processes and relative process team configurations to pinpoint the largest root of events demanding improvements or change. The sequences of events among zonal, supervisory and support teams (the elements of a full project team in hangar) should be taken into account.

Future team research should consider that most of the common team and teamwork performance models assume that models’ variables are ordered but prioritisation or variable sensitivity is not defined or fully understood. The *order* generally is not tested for discriminatory power, and past research does not explain on common ground importance of such sensitivity analysis. Apparently, more emphasis is to be given to the analysis of the principle of minimal critical order to understand and identify what is the true leverage path of variables representing teams.

Also from *section 8.5.3.2.1* of Capter 8: “The principle of minimal critical order of causality implies that any causal and logical explanation of team behaviour and performance, at any level, would contain that order as *principle of economy*. In fact, causal explanations of team performances, at one specific level of analysis, should favour explanations based on the simplest order of causality which accounted for the largest impact on the system *at that point of analysis*. Team explanations suppressing this assumption are less *parsimonious*.”

* + 1. **Team risk distribution**

In essence, an aviation hangar maintenance team is basically a configuration of resources and optimisation of team resources and configurations is desirable for performance criteria, nevertheless *business strategies may distribute team risks*. As discussed in Chapter 9, every project team gets some supports from the organisation but not adequately as it should be to grant very high performances. This concept is defined as team risk distribution. According to it, limited resources apportionment across different project teams reduces impact of local solutions to favour organisational maintenance and resilience: every team gets something but none of them will be fully protected. This is here suggested to be an implicit organisational strategy to maintain a complex economy of pooled resources. Such view certainly mirrors the Friedlander’s argument (1987, p. 304):

“*A dysfunctional work group participates with all other work groups to maintain a dysfunctional organizational system. Further, the dysfunctionality of a work group may increase the effectiveness of the organization*”

Therefore another team research direction is suggested: looking for simple team performance explanations would miss a serious point if such explanations disregard a model of the overall business approach taken by the organisation to control its economy. This may be critical in front of organisational strategies favouring organisational levels of conduct and performance.

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# **ANNEXES**