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Development of a balanced scorecard for flight line maintenance activities

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Abstract
Purpose – The purpose of this paper is to describe the development of a balanced scorecard (BSC) for flight line maintenance (MX) activities in the US Air Force.
Design/methodology/approach – The BSC development process consists of three stages: groundwork, design beginning with structuring of organizational strategic elements through performance measure identification and construction of the BSC framework, and finalization for continuous improvement.
Findings – Based on logistics expert responses the authors validated a case BSC for flight line MX activities within an aircraft maintenance unit. Validation was done with respect to perspective measures including mission, influencing factors, management, and information enhancement.
Originality/value – BSC development through identification of mission critical performance measures should improve performance of aircraft scheduling and achievement of mission objectives. Guidelines were used to develop a case validated by Air Force logistics personnel.
Keywords Logistics, Balanced scorecard, Maintenance
Paper type Case study

Nomenclature

AMU	aircraft maintenance unit	HOF	health of fleet
AWM	awaiting maintenance	HSE	health, safety, and environment
BSC	balanced scorecard	ISO	isochronal inspection
CANN	cannibalization	MC	mission-capable
CND	cannot duplicate	MICAP	mission-impaired capability awaiting parts
DD	deferred discrepancies		

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MPI	maintenance performance indicator	PMCM	partial mission-capable maintenance
MPM	maintenance performance measurement	RR	repeat-recur
MX	maintenance	TNMCM	totally not mission-capable maintenance
MXS	maintenance squadron	TMNCS	total not mission-capable supply
NFF	no faults found	USAF	US Air Force
OPS	operations		

1. Introduction

Maintenance leaders are primarily concerned with knowing how well the unit is meeting mission requirements, improving equipment performance, identifying support problems, and projecting current trends (Air Force Logistics Management Agency, 2001). It is pertinent that maintenance (MX) leaders review sortie production and MX performance constantly, and are knowledgeable about predictive MX indicators. Maintenance performance is generally assessed using standards, goals, and maintenance plans.

Flight line MX is one of the most crucial MX activities resulting from its significant impact on the airmen safety and the integrity of their missions. It can be broken down into three maintenance categories, which are minor, unscheduled, and scheduled maintenance (Airest, 2014). Several key activities of flight line MX are listed as follows:

- unscheduled repairs due to unforeseen events;
- MX operations and scheduled inspections for aircraft and aircraft components;
- MX services for the first flight, between successive flights, and for preparing an aircraft for flight during a period of service; and
- MX training and flight line safety program implementation.

A suitable MX performance measurement system provides assurance of the consistent operation of the MX activities, which is extremely critical to the strategically important flight line MX. In this paper, we propose and validate a balanced scorecard (BSC) approach to integrate and group objectives and measures in order to provide a holistic measurement system for the flight line MX activities. BSC enables the MX leaders to have access to view the MX performance in various areas at the same time.

Kaplan and Norton (1996) introduced the BSC in the early 1990s. The BSC was introduced in an attempt to reconcile problems in traditional management strategies. Traditionally management strategies overemphasized financial measures at the expense of progress and growth. This overemphasis brought about short-term gains to the detriment of long-term success. The BSC is a performance management system that allows organizations to clarify their strategy and assure that every aspect of operations is directed toward the success of these goals. When considering all important measures at once (as suggested by the BSC), management can detect whether one area is improving at the expense of another area. Kaplan and Norton (1996) suggest the following analogy to better explain the purpose of the BSC. In a cockpit, a large and complex amount of data are displayed very quickly and simply through the use of cockpit displays. These displays indicate fuel level, airspeed, altitude, bearing, and destination. Focussing on just one instrument can be fatal, just as focussing on one aspect of performance can be fatal to operational success. A BSC is designed to display all pertinent performance information simultaneously.

The structure of the paper is organized as follows: Literature Review provides a summary of papers in BSC application, MX performance measurement framework, and aircraft MX system; BSC Development Guidelines introduces the development process of a BSC; example BSC for Flight Line MX displays a proposed BSC for flight line MX activities with illustration of each perspective included in the BSC; BSC Validation presents a survey to rank the developed perspectives and measures in the proposed BSC in order to evaluate their criticality; Conclusions summarizes the paper.

2. Literature review

In the academic literature Tsang (1998) developed a structured approach to managing performance with a BSC used to inform employees of maintenance strategy. Tsang *et al.* (1999) reviewed three different approaches to maintenance performance measurement (MPM) in addition to the BSC and concluded it should be the foundation of any approach to a good performance measurement system:

(1) system audits for measuring organizational culture;

(2) data envelopment analysis used to benchmark the organization's maintenance function; and

(3) a value-based performance measure to evaluate impact of maintenance activity on the organization's future.

Four perspectives of BSC are considered in MPM literature. Parida and Kumar (2006) discussed the issues and challenges of the existing MPM. The authors pointed out that the most challenging issue now is to develop a total maintenance effectiveness system that can measure both external and internal effectiveness of a system instead of the current more internal-oriented MPM. A concept of the MPM system that integrates the hierarchical perspective as well as multi-criteria maintenance performance indicators (MPIs) are introduced at the end of the paper. To address the proposed issues, Parida and Chattopadhyay (2007) developed a multi-criteria hierarchical MPM framework for process and utility industries. External effectiveness and internal effectiveness are both involved into the framework. Major MPIs, identified by literature review and interviews, are grouped into seven criteria. Three hierarchical levels of an organization, including strategic level, tactical level, and functional level, are incorporated into the MPM framework in order to involve all the employees in the maintenance process. Kumar and Ellingsen (2000) studied the existing performance indicators in the oil and gas industry, identified the subprocesses in the maintenance management process, and linked the performance indicators to the corporate objectives in their MPM framework.

Chi *et al.* (2009) attempted a logistics industry application by first designing a survey from the BSC framework for senior supply chain executives. Another application to the supply chain environment came from development of a MPM system for multi-echelon repair inventory systems (Garg and Deshmukh, 2012). Bigliardi and Eleonora (2010) developed a BSC for agricultural machinery firms. Barnabe (2011) matched a more traditional BSC to system dynamics principles and developed a "dynamic" BSC for service-based business. Galar *et al.* (2011) incorporated the hierarchy aspect into a maintenance BSC. Five organizational levels from four perspectives of the BSC are involved into segmenting the indicators into a logical manner. This hierarchical approach provides more practical indicators to the users at each level; therefore, the four strategic perspectives of BSC are represented by the most appropriate level in the organization.

Published case studies are diverse with respect to industry and nationality. Parida *et al.* (2003) focussed constructing linkage and relationship between corporate BSC and the maintenance performance. Corporate BSC considers certain corporate strategies to evaluate the performance at various levels. One additional perspective – health, safety, and environment (HSE) – is included in the BSC besides the traditional four-BSC perspectives. Two linkages are developed, including one between BSC and MPI at corporate, division, and group level, and the other between corporate objectives and BSC with MPIs. Liyanage and Kumar (2003) linked results to performance drivers of North Sea oil and gas organizations, and extended the operations management architecture to apply the BSC concept. In another industry Alsyouf (2006) found potential for the BCS concept to improve return on investment at a Swedish paper mill by 9 percent. Parida (2007) investigated the considerable number of unplanned and shorter stops for the balling area of KK3 Plant of LKAB through maintenance process mapping (including two phases of process study and interviews), and identified the existing MPIs. The author then constructed a balanced and holistic multi-criteria MPM framework for the presented case study, based on which, nine new MPIs are developed at operational level that can effectively monitor the maintenance, as well as integrate the plant performance with corporate strategy. Chavan (2009) looked at implementation of a BSC performance measurement system in Australian corporations. Kumar *et al.* (2011) used the framework of BSC with its four perspectives to conduct maintenance audits in order to evaluate the objectives fulfillment as well as the user's satisfaction degree. The audit is based on a set of maintenance indicators that are grouped into four perspectives with their objectives included. Four phases are involved in the process of audit application, which integrates both qualitative and quantitative indicators, considers different organizational levels, and obtains results commonly demanded by users. Finally a literature review of MPM was written by Simoes *et al.* (2011). It concluded maintenance performance and management needs research aimed at both solidifying theory and promoting more practical applications. Since then research has focussed on theory of continuous improvement and maintenance performance (Maletic *et al.*, 2012), and practice in the context of manufacturing (Ahuja, 2012; Van Horenbeek and Pintelon, 2014).

Specifically, previous researchers addressed the flight line MX in different ways. De Haas and Verrijdt (1997) introduced a repairable item system to provide maintenance support for the aircraft fleet. A service level is used to evaluate the performance of the repairable item system and a mathematical model is developed to set the target of the service level. Kirkland *et al.* (2004) discussed conducting a more accurate failure prediction on avionics components by combining the environmental stress data and the traditional failure data. no faults found (NFF) occurrence (caused by intermittent faults that do not appear without the stressful operating environment) could be reduced by adding the environmental data. Serial numbers must be tracked at all maintenance level in order to ensure the prognostic success. The authors acknowledged the difficulty of collecting all the environmental data but pointed out the possibility to capture some key data elements. In other work Alfares (1999) formulated integer programs to optimize maintenance aircraft workforce schedules. Cheung *et al.* (2005) advocated for a fuzzy expert system for aircraft maintenance service. Wang (2009) studied models to optimize a logistics network applied to aircraft servicing.

3. BSC development guidelines

The BSC development process is one that requires thorough knowledge about internal operating procedures and a comprehensive understanding of the system being studied. The guidelines assure the user follows every step by breaking the BSC development process into manageable stages. Figure 1 depicts the BSC development process that consists of the three primary stages: groundwork, design, and finalization. Each stage is comprised of multiple steps, which are detailed in the remainder of this section.

3.1 Groundwork stage

The groundwork stage is the foundation of a successful BSC project. By following the steps in this stage, all of the pertinent and necessary information needed for the scorecard will be available during construction. A thorough groundwork stage will assure that key information is not overlooked. It will also assure that the gathered information is organized in a logical manner.

3.1.1 Team selection. A team of stakeholders, instead of a single person, should undertake the BSC. This allows for brainstorming and group discussion. It also facilitates thorough review of report documents. The team should be comprised of personnel from all of the involved functions and should be representative of the skill sets present in the organization. Inclusion of all stakeholders will facilitate acceptance and enthusiasm for BSC implementation. The members of the BSC team will act as ambassadors for the BSC, accelerating its acceptance and use (Niven, 2002). Each team member should be qualified to provide expert opinions about their organizational function. An understanding of BSC concepts and its development process is imperative for all team members. Skill in quantitative analysis must be present among the team, as this is extremely useful during the finalization of measures.

While team size is ultimately up to the team leader, a standard BSC team has approximately seven members. In general, more than seven members may create difficulties in coordinating group efforts; while less than seven may not bring enough viewpoints to the process. The team leader is responsible for coordinating all team meetings and corresponding with superiors (Niven, 2002). The team leader can assign specific duties to other members of the team as needed during the development process.

The goal for team member selection is to represent as many levels of the organization as possible. The reasoning behind this goal is that a higher-level supervisor, such as a unit commander, understands overall strategy and the desired outcomes of the organization. In addition, there are many low-level aspects of operations that are important to performance measurement and better understood by the persons who work at this level every day.

3.1.2 Strategic framework. Organizational strategy is the guiding factor behind the BSC. Organizational strategy is defined as a set of long-term goals that, if successfully achieved, will revolutionize the way a unit operates and improves operations. Without strategic alignment or the integration of this organizational strategy into the BSC, a BSC is merely a collection of performance measures. Strategic planning and alignment to a given strategy should be the top priority in any BSC venture. There is a large gap between having a good strategy and effectively implementing it. The BSC provides a framework to transition from deciding to have a strategy and actually using it (Niven, 2002). The next section discusses a few of the basic strategic components to be gathered. Identification of an organization's strategy will help determine the most relevant data to collect.

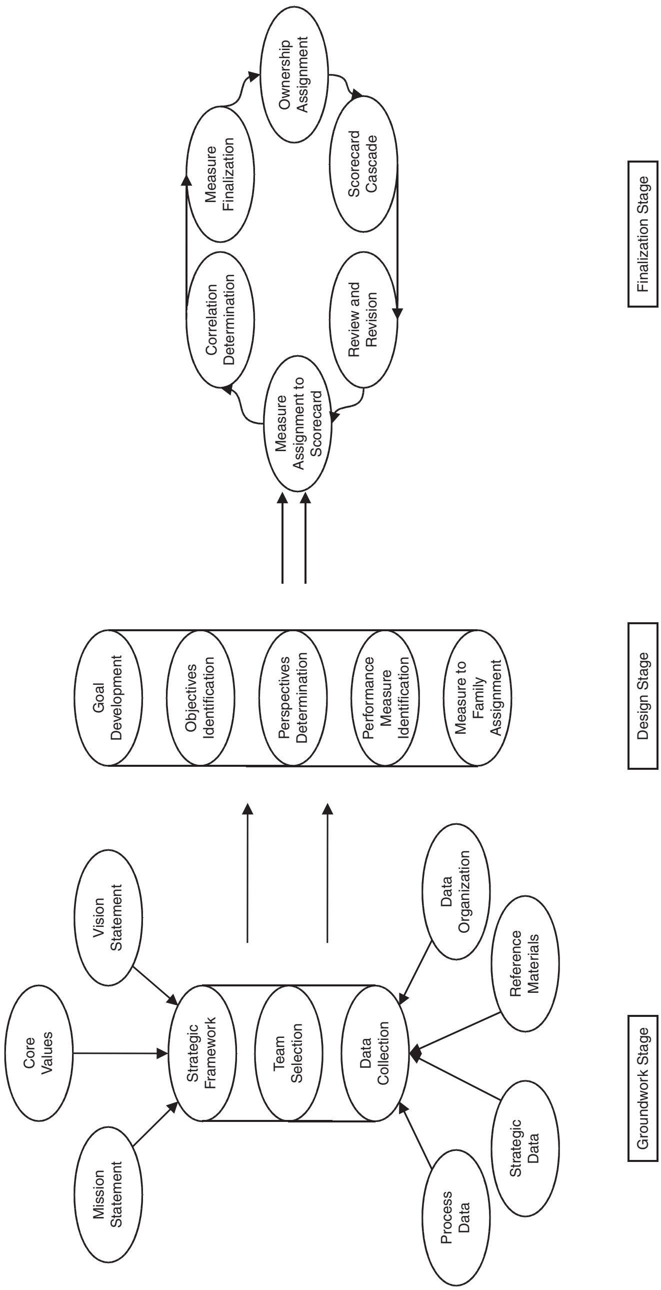

Figure 1.
BSC process diagram

The process of strategic alignment begins at the top of the participating organization, regardless of its scope or size. The unit commander and relevant subordinates must come together to determine what the organizational strategy is, and where opportunities for achievement of this strategy exist. This is a complex process that requires time and effort. There is often disparity between the commander and other members of the organization on how the organizational strategy is to be implemented. In many cases, a documented strategy does not exist. In this case, a sound organizational strategy must be developed. The essential strategic elements for a successful BSC are mission, core values, and a vision statement (Niven, 2002). If these strategic elements are already in existence and are approved by the team, they can be integrated into the framework. Otherwise these elements must be developed as described in the following sections.

Mission statement. Mission statements have been adopted by almost every organization in existence. They are used to communicate fundamental beliefs and identify target goals (Kaplan and Norton, 1996). A mission statement should be motivating and inspirational. An effective mission statement is not something that changes every year but lasts for many years as a foundation for the organization. A mission statement should be easily understood and communicated down to the lowest level of the organization (Niven, 2002). An example of mission statement is that of the US Air Force: "To defend the United States through control and exploitation of air and space."

Core values. "Values are the timeless principles that guide an organization (Niven, 2002)." These principles are deeply held beliefs that exist within the organization and are demonstrated through the day-to-day behaviors of all employees. These values set the tone for an organization by telling each member of the unit how to accomplish their mission. For example, the core values of the Air Force are:

- integrity – do the job right the first time;
- service – mission accomplishment over personal gain; and
- excellence – put forth the best possible effort all of the time.

Vision statement. A vision statement is a snapshot of the future. It contains multiple long-term goals that can take anywhere from several years to a few decades to achieve. Many of the long-term goals from a vision statement can help to define the characteristics of the BSC perspectives. It is important to avoid vague catchwords and phrases. The use of very technical words is also discouraged since all stakeholders may not be familiar with such language. It should be clear to all stakeholders, not just the upper command, where the organization is going and exactly how they plan to get there (Brown, 1996).

3.1.3 Data collection. Data collection is an essential step in the BSC development process. The following subsections describe the key types of data and data collection activities. The development of a BSC generates large amounts of data. This data must be organized and stored in a logical manner to prevent contamination or loss of pertinent information. One team member should be delegated the responsibility of organizing the data and keeping it up-to-date by maintaining the latest version of all relevant documentation. Master copies of all reference materials should be accessible in a secure, central location. This protects the data and provides ready access to team members.

Process data. The first step in data collection is to collect data on the processes that are to be monitored by the BSC. Details on process data collection are as follows:

- determine exactly what each process is and locate any existing documentation about the process;
- determine the chain of command for the process;
- document the current process as it occurs in the organization; and
- compare and contrast the existing and team-developed documentation about the current process.

Strategic data. The next step is the collection of strategic planning data from the highest-level command. This data collection does not exclusively involve the highest-level commander, but all those involved in strategic planning or leadership of the unit. This information is essential for the strategic planning portion of BSC development. Specifically, it will help to determine what measures should be monitored and how they should be linked throughout the scorecard. This data should be gathered in personal interviews with the commander and others involved in the strategic planning process. The following are pertinent questions to have answered (Niven, 2002):

- What is your interpretation of the mission statement, core values, and vision statement?
- Who are your customers?
- What key strategies will help to achieve your vision?
- How can these strategies be achieved?
- What measures or data do you track to monitor success?
- What targets do you use for these measures?
- What related reports do you find most useful?

Reference materials. Reference materials are published documents that contain information on processes and their performance measurement. Reference materials also include information pertaining to the BSC and its application. These materials assist in identifying measures and perspectives for the scorecard and indicate the relative importance of measures or processes. It is essential to gather materials from as many different sources as possible. The following are samples of potential sources:

- Published manuals and training guides – these documents provide information on what performance-related information the unit already monitors. Manuals are an excellent information source for potential BSC measures and instruction on how they should be monitored.
- Health of fleet reports (HOF) – HOF reports are a source for many measures that are already tracked and reported. Since these measures are already in operation, it is much easier to integrate these measures into a BSC.
- In total, 9,302 reports – since performance measurement of the measures on the 9,302 reports are required by ACC, these measures are considered vitally important.
- Public literature – published research provides information on the BSC and its development and implementation.

- Performance documents – any documents other than those named above that contain relevant performance measures.
- Expert interviews – personnel with a high level of experience in their unit or career track often can suggest additional important measures other than those that are currently being monitored.

3.2 Design stage

The design stage begins with structuring the strategic elements of the organization and progresses through performance measure identification and construction of the basic BSC framework.

3.2.1 Goal development. Strategic planning informs everyone in an organization where he or she is going and how to get there. The overall strategy must be broken down into long-term goals. These are goals that can revolutionize the way an organization operates by taking them from their current state to envisioned future success. These goals should be future-focussed with a time frame ranging between five and 20 years. Milestones should be identified to divide the long-term goals into shorter time buckets. Milestones are subdivisions of a goal that are used to check progress toward achievement of the goal. These long-term goals can then be transformed into performance measures further on in the BSC development process. Each goal must have a specific target that is either numerical or descriptive. These targets are the projected optimal result for each goal.

Brown identifies five common problems associated with goal setting (Brown, 1996). One should review all pertinent goals to verify that they do not contain any of these flaws:

(1) goals that are really projects, activities, or strategies – the best way to avoid this is to ensure that each goal has at least one measure in the scorecard;

(2) goals that are solely based on past performance – many organizations simply add 5 or 10 percent to last year's goal without justification;

(3) arbitrary stretch goals – developing a goal without good reason or randomly selecting a competitor's goal should be avoided;

(4) inconsistent short-term and long-term goals – all short-term goals should be components of some long-term goal; and

(5) inconsistencies in goals at different levels of the organization – every goal should cascade down from a higher goal.

3.2.2 Objectives identification. Identifying objectives is a translation of strategy and long-term goals into specific time lines and events. Each long-term goal has a realistic target, and milestones have been identified as a portion of that target. These goals and targets will be placed as measures in the objective perspective to show success in strategic objectives.

3.2.3 Perspectives determination. As previously discussed, the original Kaplan and Norton (1996) BSC suggested four perspectives:

- financial perspective;
- customer perspective;
- internal business process perspective; and
- learning and growth perspective.

Kaplan and Norton (1996) recognize that these four perspectives "should be considered a template, not a straight jacket." Their perspectives are intended to portray the essential elements that can lead to success in a typical organization. Although four is standard there is no set rule for determining the number of perspectives in a scorecard. While fewer than four is uncommon, there are many instances of more than four. If there are more than four key elements that give a competitive edge or portray key competencies, they should all be included as perspectives. However, care should be taken when adding perspectives because too many perspectives can lead to scorecards with large numbers of stand-alone perspectives that are unrelated to each other. Niven (2002) suggests that the true test of perspectives is whether they can be intertwined to tell a coherent story. Success in any one perspective can be linked to success in the others. Improvements in lower perspectives lead to good results in higher perspectives, which then lead to realization of the vision.

3.2.4 Performance measure identification. At this point in the development process, there is a success strategy mapped out, and objectives for success have been determined. Using these objectives, the BSC perspectives have been identified. The next step is to determine possible measures for inclusion in the BSC. Using the materials gathered during the groundwork stage, all relevant performance measures should be identified and listed. Each document should be thoroughly reviewed and all identified measures should be compiled. Equations or formulae used to calculate the measures should be included along with any targets for each measure. This list serves as a pool from which to draw the key measures for the performance objectives. This list is not yet the master list of measures; this is the list of measures that are currently being tracked. During the development of the performance objectives, it may become apparent that additional measures (that are not currently tracked) are needed to track the BSC objectives. These new measures will become more apparent as the project progresses, and should be listed separately as they are identified. Along with all measures that are listed, it is useful to have a set of parameters such as: maximum, minimum, optimal, and benchmark (how other similar organizations perform). Data without goals or comparisons are meaningless (Brown, 1996). For example knowing that the phase average for a B-52 wing is 215 hours is not useful information unless it is known that the phase average should be approximately 150 hours. The comparison data is what indicates the actual performance of a measure.

3.2.5 Measure to family assignment. After the list of measures is compiled, a logical organization needs to take place. The measures are assigned to families based on similar characteristics or applications. An example of a measure and its family is sorties flown and the productivity family. Sorties flown measures productivity when used in the context of a maintenance unit; therefore, it is assigned to the family of productivity-related measures. Assigning measures to families is an initial starting point to the construction of the BSC. Once families are created, they are assigned to perspectives in the BSC. It is important to note that each family should be included in only one perspective. However, one perspective can be comprised of more than one family. This facilitates a smooth process for adding measures to the scorecard. If a productivity measure is required, it can be drawn from the productivity family. If a measure becomes too expensive or cumbersome to measure, it can be replaced by another similar measure from the same family.

3.3 Finalization stage

The finalization stage is the continuous improvement stage of the development process. This cyclical stage includes assignment and reassignment of measures to the BSC based on their pertinence to the ever-changing activities and current strategies of the organization. This stage continues over the life cycle of the BSC.

3.3.1 Measure assignment to the BSC. An exhaustive list of currently tracked performance measures and candidate new measures now exists. The next step is to select measures from this list for inclusion on the BSC. In the measure selection process, it is important to note that a single person or scorecard should monitor no more than 20 measures (Brown, 1996). If necessary, measures can be combined into aggregate measures (aggregation of measures is discussed later in this paper). When selecting measures, the most important factor is to ensure that each chosen measure reflects the strategies developed earlier in the process.

3.3.2 Correlation determination. This can be the most challenging step in the development of an effective BSC. A scorecard without strategic linkages is simply a group of unrelated performance measures. The key is to determine how the strategy relates to each perspective in the BSC. Determining correlations (the way in which each perspective contributes to the success of the overall strategy) begins with the objective perspective. This perspective contains the strategic goals for an organization, and all improvements elsewhere in the BSC should positively affect it. The correlation process works through each perspective, showing how each perspective relates to the objective perspective. The following is an example of this process.

The correlation process deals with building linkages from the other perspectives into the objective perspective. The objective perspective contains measures that directly reflect the accomplishment of objectives identified in objectives identification. With the introduction of measures into each perspective of the BSC, the following analysis should take place. The relationships between success in a new measure and success in other measures already in the BSC should be sought. This relationship can be between the new measure and a measure in the objective perspective, or it can be between the new measure and a measure elsewhere in the BSC that has already been linked to the objective perspective. If no linkages can be identified, the measure is either a diagnostic measure or has no reason to be on the scorecard. For more information on distinguishing between diagnostic and strategic measures, see the section on measure finalization.

After determining how the strategy is reflected in the measures, a hypothesis should be made about their correlation. The hypothesis is a prediction of how improvements in each perspective will lead to an improved bottom line in the objective perspective. As a hypothetical example, an increase in departure reliability in the management perspective of 10 percent may have a positive impact on sorties flown in the objective perspective of three sorties more per month. Each hypothesis should be tested and revised to give a more accurate correlation as needed. During the infancy of the scorecard, the testing and revision should occur frequently, possibly every quarter. As the BSC matures, testing and revision may occur once a year or less. Occasionally, the hypothesis turns out to be false and the hypothesized correlation does not exist. Upon determining that a hypothesis is false, it should be eliminated and replaced with a new strategically aligned hypothesis.

3.3.3 Measure finalization. The pared down measures can now be assigned to the actual scorecard. These measures were selected based on their strategic linkage in the scorecard and accurately depict the strategy of the organization. At the conclusion of an initial BSC development, there may be gaps in the correlation where the correlation does not continue all the way through the scorecard. The gaps in the correlation indicate where strategic planning needs to include other aspects, such as internal enhancement or influencing factors. The BSC bridges the strategic gap between organizational success and the factors that influence it. After any gaps in the correlation are filled, there may be other measures that still need to be added. These are called diagnostic measures that are not linked to strategy but are still important. These are measures that describe key operating statuses. The scorecard can be analogically compared to a car dashboard. The speedometer, odometer, and tachometer are strategic measures. The diagnostic measures are the low gaslight, engine maintenance light, and the low oil pressure light. Diagnostic measures help to identify problems before they become serious.

3.3.4 Ownership assignment. This is an essential step in BSC development. Each measure must have an owner who is responsible for tracking the measure. They have the responsibility to provide thorough documentation describing the measure, provide reasoning for past performance, and supply other information that will help others to interpret and assess the measure. Although a measure may appear on multiple scorecards, there is never more than one owner. The use of multiple scorecards is discussed in the following section.

3.3.5 Scorecard cascade. In general, the first BSC developed in any organization is a high-level BSC. After a high-level BSC has been created, it should be cascaded. Cascading is a form of subdividing measures. The measures on a high-level scorecard are often comprised of other lower-level measures or aggregates. Cascading is the structuring of these lower-level measures into lower-level scorecards. As previously noted, each person should only have 20 or fewer measures to monitor. The common practice in cascading a scorecard is to have each manager create a scorecard tailored to his or her responsibilities. Their scorecards contain measures that aggregate into the measures on the higher-level scorecard. An example of aggregate measures would be wing sorties flown, which is comprised of the sorties flown in each squadron. A hypothetical example of a cascaded scorecard would be each squadron's measure of sorties flown feeds into the aggregate measure of sorties flown on the wing scorecard. The lower-level scorecards will focus on unit-specific responsibilities. The measures on a high-level scorecard are generally very abstract while the measures on the lower-level scorecards become increasingly more concrete. When cascading scorecards, it is important to only put the measures necessary to the person or unit who uses the scorecard. A scorecard for the flight line will not contain measures that pertain to munitions. However, the higher-level scorecard over both these units will contain measures from both flight line and munitions.

3.3.6 Review and revise. Periodically, a BSC must be revised and updated. This review and revision should take place frequently during the infancy of the BSC. In the beginning, review should take place every quarter and continue until the hypotheses made have been validated. As the BSC matures, review can be conducted annually or as strategic planning requires. Basic revisions can take place at any time. These can include cascading down additional scorecards when new units are added or reorganized. Strategic reviews should occur on the completion dates of milestones or after any change in organizational strategy. At this time, major changes can be made to the scorecard, such as strategy changes, using different measures, or changing targets for measures.

4. Example BSC for flight line MX

The BSC development guidelines described were used to develop an example BSC for flight line MX activities within an aircraft maintenance unit (AMU). The resulting BSC is shown in Figure 2.

The proposed BSC adapted Kaplan and Norton's (1992) four traditional BSC perspectives into mission perspective, influencing factors perspective, management perspective, and internal enhancement perspective according to the flight line MX objectives and strategies. The BSC translates the general MX missions into specific indicators grouped into different MX perspectives, which are connected to each other to provide the MX leaders with a holistic view of the MX performance.

4.1 Mission perspective

This new perspective, specially customized for the flight line MX, includes measures that evaluate the conditions of the aircraft, which closely related to the MX operations. Excellent MX operations will enhance these aircraft performance indicators, such as the number of aircrafts on mission (sorties flown) or the percentage of the designated missions that can be conducted successfully by the aircraft (mission-capable (MC) rate). Five measures are involved in the mission perspective:

- maintenance hours per flying hour;
- MC rate;
- partially mission-capable maintenance (PMCM);
- sorties flown; and
- totally not mission-capable maintenance (TNMCM).

4.2 Influencing factor perspective

This perspective attempts to identify and measure the collaboration among multiple MX activities as well as the functional process of the MX activity, both of which have great impact on flight line MX objectives; therefore, we consider the measures stemming from the influencing factor perspective. Four included measures are:

- cannibalization (CANN) rate;
- mission-impaired capability awaiting parts (MICAP) fill rates;
- maintenance scheduling effectiveness; and
- total not mission-capable supply (TNMCS).

4.3 Management perspective

Similar to customer perspective in the traditional BSC, management perspective focussed on satisfying customer demand associated to the flight line MX with consideration of several performance measurement aspects, such as time, quality, and service. The following seven measures effectively represent the objectives the flight line MX activities aim to achieve on customer service:

- adherence to operations (OPS)/maintenance squadron (MXS) schedule;
- deferred discrepancies (DD) rate awaiting maintenance (AWM);
- total maintenance deviations;

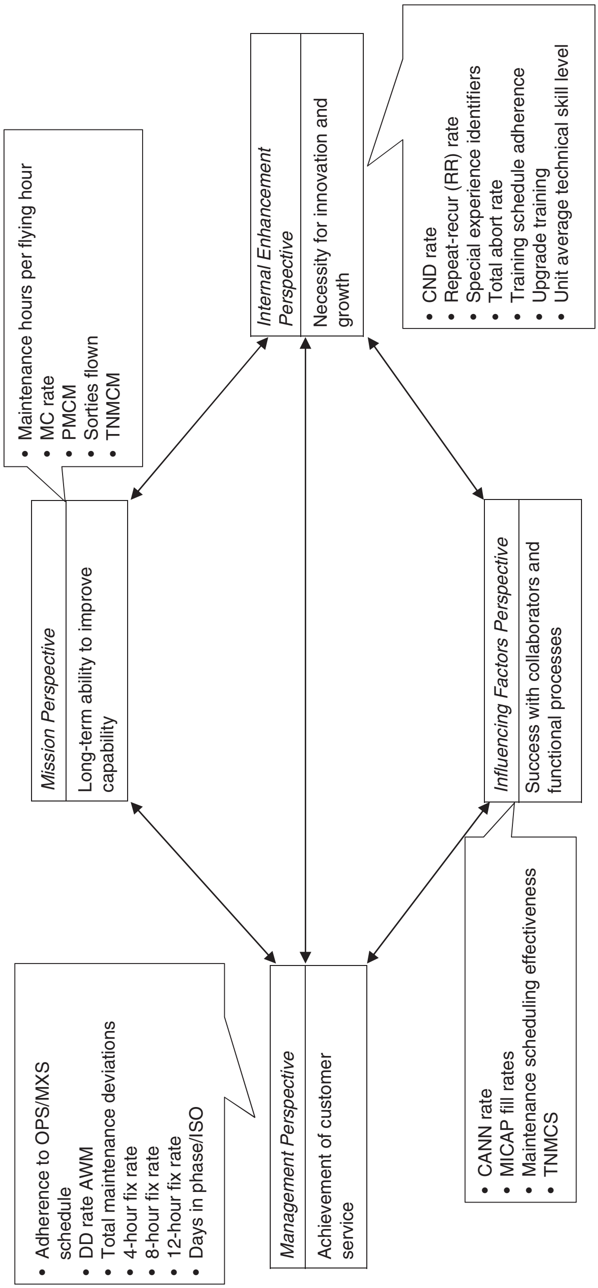

Figure 2.
Example BSC for AMU flight line MX activities

- four-hour fix rate;
- eight-hour fix rate;
- 12-hour fix rate; and
- days in phase/isochronal inspection (ISO).

4.4 Internal enhancement perspective

Adapted from innovation and learning perspective in the traditional BSC, internal enhancement perspective is created for flight line MX to emphasize and maintain the competitive success through innovation and growth. Process innovation in MX activities may increase the customer satisfaction and reduce the MX cost. Therefore, measures related to MX innovation are considered, such as cannot duplicate rate. Since a lot of duties in flight line MX are conducted by MX personnel, trainings, and supporting materials that can enhance their problem-solving ability during MX process are critical to improve the existing MX performance. They are assessed by measures like special experience identifiers and upgrade training. Seven measures are involved in internal enhancement perspective:

- cannot duplicate (CND) rate;
- repeat-recur (RR) rate;
- special experience identifiers;
- total abort rate;
- training schedule adherence;
- upgrade training; and
- unit average technical skill level.

Through enhancing the MX performance, BSC has indirect but significant impact on military aviation. The four perspectives have a complete coverage of measures to assess the flight line MX activities and lead to MX improvement, which avoids accidents that can threaten airman safety and reduce military planes, maintains excellent aircraft performance that guarantees the mission accomplishment, and extends the expected life of the aircraft.

5. BSC validation

An anonymous questionnaire was developed to elicit the expertise of logistics personnel in ranking the criticality of the measures on the example BSC. Attendees of the 2003 LOA National Conference completed the questionnaire. In total, 26 viable questionnaires were collected and analyzed. The questionnaire requested that the respondent rank each of the four perspectives in decreasing criticality and rank each measure within the four perspectives by decreasing criticality within their perspective. The rankings used an increasing numeric scale to portray relative criticality, the lower the number, the higher the criticality; with 1 being the most critical. The questionnaire also requested that the respondents suggest any omitted measures that they deemed pertinent.

A count of the number of times each perspective and each measure within each perspective was assigned a particular ranking (1, 2, 3, and so forth) was computed. The corresponding percentage represented the number of times each perspective or measure was given that ranking out of the total number of questionnaires. The percentages allowed the data to be conceptualized in a more meaningful manner.

The analyzed data is presented in a graphical format in the following sections. The graphs are stacked bar graphs with each column representing a specific perspective or measure. The bars contain the percentages of each ranking (1s, 2s, 3s) that were obtained by each perspective or measure within its perspective. Separate graphs represent the criticality of the four perspectives and the criticality of each measure within its perspective.

Table I presents the summary of the criticality of the perspectives from all 26 viable respondents. The results indicate that the mission perspective is the most critical perspective with 62 percent of the respondents giving it the top ranking (1). From the results, it can be concluded that management perspective is the next most critical with 23 percent of the respondents ranking it as the most critical (1). The least critical perspective is internal enhancement perspective with 62 percent of the respondents ranking it as the least critical (4). This is an expected finding as this perspective contains measures that are least tangible and has the most measures that are not currently being tracked by the Air Force.

Table II presents the criticality of the mission perspective measures. The measures were ranked on a scale from 1 to 5, with 1 being the most critical measure. The results clearly indicate the MC rate is the most critical measure with 58 percent of the individuals ranking it as the most critical (1). Maintenance hours per flying hour measure is the second most critical with 50 percent of the respondents ranking it as first or second most critical (1 or 2). It is obvious by the graph that PMCM is the least critical measure with 58 percent of the respondents ranking as the least critical (5) and no respondent ranking it as most critical. Based on these findings, PMCM is a strong candidate for removal from the preliminary BSC.

Table III presents the criticality of the influencing factors perspective measures. The measures were ranked on a scale from 1 to 4, with 1 being the most critical measure. The results indicate the MICAP fill rate is the most critical measure with 38 percent of the individuals ranking it as the most critical (1). The ranking of the other measures in this perspective are less conclusive. Interestingly, maintenance scheduling effectiveness has the next highest percentage of respondents (31 percent) ranking it as most critical (1) and the highest percentage of respondents (50 percent) ranking it

Criticality	Mission	Influencing factors	Management	Initial enhancement
1	0.62	0.03	0.23	0.12
2	0.19	0.35	0.27	0.19
3	0.12	0.35	0.46	0.08
4	0.08	0.27	0.04	0.62

Table I. Distribution of responses to perspectives

Criticality	Maintenance hours/fly hours	MC rate	PMCM	Sorties flown
1	0.19	0.58	0	0.19
2	0.31	0.23	0.08	0.12
3	0.15	0.08	0.08	0.38
4	0.19	0.04	0.27	0.19
5	0.15	0.08	0.58	0.12

Table II. Distribution of responses to the mission perspective measures as least critical (4). Respectively, 53 and 42 percent of the respondents rank CANN rate and TNMCS as most (1) or second most (2) critical.

Table IV presents the criticality of the management perspective measures. The measures were ranked on a scale from 1 to 7, with 1 being the most critical measure. The results strongly indicate the adherence to OPS/MXS schedule is the most critical measure with 58 percent of the respondents ranking it as most critical (1). The next most critical measure is total maintenance deviations with 39 percent of the respondents ranking it as most (1) or second most (2) critical. In total, 12-hour fix rate was deemed more critical than the four-hour fix rate and eight-hour fix rate. Potential measures for removal from the BSC are DD rate AWM and four-hour fix rate.

Table V presents the criticality of the internal enhancement perspective measures. The measures were ranked on a scale from 1 to 7, with 1 being the most critical measure. This perspective's measure ranking results are less conclusive. The results indicate that CND rate, RR rate, upgrade training, and unit average technical skill level are the most critical measures with the greatest number of respondents ranking these measures as most (1) or second most (2) critical. Special experience identifiers was the ranked least critical with 50 percent of the respondents ranking it as the least critical (7).

Table III. Distribution of responses to the influencing factors perspective measures

Criticality	CANN rate	MICAP fill rates	Maintenance scheduling effectiveness	TNMCS
1	0.15	0.38	0.31	0.15
2	0.38	0.27	0.08	0.27
3	0.38	0.19	0.12	0.31
4	0.08	0.15	0.5	0.27

Table IV. Distribution of responses to the management perspective measures

Criticality	Adherence to OPS/ MXS schedule	DD rate AWM	Total m. deviation	4-hour fix rate	8-hour fix rate	12-hour fix rate	Days in phase/ISO
1	0.58	0.04	0.08	0.08	0.04	0.15	0.03
2	0.08	0.08	0.31	0.12	0.15	0.05	0.23
3	0.08	0.04	0.12	0.12	0.15	0.15	0.35
4	0.08	0.23	0.19	0.15	0.08	0.19	0.08
5	0.15	0.15	0.12	0.19	0.27	0.08	0.08
6	0	0.19	0.12	0.12	0.31	0.19	0.08
7	0.03	0.27	0.08	0.31	0	0.19	0.15

Table V. Distribution of responses to the internal enhancement perspective measures

Criticality	CND rate	RR rate	Special experience identifiers	Total abort rate	Training schedule adherence	Upgrade training	Unit average technical skill level
1	0.19	0.15	0	0.27	0.04	0.19	0.15
2	0.19	0.27	0.08	0	0.15	0.15	0.19
3	0.04	0.08	0	0.19	0.23	0.23	0.19
4	0.12	0.08	0.23	0.12	0.12	0.15	0.19
5	0.19	0.31	0.04	0.15	0.08	0.08	0.15
6	0.23	0	0.15	0.23	0.23	0.12	0.04
7	0.04	0.12	0.5	0.04	0.15	0.08	0.08

6. Conclusions

In this paper, the necessity of developing a performance measurement system for flight line MX is illustrated and a brief review of literature related to BSC and flight line MX is presented. The paper also provides development guidelines that will facilitate strategically aligned BSC development through the identification of mission critical performance measures that seek to improve the performance of aircraft scheduling and achievement of mission objectives. These guidelines are used to develop an effective management system for the flight line MX – a BSC approach that integrates different MX measures into four perspectives to view an organization within one performance measurement framework. The proposed BSC aligns the flight line MX to the long-term strategies and missions of the military aviation.

A survey is conducted to evaluate the perspectives and measures included in the proposed BSC. The validation process indicates that the mission perspective is the most critical perspective with the management perspective ranked as the next most critical. The respondents indicate that the least critical perspective is internal enhancement perspective. Within the mission perspective, MC rate and PMCM are the most and least critical measures, respectively. The MICAP fill rate is ranked as the most critical measure within the influencing factors perspective. Within the management perspective, the adherence to OPS/MXS schedule is the most critical measure, and the least critical measures are DD rate AWM and four-hour fix rate. The CND rate, RR rate, upgrade training, and unit average technical skill level are the most critical measures within the internal enhancement perspective.

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