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CONTROLLING AND IMPROVING THE PROVISION OF AFTER-SALES SERVICES

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Executive summary

The fierce competition coming from the emerging markets, the high rate of technological innovation and the increasing customers' expectations force industrial companies to shift their traditional product-centric business perspective to a more profitable and sustainable customer-oriented strategy. Since 1990s, in fact, companies operating in the western mature markets have progressively realised the importance of complementing industrial goods with the provision of value added services. This trend, called *Servitization*, is a process where manufacturing companies embrace service orientation and develop more and better product-services with the aim of surviving on the market and enhancing firm performance (Ren and Gregory 2007). Companies provide the so-called *Product-Service Systems*, that is, they offer solutions for sale that consist of tangible products and intangible services, which are designed, combined and delivered so that they are jointly capable of fulfilling specific customer's needs (Mont 2001; Brandstotter *et al.* 2003).

Several authors (Anderson and Narus 1995; Cooper 1995; Cohen and Whang 1997; Mathieu 2001; Oliva and Kallenberg 2003; Cohen *et al.* 2006; Baines *et al.* 2009, to mention a few) have reported the benefits associated with this business especially in terms of profitability, competitive advantage, customer retention and environmental sustainability. One of the most challenging outcomes is related to the profits that selling services may generate: the service market, in fact, can be four or five times larger than the market for products (Bundschuh and Dezvane 2003) and may produce at least three times the turnover of the original purchase during a given product life cycle (Wise and Baumgartner 1999; Alexander *et al.* 2002), contributing to about 40%–50% of the total revenue, and to a profitability of up to 20%–25% (Alexander *et al.* 2002; Craemer-Kühn 2002; McClusky 2002).

However, although services are thought to deliver higher margins, most organisations find quite problematic to transit from a product-centric view to a more innovative product-service one. A Bain & Co's survey (Baveja *et al.* 2004) reveals that only 21% of the sampled companies have experienced a real success with their service strategy. According to a Neely's survey (2009), 53% of firms which had declared bankruptcy were selling product-services. It occurs that manufacturing companies, especially Small and Medium Enterprises, which heavily invest in extending their service business, increase their service offerings but incur higher costs, and eventually do not achieve the expected correspondingly higher returns (Gebauer *et al.* 2005; Visnjic and Van Looy 2009; Neely 2009). This implies that, instead of managing a transition from products to services, product manufacturers fall into the so-called ‘‘service paradox’’. Overcoming this hitch represents a major managerial challenge (Oliva and Kallenberg 2003; Baveja *et al.* 2004).

To properly provide these services, companies must radically change the way they operate, moving beyond their product strategies and converting them into product-service ones (Karlsson 2007; Panizzolo 2008). They need to mature the capability to design and deliver services rather than products and develop new knowledge, organizational principles, metrics and incentives which firms do not currently possess. In particular, a fundamental requirement lies in designing specific and appropriate tools to help companies in monitoring their current and future results and the critical trends of the beneath processes.

Concerning this purpose, this PhD thesis aims at dealing with the definition of a **product-process matrix** which indentifies a correspondence between product characteristics and suitable service processes (namely technical support processes), at developing an appropriate **Performance Measurement System** and at suggesting two tools which can support companies to control and improve the provision of their product-services:

i) a **dashboard** which monitors the current companies’ results through proper and rigorous indicators specifically defined to measure the service performance and to identify the beneath critical processes which need to be (re-)designed;

ii) a **management cockpit** which assesses the impact of future operational decisions on the performance results of a company and identifies the main levers to manoeuvre and adjust like the knobs on a control panel.

To achieve the main outcomes of this research, a procedure with logical and specific steps to accomplish has been defined. This procedure is made up of six repeatable steps that can be followed anytime it is required to support a company in designing (or reviewing), controlling and improving the provision of its product-services.

The validity and applicability of the whole procedure has been tested with one case study.

Structure of the thesis

This thesis is structured according to the following chapters.

Chapter 1 – defines the background where this research work is set. It deals with the concepts of Servitization and Product-Service Systems and, in particular, it pauses over the provision of After-Sales Services.

Chapter 2 – is a literature review on Performance Measurement Systems and their applications in the After-Sales area. This chapter puts emphasis on the main characteristics that are required to define a Performance Measurement System specific for the needs of this business.

Chapter 3 – highlights the main research gaps, the scope of this PhD thesis and the expected outcomes. Moreover, it proposes a six-step procedure which has been defined to develop a product-process matrix, an appropriate Performance Measurement System and to carry out a dashboard and a management cockpit.

Chapter 4 –outlines in detail step 1 and step 2 of the procedure and deals mainly with the definition of appropriate After-Sales processes.

Chapter 5 – is about step 3 and step 4 of the procedure, and it concerns the design of a Performance Measurement System and the development of its relative dashboard.

Chapter 6 – describes in detail step 5 and step 6 of the procedure, that is the simulation model and how this dynamic analysis is functional to the creation of a management cockpit.

Chapter 7 – reports a case study carried out in an agri-machine company, Orkel AS, and shows how the six-step procedure has been applied.

Chapter 8 – reports the conclusion of this work, the scientific and the managerial implications and the further developments.

Figure 1 reports the structure of this thesis.

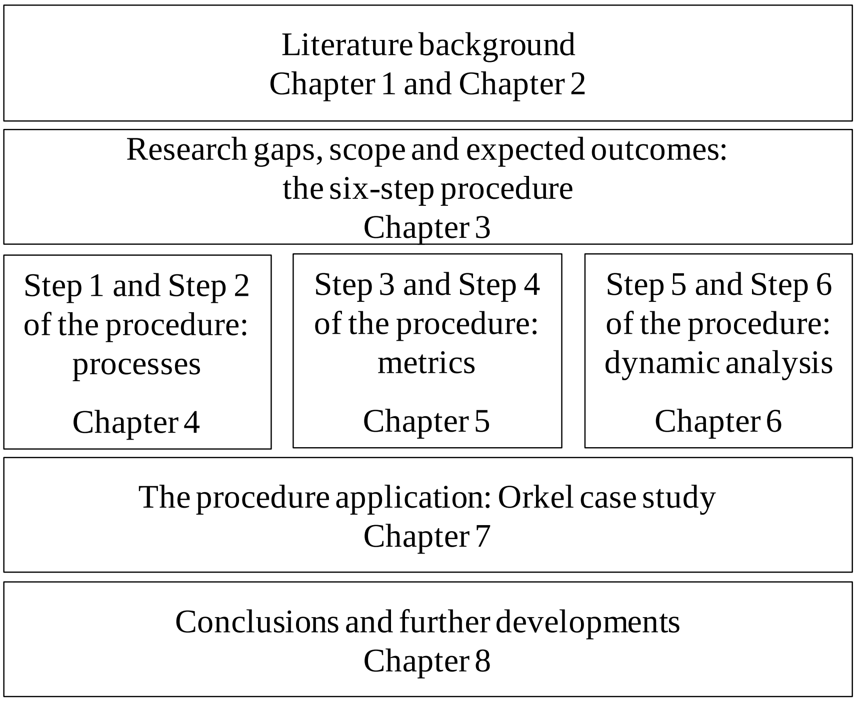

Figure 1 – Structure of the thesis

Acknowledgments

This PhD experience has been one of the most interesting and challenging adventures of my life. As any fascinating trip, it gave me the chance to explore and arouse my curiosity, to know new people and cultures and to get unexpected learning and findings. Looking back, I am thankful for all I have received throughout these years and I am extremely grateful to all those who came along this journey with me.

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The first stage was at Zaragoza, in Spain, at the Zaragoza Logistics Center, where I had the chance to enforce my logistics background following several methodological courses. I am really thankful to have joined this program especially for having been challenged to work in a highly professional and international environment.
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As any traveller loves thinking, even if this journey has arrived to an end, I know that there is still a long way to go!

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Chapter 1
State of the Art in After - Sales Services

This chapter defines the context where this research work is set. It proposes a literature review about the concepts of Servitization, Product-Service Systems and, more in detail, about After-Sales services, the main subject of this thesis. Advantages and challenges in approaching this new business are highlighted at the end of the chapter.

1.1 From products to services: the Servitization process

The fierce competition coming from the emerging markets, the high rate of technological innovation and the increasing customers' expectations force industrial companies to shift their traditional product-centric business perspective to a more profitable and sustainable customer-oriented strategy. Nowadays customers require more services and are no longer satisfied with the goods alone. In other words, customers' behaviour has changed dramatically: whereas once customers purchased products by basing their decision primarily on tangible aspects, today their purchasing decision is affected by a far wider range of needs that manufacturers have to cover by widening their portfolio of services (Panizzolo 2008). In order to be differentiated from rivals and avoid to compete only on the basis of costs, companies must strive in ensuring a long-lasting and stable relationship with the final customer through the overall product life-cycle. They have to move beyond production and offer services and solutions by delivering products with tangible and intangible elements of differentiation to make them perceived as unique, not easily replaceable and qualified for setting premium prices.

As revealed by Neely (2009), who analysed the incidence of this phenomenon through an extensive survey of manufacturing companies operating on a global scale, more than 30% of industrial companies belonging to developed economies are “mixed”, since they provide products and also services. On the contrary, in the emerging countries, companies are not motivated to move towards the provision of services: for instance, China, given its recent progression towards development, is the country with the highest rate of pure manufacturing firms.

This trend towards selling product-services was first discussed in the late 1980s by Vandermerwe and Rada (1988). They coined the term *servitization* to identify “the move by which companies expand their offerings through integrated packages of products, services, support, self-service and knowledge to add value to the core business of the company”.

This concept received an increasing attention over the years in the mainstream of engineering and management literatures and lots of definitions of *servitization* have raised. A reference definition might be the one provided by Ren *et al*. (2007), who consider the *servitization* as a “change process wherein manufacturing companies embrace service orientation and/or develop more and better services, with the aim to satisfy customers’ needs, achieve competitive advantages and enhance firm performance”.

The fundamental principle of *servitization* is to increase the value of the product offered to the customers by providing additional services that will complement its use, function, deployment or application. According to Hewitt (2002), “the popular advice to manufacturers is that, to sustain competitiveness, they should move up the value chain and focus on delivering knowledge intensive products and services”. This represents a major managerial challenge (Oliva and Kallenberg 2003; Baveja *et al.* 2004) since companies must radically change the way they operate, moving beyond their product strategies and converting them into product-service ones (Karlsson, 2007; Panizzolo 2008).

1.2 Product-Service Systems: concept and definitions

According to Neely (2009), "*servitization* involves the innovation of an organisation's capabilities and processes so that it can better create mutual value through a shift from selling product to selling *Product–Service Systems*".

The term *Product–Service Systems* (PSS) was firstly adopted by Goedkoop *et al.* (1999) in order to identify "a marketable set of products and services capable of jointly fulfilling a user's needs". A PSS uses an established, physical product as the vehicle or platform, for delivering services related to the product (Heiskanen and Jalas 2000; Bartolomeo *et al.* 2003). Several authors have tried to identify, categorize and describe different forms of PSSs (Hockerts and Weaver, 2002; Behrend *et al.* 2003; Tukker, 2004; Neely 2009) and, in particular, three categories of PSSs have been identified according to who owns the PSS and who uses it (Baines *et al.* 2007; Pezzotta *et al.* 2009):

- *Product-Extension services* - these services are characterized by the customer ownership of the physical good. Product-extension services enhance the utility that the ownership of the product delivers to the customer (e.g. repair, maintenance and upgrading and take-back, etc.). In particular, this class of product-based services refers to services which are usually provided and managed during the middle and end of life phases of a product life cycle and are devoted to supporting customers in the usage and disposal of the goods (Patelli *et al.* 2004b). For this reason, they are also called *After-Sales services*.
- *Product-Utility services* - this category refers to two main areas of service which are connected with rentals and leasing. The provider is the owner of the product but the customer uses directly the product and the related service (e.g. car-sharing, car-pooling, leasing).
- *Product-Results services* - this is a situation where a provider supplies a complete solution to an on-going need for a customer. The customer does not own and use the product, but uses only the functionality and the results created (e.g. voicemail, energy service contracting).

Service increasingly becomes an element of the offering from product extension to utility and result solutions (Mont 2001; Aurich *et al.* 2006). In this context, it is evident how the relationship between product and service is complementary rather than substitutive: products tend to be reinforced by services (Mont 2001).

According to Oliva and Kallenberg (2003), the transition from pure-product to pure-service providers is a continuum and manufacturing firms move along this axis as they incorporate more product-related services (Figure 1.1). It is a long-term gradual process which drives companies from being pure manufacturers towards being, firstly, suppliers of simple services as product add-ons (Product-Extension services) and, in a second instance, providers of more forward-looking solutions, wherein customers benefit from the functionalities and/or utilities created by the product-service package (Product-Utility and Product-Results services).

Both product and services are used to fulfil customers' needs, but the ratio between the "product value" and the "service value" can vary, according to the market specifications and the customers' needs. In some contexts the value embedded in the product can still comparatively play a relevant role for the client; conversely, other markets would consider the product a mere commodity, shifting the judgement on the portfolio of services provided.

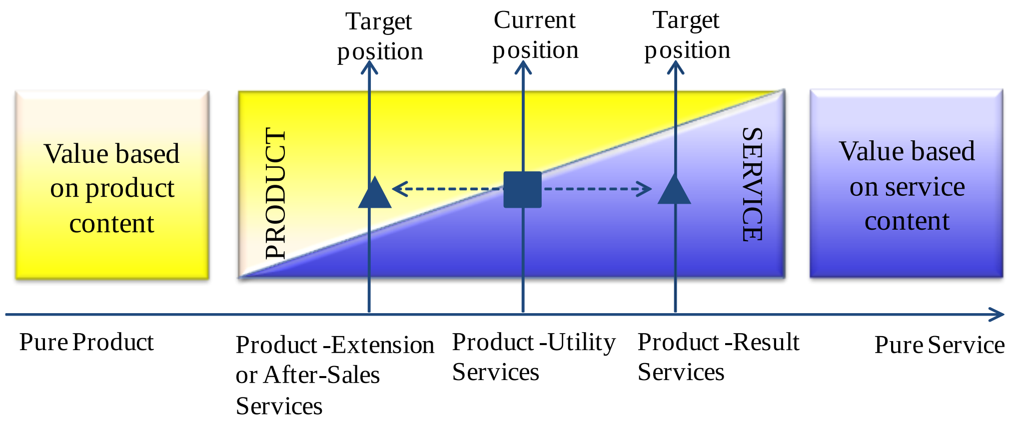


Figure 1.1- The product-service continuum (adapted from Oliva and Kallenberg 2003)

As companies go along an appropriate service culture development, they can determine their current positioning along the product-service axis and accurately identify the pathway (target position) along which they gradually increase - or decrease - their "service value" ratio.

The key idea behind the provision of PSSs is that consumers do not specifically demand products, but rather they are seeking the functionalities that these products and services provide. Analysing the literature, most of the authors (Goedkoop *et al.* 1999; Mont 2001; Elima 2003; Manzini and Vezzolli 2003) see the purpose of a PSS as functional for a competitive strategy and thus directly linked to the customer satisfaction and economic capability. Moreover, in some definitions the PSS is also considered as a way to achieve sustainability (Manzini *et al.* 2001). By using a service to meet some needs rather than a physical object, more needs can be met with lower material and energy requirements (Roy 2009). From this point of view, the PSS model inherently describes a shift in business orientation from material products to immaterial services that motivate companies to increase material efficiency and reduce material consumption. This approach may lead to a "sustainable" PSS, designed to deliver value to the customer throughout the life cycle of the offering in an economically profitable, environmentally efficient and socially responsible manner. It can be a way to promote dematerialization that could lead to decrease the environmental burden (Williams 2007).

In any case, the provision of PSSs, both in terms of simple services and of more complex solutions, is a long-term gradual process which needs to be carefully monitored by companies and requires the creation of business models, organisational structures and knowledge new to the product manufacturers.

1.3 After – Sales Services

Regarding the scope of this PhD thesis, work has been addressed to the first step of the *servitization* process, namely to the provision of *Product-Extension services* or *After-Sales (AS) services*, where products are sold in a traditional manner and include, in the original act of sale, additional services to guarantee functionality and durability of the product owned by the customer.

Several definitions of AS service can be found in managerial literature. They mainly differ with respect to both the extension assigned to the concept of AS and its role inside the service chain (Cohen and Lee 1990; Ehinlanwo and Zairi 1996; Asugman *et al.* 1997; Urbaniak 2001; Gaiardelli *et al.* 2007).

Despite the different definitions, some peculiar features related to the provision of AS services can be pointed out (Patelli *et al.* 2004a):

- *AS services represent a business*

  In most organisations selling AS services represent a business, which can generate significant profitability, often greater than the one generated by product sales. AS represents an organisational unit and its management has to reach adequate financial results (costs, revenues, operating profit, Return On Assets (ROA), cash flow) and competitive performance (market share, market penetration, customer satisfaction and loyalty, competitors' results). In order to develop the AS business, a proper balance between the orientation to profitability and the one to customer satisfaction and loyalty, as well as an adequate level of investments, have to be assured, both in the short term, as well as in the long term.
- *AS is a service*

  As already mentioned, AS is a type of PSS and it represents the first step along the product-service continuum transition. AS is a service, thus some typical characteristics of services (Fitzgerald *et al.* 1991) have to be considered when dealing with it: i) the distinction between front-office and back-office activities, ii) the relevance of some intangible assets, such as human resources, iii) the proximity to the customer, iv) the relevance of indirect costs, and v) the focus on the service level (quality and timeliness). AS effectiveness depends mostly on front-office activities, while efficiency comes from back-office ones.
- *AS is a process*

  AS can be viewed as a process made up of different activities, carried out by actors belonging to different functions and organisations. The sum of these activities are needed to maintain, after the delivery takes place, product quality and reliability in order to increase customer satisfaction (Ehinlanwo and Zairi 1996).
- *AS is an organisational unit*,

  The manager in charge of this organisational unit has different possible economic responsibilities, since the unit can be seen as a cost centre, a profit centre or an investment centre. A set of performance measures needs to be implemented in order to analyse the variances between budgeted goals and actual results, to evaluate strengths and weaknesses of the organisational unit and to support decisions.

- *AS services are supplied through a service network*

  The provision of AS services does not involve just a mere ancillary function within a manufacturing company but it encompasses a series of primary and supporting processes and involves independent organizations with very often conflicting objectives and behaviours. In general, the service network is made up of one (global) focal firm (which owns a brand and/or provides a main product-service), and a network of third party service providers. The focal firm, according to its strategy and its competences, may decide to internally perform some activities and outsource others to third parties, building different forms of relationship with them. The key for managing AS activities and achieving high performance results is to establish a collaborative and active interaction within the company itself, the third parties involved in the service network and the final customers (Edvardsson *et al.* 2005) and to satisfy all their relative goals.

1.3.1 The role of After-Sales services during the product life cycle

AS services are generally provided as product add-ons and they are supplied to support customers in the use and disposal of the product itself. According to the different phases of a product life cycle, AS services are delivered during the middle and end of life phases. In particular, customers can require them when they buy the product, during its usage, when they need to re-establish its functioning and when they have to retire and dismiss it (Figure 1.2).

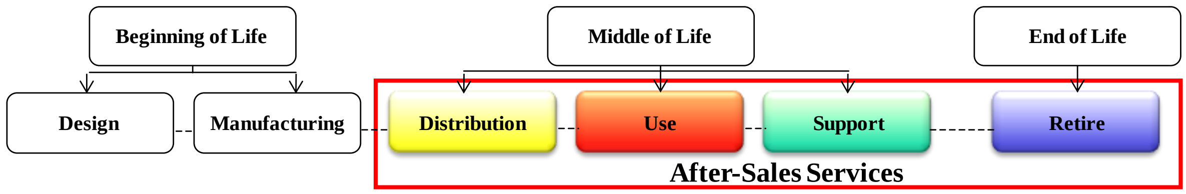


Figure 1.2 – AS in the Product Life Cycle model (adapted from Ciceri *et al.* 2009)

AS services represent a wide portfolio of activities: Goffin (1999) attempts to classify them according to each specific stage of the product life cycle (Figure 1.3).

Four categories are identified:

1. *services associated with selling the product* – they are required during the process of transferring the ownership of the product to the customer in order to make it work. They can be: installation, training, product documentation, financial or insurance services and extension or customization of the warranty.
2. *services associated with the use of the product* – they are required to facilitate and improve the procedures for an efficient use of the product by the user as well as to assess periodically any unforeseen issues that may arise. They can be: customer care, upgrades and product check-up.
3. *services associated with the recovery of product functions* – they include all activities, mainly of technical nature, for maintenance and repair of products and replacement of defective parts, in order to restore the functionality of the product.
4. *services associated with the disposal of the product* – they refer to absorbing EU regulations regarding the sustainable dismissal of the products at the end of their useful life span.

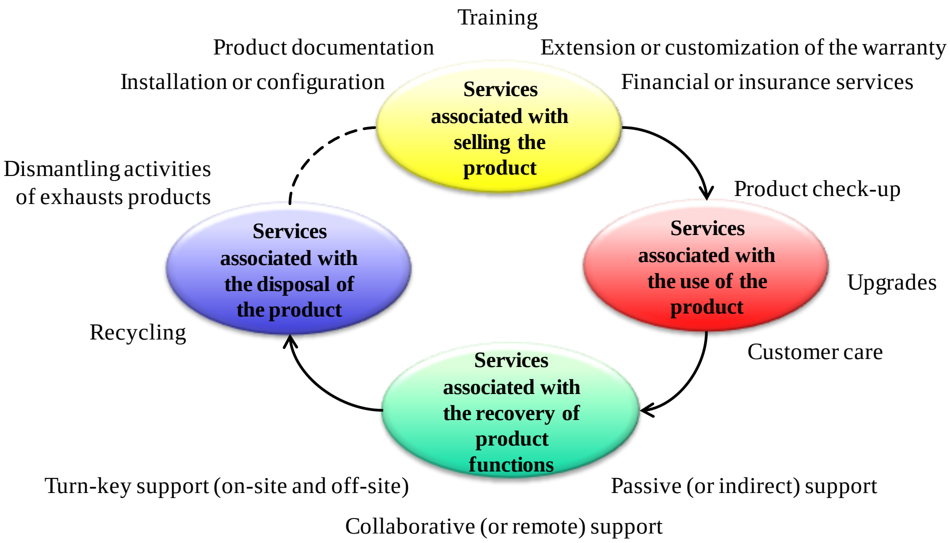


Figure 1.3 – AS services portfolio along the Product Life Cycle (Goffin 1999)

The third type of services is definitely the most common one, and it is also the main focus of this research work. It is often quoted as *technical support* and it is requested by the customer or offered by the producer following (or anticipating) a malfunction of the product. Cavalieri and Corradi (2002) and Legnani *et al.* (2009) identify different typologies of support according to the service level offered, the type of product sold, the level of involvement of the customer and the sustained costs. The support processes can be:

- *passive (or indirect)* - the company provides an appropriate documentation to the customer who is able to autonomously perform the diagnosis, identification and application of the solution;
- *collaborative* - the customer autonomously sorts out the problem with the help of an expert through a remote connection;
- *turn-key* - the customer is not able to solve the problem and needs the help of an expert who solves the problem. This support can be of two types: off-site, when the company collects the faulty product through its assistance channel, repairs and gives it back to the customer, and on-site when the intervention is performed at the location where the defective item is installed.

1.4 The "Service Paradox"

Since the provision of services, and in particular of AS services, has been acquiring a strategic importance for those companies operating in mature markets, several authors (Anderson and Narus 1995; Cooper 1995; Cohen and Whang 1997; Mathieu 2001; Oliva and Kallenberg 2003; Cohen *et al.* 2006; Baines *et al.* 2009, to mention a few) have reported the benefits associated with this business especially in terms of profitability, competitive advantage and customer retention. More in detail:

- selling services generate profits: the service market, in fact, can be four or five times larger than the market for products (Bundschuh and Dezvane 2003) and may produce at least three times the turnover of the original purchase during a given product life cycle (Wise and Baumgartner 1999; Alexander *et al.* 2002), contributing to about 40%–50% of the total revenue, and to a profitability of up to 20%–25% (Alexander *et al.* 2002; Craemer-Kühn 2002; McClusky 2002).
- AS services can be considered a lever in competitiveness, mainly in global markets where a decreasing profit from product sales has occurred. AS is a key differentiator for manufacturers and it can even represent a way to recover from losses caused by a former competition on price held with competitors on the original product (Wise and Baumgartner 1999; Gallagher et al., 2005).

- AS services are a way to collect feedback information for continuous improvement (Armistead and Clark 1991, Cohen and Whang 1997; Thoben et al. 2001). The continuous interaction between the company and the customer after the purchase of the product makes possible to recover from failures in meeting the customer's requirements. These elements are crucial to propose new high added-value solutions on the market. Data about reliability of products and services are an important means for finding information to develop new solutions, improve sales and marketing activities, and enhance customer relationship management.
- AS services are considered a powerful marketing force for establishing durable customer loyalty and promoting the company's brand (Anderson and Kerr 2001; Campbell 2003). AS activities aim at retaining and obtaining satisfaction from the customer, who lately would accord brand loyalty to the company, assuring future sales and a better image.

However, despite these positive advantages, most organisations find quite problematic to transit from a product-centric view to a more innovative product-service one. A Bain & Co's survey (Baveja *et al.* 2004) reveals that only 21% of the sampled companies have had real success with their service strategy. According to Neely's survey, 53% of firms which had declared bankruptcy were selling product-services. It occurs that manufacturing companies which heavily invest in extending their service business, increase their service offerings but incur higher costs, and eventually do not achieve the expected correspondingly higher returns (Gebauer *et al.* 2005; Visnjic and Van Looy 2009; Neely 2009). This implies that, instead of managing a transition from products to services, product manufacturers fall into the so-called ‘‘service paradox’’.

In order to overcome this hitch, companies need to mature the capability to design and deliver services rather than products and increase their service awareness, accepting the risk of extending the service business and believing in the economic potential of services (Gebauer *et al*., 2005).

New knowledge, organisational principles, metrics and incentives which firms do not possess are necessary to be developed (Oliva and Kallenberg 2003; Baveja *et al.* 2004). In particular, a fundamental requirement lies in designing the appropriate processes to carry out, either as a part of the company's operations or through third parties, as well as a set of rigorous and specific performance indicators which monitor the main critical trends.

1.5 Conclusions

In several manufacturing industries selling product-services is recognised as a key of competitive success. Hence, companies need to move from a pure product orientation towards a product-service one. It is proved that this shift is very challenging and it can be very difficult if companies do not develop an appropriate service culture and the capability to design and deliver services in an effective and efficient way.

The provision of services require the definition of specific business models, the creation of proper organisational structures and the development of new incentive mechanism.

In particular, a key issue is to check and control all the processes and activities which are carried out to provide product-services: a fundamental requirement lies in designing specific and appropriate tools to help companies in monitoring their current and future results and the critical trends of the beneath processes.

Concerning this purpose, this PhD thesis aims at dealing with the definition of a product-process matrix, which indentifies a correspondence between product characteristics and suitable service processes, at developing an appropriate Performance Measurement System and at providing a dashboard and a management cockpit as decision making tools to support companies in controlling and improving the provision of their product-services.

The research is addressed to AS services, and, more in detail, to the provision of technical support to customers.

Chapter 2
State of the Art in After-Sales Performance Measurement

This chapter reports a literature review on Performance Measurement.
It aims first at clarifying the topic and at providing some definitions about key and inter-related concepts, such as Performance Management, Performance Measurement and Performance Measurement System (PMS). Then it reports the evolution of Performance Measurement in the operations management literature and gives a picture of the main contributions and applications for the AS area. The comparison with the characteristics of PMSs designed for monitoring operations management issues and the distinguishing features of AS services, allow to define the main characteristics and requirements of a PMS specific for the needs of the AS business. These considerations and the main challenges are reported at the end of the chapter.

2.1 Performance Management and Performance Measurement

Performance Measurement has become a popular topic for both industrialists and academics, reaching the stage of being identifiable as a specific subset in the operations management literature (Pilkington and Liston-Heyes 1998).
According to Neely *et al.* (1995), Performance Measurement can be defined as "the process of quantifying the efficiency and effectiveness of actions" and can serve a variety of purposes: it can be used as a vital management and decision-making tool and it can provide information helpful to make improvements in operations, program design

and service delivery (Dinning 1996). Performance Measurement is the key agent for change as it assesses the progress made towards achieving predetermined performance goals (Amaratunga and Baldry 2002; Ghalayini and Noble 1996; McAdam and Bailie 2002). Performance Measurement supports Performance Management which is a philosophy that creates the context for measuring. Performance Measurement and Performance Management cannot be separated since measures only tell what the consequences of the decisions that created the context are (Lebas 1995). For the sake of clarity, Table 2.1 reports the processes involved in Performance Measurement and in Performance Management.

Performance Measurement	Performance Management
• measures based on key success factors • measures for detection of deviations • measures to track past achievements • measures to describe the status potential • measures of output • measures of input • etc.	• training • team work • dialogue • management style • attitudes • shared vision • employee involvement • multi-competence • incentive, rewards • etc.

Table 2.1 – Performance Measurement and Performance Management processes (Lebas 1995)

As it can be seen from Table 2.1, the processes involved are not the same but they feed and support one another.

A Performance Measurement System (PMS), can be defined as “the set of metrics used to quantify both the efficiency and the effectiveness of actions” (Neely *et al.* 1995). A PMS is the means through which Performance Measurement is carried out. According to Forza and Salvador (2000), a PMS is an information system that supports managers in the Performance Management process since it mainly fulfils two primary functions: the first one consists in enabling and structuring communication between all the organizational units (individuals, teams, processes, functions, etc.) involved in the process of target setting. The second one is that of collecting, processing and delivering information on the performance of people, activities, processes, products, business units, etc.

According to Santos *et al.* (2007), a PMS (or a BPM[1]) can be read according to three different dimensions:

- *Features*, which are the properties or elements that make up a PMS;
- *Roles*, which are the purposes or functions that are performed by a PMS;
- *Processes*, which are the series of actions that are combined together to constitute a PMS.

Table 2.2 reports the typical elements that belong to each category:

Features
• performance measures (including features such as multidimensional, leading/lagging, efficiency/effectiveness, internal/external, vertically and horizontally integrated, multi-level) • objectives/goals (often referring to strategic objectives) • supporting infrastructure (which can include data acquisition, collation, sorting, analysis, interpretation and dissemination) • targets • causal models • hierarchy/cascade • performance contracts • rewards
Roles
• strategy implementation/execution • internal communication • measure performance/performance evaluation • monitor progress • planning • external communication • performance improvement • feedback • benchmarking • control • etc.
Processes
• information provision • measures design/selection • data capture • target setting • identify stakeholders needs and wants • data analysis

[1] When a PMS focuses on "business" performance measures and it excludes "organizational" measures typical of the public and no-profit sectors, then it can also be called Business Performance Measurement (BPM) system. For the purpose of this thesis, the term PMS is used meaning "business" performance measures.

• decision making • etc.

Table 2.2 – Main Features, Roles and Processes of a PMS (Santos *et al.* 2007)

The objective of this thesis is to present the main requirements and characteristics of a PMS specific for the needs of the AS area. Therefore the emphasis of the following literature analysis is mainly on the *Features* dimension of a PMS.

To conclude this brief excursion on the notions of Performance Management, Performance Measurement and PMS, it has to be remarked that these concepts are very interrelated one to each other and it is not always very easy to discern exactly their meaning and functionality. Comparing and analyzing Table 2.1 and Table 2.2, in fact, it comes out that some elements are the same or very similar in their meaning.

Santos *et al.* (2007) remark that researchers need to bear in mind that when they specify the features, roles and processes present in a PMS, these specifications will define the boundaries of the system, and hence the research being undertaken. The greater the number of features, roles or processes to be included in the definition, the more difficult it will be to distinguish Performance Measurement from Performance Management.

2.2 The evolution of Performance Measurement

Performance measurement has its roots in early accounting systems which have been characterized as being financially based, internally focused, backward looking and more concerned with local departmental performance than with the overall health or performance of the business (Johnson and Kaplan 1987; Keegan *et al.* 1989; Neely *et al.* 1995; Olve *et al.* 1999). As a consequence, in the late 1980s and early 1990s there was a great interest in the development of more balanced performance measurement systems.

Different frameworks addressing both the corporate level and the strategic business areas (Kaplan and Norton 1992, 1996; Olve *et al.* 1997) were proposed, while activities and processes were identified as relevant aspects of performance (Kaplan and Johnson 1987; Johnson 1992; Lorino 1995; Wright and Keegan 1997). It was also stressed the necessity to consider both tangible and intangible aspects, efficiency and effectiveness, innovation as well as the need to complement traditional financial measures with non financial ones (Eccles 1991; Stewart 1991). For a balanced approach, Marksell (1991) suggests that companies should understand that, while financial performance measurements are important for strategic decisions and external reporting, day to day control of manufacturing and distribution operations is often handled better with non-financial measures.

Dynamic, relevant, suitable, multidimensional, internal and external performance measures were introduced in order to benchmark the results of an organisation with the competitors' performance (Dixon *et al.* 1990; Lynch and Cross 1991). The necessity of integrating operative actions, organisation's mission and strategic objectives, pushed also researchers and industrial managers to address their efforts mainly on developing and deploying integrated PMSs able to link the strategy formulation to its implementation, to combine financial and operational measures, as well as long-term oriented metrics, with financial short-term oriented indicators. Balanced and multidimensional frameworks and methodologies, such as the Performance Measurement Matrix (Keegan *et al.* 1989), the Results and Determinants framework (Fitzgerald *et al.* 1991), the SMART Pyramid (Lynch and Cross 1991), the Balanced Scorecard (Kaplan and Norton 1992, 1996), and the EFQM framework (Olve *et al.* 1997; EFQM 1998), were therefore developed in order to encompass the different functional areas and the related value added processes of a company.

Lately, it has also been observed an evolution from intra-organisational measures to supply chain ones (Lapide 2000; Gunasekaran *et al.* 2001; Bullinger *et al.* 2002; Hausman 2003; Brewer and Speh 2000). The ever increasing complexity of supply chains, in fact, has put pressure on the measurement of those activities required to coordinate and control integrated processes and channels.

2.3 A focus on After-Sales Performance Measurement

The importance of service, and more specifically of the After Sales one, requires a thorough monitoring and measuring of its activities in order to assess and ensure a proper balance between business and operational objectives.

However, despite the increasing importance of AS service as a key ingredient of the competitive success of manufacturing companies (Cohen and Lee 1990), applications of PMS specifically designed for capturing the typical performance dimensions of the AS domain are very few (Lange et al. 2007; Neely et al. 2000). Moreover, according to

Gaiardelli *et al.* (2007) and Santos *et al.* (2007), literature contributions present a very fragmented picture. In particular:

- *management accounting* literature shows that a noteworthy number of research works have dealt with the analysis of financial accounting and long-term oriented perspective in order to evaluate the contribution of AS to the creation of value along with the product life-cycle (Fabrychy and Blanchard 1991; Shields and Young 1991; Artto 1994). Proposed methodologies and frameworks have been focused mainly on cost, adopting either the perspective of the supplier, such as life-cycle costing (Cooper and Slagmulder 1999, 2003) or of the customer, such as total cost of ownership (Ellram 1995). In such cases performance measurement approaches have mainly embraced the strategic business level, while scarce attention has been devoted to operative and nonfinancial metrics;
- from a *strategic control* perspective it emerges that an integrated view on performance measurement has not been adopted when dealing with the AS strategy. In this case frameworks and recommendations suggested by the authors have been directed on how to design the service mix (Frambach *et al.* 1997; Mathieu 2001; Yamashina and Otani 2001), to adopt pricing decisions (Kim and Park 2008), or to design the AS service organisation (Gebauer *et al.* 2008) and network (Armistead and Clark 1991; Löfberg *et al.* 2010). Performance evaluation has been considered only at the strategic business level, with a general perspective, but no detail has been given on the definition of relevant metrics and their drill-down to operational ones. Only a few authors have suggested sets of performance metrics as tools to test and verify the coherence between the strategic objectives and the effect of the actions undertaken (Agnihothri *et al.* 2002);
- in the *operations*, works oriented to the development and deployment of performance measurement frameworks dealing with AS processes, service supply chains and networks are very fragmented (Patton and Bleuel 2000; Brun *et al.* 2004; Patelli *et al.* 2004b). This is an unexpected result because in the recent years the extension of performance measurement from the single firm to supply chains and networks has emerged as a relevant research topic in the operations management field (Beamon 1999; Chan 2003). Also the well known and widespread Supply Chain Operations

Reference (SCOR) model (Supply Chain Council 2010) does not formalise AS as a consistent set of well established processes.

Numerous and detailed performance measures have been proposed to analyse the spare parts logistics area (Papadopoulos 1996; Hopp *et al.* 1999; Huiskonen 2001; Zhang *et al.* 2001; Bijvank *et al.* 2010). However, performance measurement has been limited to very specific efficiency (Persson and Saccani 2007) or effectiveness indicators, which are usually operative and generally oriented to internal service level metrics, often neglecting the assessment of the level of service as perceived by the end customer.

Table 2.3 summarizes the above literature contributions:

Area	**Emphasis**	**Authors**
Management accounting	Financial and long term perspectives with focus on costs	Fabrychy and Blanchard 1991; Shields and Young 1991; Artto 1994; Cooper and Slagmulder 1999, 2003; Ellram 1995
Strategic control	Strategic business level with a general perspective. No emphasis on operational metrics	Frambach et al. 1997; Mathieu 2001; Yamashina and Otani 2001; Kim and Park 2008; Gebauer et al. 2008; Armistead and Clark 1991; Löfberg et al. 2010
Operations	Spare parts logistics: efficicency and effectiveness	Papadopoulos 1996; Hopp *et al.* 1999; Huiskonen 2001; Zhang *et al.* 2001; Bijvank *et al.* 2010; Persson and Saccani 2007
	AS processes, service supply chains and networks: fragmented contributions with different emphasis	Patton and Bleuel 2000; Brun *et al.* 2004; Patelli *et al.* 2004b; Beamon 1999; Chan 2003; Supply Chain Council 2010

Table 2.3 – AS performance measurement contributions

2.3.1 Main challenges

According to several authors (Dixon *et al.* 1990; Eccles 1991; Fitzgerald *et al.* 1991; Lynch and Cross 1991; Stewart 1991; Kaplan and Norton 1992; Fitzgerald and Moon 1996; Bititci *et al.* 2000), an effective PMS for monitoring operations management issues has: i) to be articulated according to different levels of analysis, considering both strategic and operational decision making levels, such as strategic business areas, processes and organisational units; ii) to balance financial and non financial indicators; iii) to jointly consider long term and short term results, tangible and intangible aspects, efficiency and effectiveness.

As a consequence, also a PMS specifically thought to capture all the critical aspects of the AS area needs to be organised in such an integrated structure. This is one of the most challenging issues related to the design of a PMS for the AS service needs.

Some valuable contributions have been recently proposed to fill this gap. An interesting input regards the results achieved by the EU-funded project InCoCo-S (Osadsky *et al.* 2007), where a reference model for the collaboration between service providers and manufacturers has led to the definition of processes, metrics and related best practices to perform. In addition, Gaiardelli *et al.* (2007) introduce a framework which integrates the features of some existing models (Kaplan and Norton 1992; Lynch and Cross 1991; Supply Chain Council 2010) to carry out an all embracing PMS for AS services. The framework, conceived for a single company operating in a service network, addresses several performance areas into strategic, process, activity and development/innovation areas, giving emphasis to both efficiency and effectiveness measures as well as to internal and customer-oriented ones.

Moreover, following the analysis proposed by Santos *et al.* (2007) and summarised in Table 2.2, regarding the *Features* dimension (which is the only dimension taken into account for the development of this thesis), it is argued that a PMS cannot exist if its *performance measure* architecture is not embedded with a *supporting infrastructure*. This infrastructure can vary from simplistic manual methods to sophisticated information systems and supporting procedures (Neely 1998). Therefore, integrating performance measures with supporting infrastructure represents the second managerial challenge to face.

Finally, according to Table 2.2, within the *Features* category, there are other elements that can be implemented to make a comprehensive PMS, even though they are not considered vital in the study carried out by Santos *et al.* (2007). Hierarchy and causal models are characteristics that triggered researchers' interest. In particular, several authors claim that efforts should be addressed to identify the causal models and the relationships between measures (Flapper *et al.* 1996; Neely 1999; Bititci *et al.* 2000). In reality, in spite of the recognised importance of understanding the relationships among the various performance indicators in developing a complete measurement system, too many organisations still define their measurement systems without understanding the dynamic interdependencies and trade-offs between measures and, ultimately, the process underlying the performance generation (Santos *et al.* 2002).

2.4 Conclusions

This literature review aims at contributing to a better understanding of the peculiarities that a PMS specifically designed for the needs of the AS area should present. The analysis reveals that contributions regarding the AS field are still very fragmented and focused on different and disparate aspects without having an integrated view.

The evolution of Performance Measurement in the operations management literature offers ideas about how a comprehensive PMS suitable for the AS requirements should be developed. From the analysis, the following challenges come out:

- necessity to organise the PMS in an integrated structure, which includes strategic and operational indicators, financial and non-financial indicators, long term and short term results, tangible and intangible aspects, efficiency and effectiveness;
- necessity to embed the PMS with a supporting infrastructure;
- necessity to design a hierarchical architecture of the PMS and identify the causal models and the relationships between measures.

The work proposed in this thesis tries to overcome these challenges proposing a comprehensive PMS for the AS area and its relative supporting decision tools.

Chapter 3
The six-step procedure

This chapters defines the architecture and the contents of this work. The literature review carried out in the previous sections has highlighted some room for researching. The main gaps which have been identified, the questions which have driven this PhD thesis and the main hypotheses used to define the boundaries of the work are hereafter reported. Moreover, the procedure developed and adopted to achieve the main outcomes of this thesis, namely a product-process matrix, a PMS, a dashboard and a management cockpit, is also illustrated.

3.1 Research gaps, research questions and expected outcomes

As already emphasized in Chapter 1, manufacturing firms can rarely remain as pure manufacturers if they want to survive in the developed economies: they have to move beyond production and offer services and solutions, delivered through their products.

To properly provide these services, companies must radically change the way they operate: they have to move beyond their product strategies and convert them into product-service ones (Karlsson 2007; Panizzolo 2008). They need to mature the capability to design and deliver services rather than products and develop new knowledge, organizational principles, metrics and incentives which firms do not currently possess. In particular, it comes out that companies necessitate specific and appropriate tools which could help them in measuring and monitoring their results and the critical trends of the beneath processes.

According to this need, a detailed literature analysis about Performance Measurement has been carried out in Chapter 2. The goal of this study has been to understand which are the main requirements and characteristics that a PMS appropriately designed for the needs of the AS field should have. From the analysis it comes out that applications of PMS specifically designed for capturing the typical performance dimensions of the AS domain are very few and they do not have a well defined architecture.

A comprehensive PMS should be organised in an integrated structure which includes strategic and operational indicators, financial and non-financial indicators, long term and short term results, tangible and intangible aspects, efficiency and effectiveness. Moreover, it would be advantageous if the PMS had a hierarchical structure which drills metrics down into different levels of details, from strategic indicators to more diagnostics ones. The former provides aggregate and strategic information which summarizes the main trend of the AS business unit, while the latter provides more detailed and specific information about the underlying processes that it diagnostically measures.

The literature review emphasizes also another interesting aspect that should be considered when developing a complete measurement system: the need to identify the relationships among the various performance indicators in order to understand the dynamic interdependencies and trade-offs between measures and, ultimately, the process underlying the performance generation.

Finally, the analysis highlights that in order to measure the performance of a company, it is not enough to have a complete and structured PMS but it is important to embed it with a supporting infrastructure which can range from simplistic manual methods to sophisticated information systems.

According to these gaps and requirements, this PhD thesis aims at providing supporting tools which can help companies to control and improve their performance results.

Therefore, the main research question which guides the entire project is: **how to control and improve the provision of AS services of a company?**

Providing an answer to this research question implies a response to some secondary research questions (RQ) which can be stated as it follows:

RQ1. What are the key processes encompassed by the AS area? What is the relation with the characteristics of the products offered to the customers?

RQ2. How to evaluate the overall performance of the AS service area? How should a PMS be structured?

RQ3. How should the performance results be visualized?

RQ4. How to improve the current performance of a company and manoeuvre its future operational decisions?

Answering to these questions has stimulated some new research and it finally allowed to come up with the following results (R):

R1. A **product-process matrix** which indentifies a correspondence between product characteristics and suitable AS service processes;

R2. A **hierarchical and integrated PMS** which spans several indicators of different nature and allows to examine strategic trends and to make process-diagnostics analyses which help to identify the beneath critical processes that need to be (re) designed;

R3. A **dashboard** which controls and monitors the actual AS results of a company according to the structure of the designed PMS;

R4. A **management cockpit** which assesses the impact of future operational decisions on the performance results of a company and identifies the main variable-levers to manoeuvre and adjust like knobs on a control panel. This tool has been designed considering the causal relations and interdependencies existing among the performance indicators defined in the developed PMS.

The remainder of this thesis shows how the research questions have been approached in order to achieve the above reported outputs.

3.2 Scope of the research

The whole work has been developed according to some assumptions that helped to define the boundaries and the scope of this PhD thesis.

Research has mainly been addressed to AS services, where products are sold in a traditional manner and include, in the original act of sale, additional services to guarantee functionality and durability of the product owned by the customer. More in detail, the work is addressed to the provision of technical support and related spare parts to customers.

Moreover, even though a complete analysis should cover the entire service network, this project is tuned to analyse the AS service area of a focal company which operates within a service network (Figure 3.1). The relations within the internal functions of the focal company and the related primary and supported processes are studied and examined. Few interrelations with the third service providers and the final customers are considered.

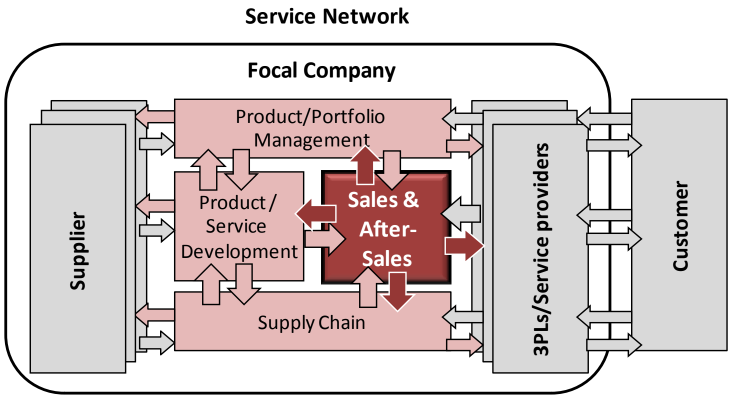


Figure 3.1 – Focal company and AS service area: scope of this PhD thesis

3.3 The developed procedure: a six-step process

To achieve the main outcomes of this PhD thesis, a procedure with a series of logical steps to systematically accomplish has been defined (Figure 3.2).

This procedure is made up of repeatable steps that can serve as guidelines and can be followed anytime it is required to support a company in designing (or reviewing), controlling and improving the provision of AS services. Each step is composed by semi-standardized modules built following some specific methodologies[2]. The application of these modules (or of lightly customized forms) leads to achieve the main outcomes of this project.

[2] Methodologies will be briefly mentioned later on in this chapter while their detailed description will be provided in the following chapters.

The first four steps are carried out to assess and monitor the current results of a company (AS-IS state) and they drive the development of a product-process metrix, a PMS and the related dashboard. The last two steps are executed to value the impact that future decisions may have on the current results of a company (evaluation of TO-BE states) and they lead to the development of a management cockpit.

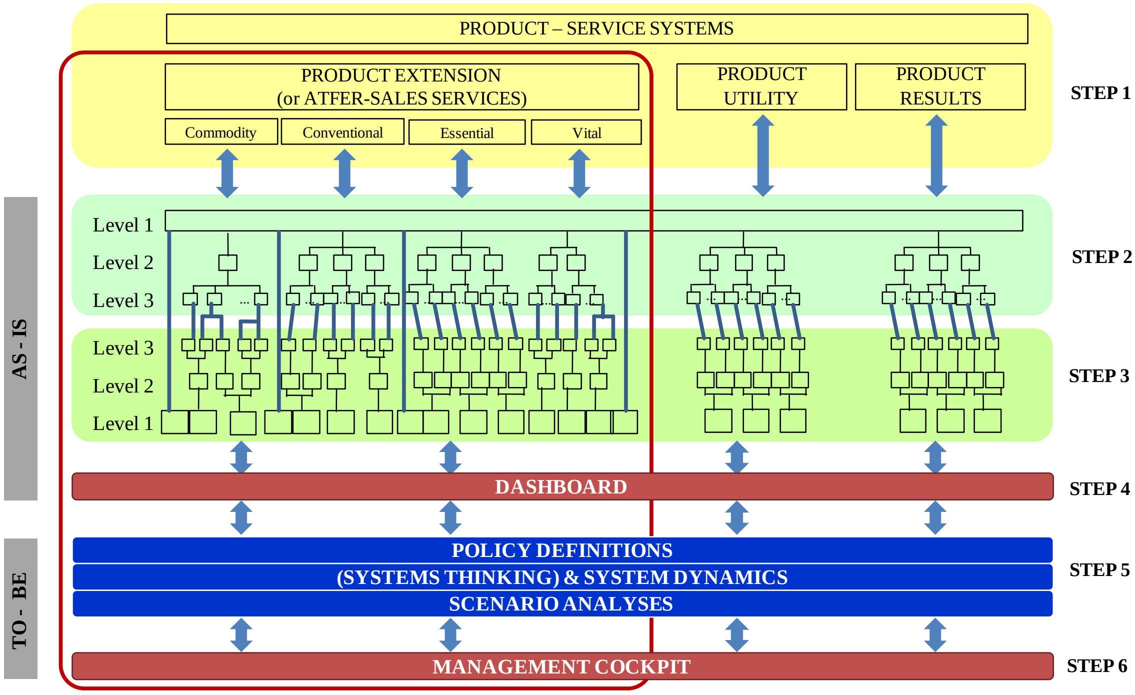


Figure 3.2 – The procedure to evaluate and control the current and future AS results of a company

More in detail, the steps are defined as it follows:

Step 1 – Identify product-processes relation

At a strategic level, when companies define their business models and the markets they want to address, they need also to identify which types of support process to handle in accordance with the characteristics of the products they are selling. This step aims at understanding and detecting what is the most suitable typology of assistance support to carry out at the tactical and operational levels in accord with the characteristics of the products sold on the market. In particular, within the AS services (or Product Extension) category, products can be classified as commodity, conventional, essential or vital ones:

each of them requires a specific technical support with different time-frames of interventions.

Step 2 –Map processes

When analysing a company (or a network), understanding and modelling its business processes represent an important starting point (Stadtler and Kilger 2005). This step gives a basic understanding of the business processes and it lays the foundation for proceeding with the design of a PMS (Andersen and Fagerhaug 2002).

In order to facilitate companies in mapping their AS processes, a hierarchical structure with a detailed description of the main assistance processes and their relative activities will be defined following the formalism adopted by the Supply Chain Council in its reference models (Chapter 4). Mapping will be carried out exploiting the XCOR methodology (Supply Chain Council 2010).

Step 3 – Measure performance

Evaluation of results and identification of corrective actions against defined objectives are elements that cannot be neglected for the success of an organization. For this reason, a multi-levelled set of metrics for the evaluation of the AS service area will be built using the same semantic structure and formalism adopted by the Supply Chain Council in its reference models (Chapter 5). The PMS will be arranged according to two structures: a hierarchical and a process-diagnostics ones. Indicators will range from strategic measures used to monitor the overall performance of the company to more diagnostic measures used to identify critical processes.

Step 4 – Display metrics through a dashboard

Making visible the results achieved by the company and compare them with set target values is extremely powerful to assess the current position of the company and to allow internal and external benchmarks. An easy and user friendly dashboard for the calculation and visualization of the current performance of the company is provided according to the hierarchical and process-diagnostics structures defined at the previous step.

Step 5 – Make a dynamic analysis

Modelling complex structures, such as the AS service one, requires to understand how the system behaviour is produced and to exploit this understanding to predict the consequences over time of policy changes to the system (Santos *et al.* 2002). System Dynamics is a method to depict and understand the interactions which produce the system behaviours. It is a tool to represent, analyse and explain the dynamics of complex systems along the time and it is a powerful method which helps to design better operating polices and to guide changes in the systems. Referring to the specific case of this project, System Dynamics will be adopted as the approach to foster the understanding of the logic underlying performance generation and to identify the factors that may trigger off effective changes in the AS service area. Continuous simulations and what-if analyses will be developed to capture the structure of the AS business and to predict aspects of its behaviour, with the purpose of solving a certain problem.

Step 6 – Control the system through a management cockpit

Prospects of any company business depend on the ability of controlling and manoeuvring future operational decisions. Through the dynamic analysis of different scenarios realised in the previous step, it is possible to understand the main factors and causal relations that generate changes in the provision of AS services and the impact that these changes have on the company results. These considerations can be arranged in a management cockpit where the effect that future operational decisions have on the performance of the AS service area can be visible and adjustable like the knobs on a control panel.

3.4 Conclusions

This chapter frames the architecture of this project as it clearly sets which research gaps it aims at filling, defines the boundaries of the research and specifies the main expected outcomes.

A procedure of six steps has been designed in order to define the logical stages to accomplish for developing a product-process matrix, designing a PMS, creating a dashboard and implementing a management cockpit. Next chapters (Chapter 4, 5 and 6) will describe each step of the procedure and the methodologies adopted. Finally an application to a real case study is reported in Chapter 7.

Chapter 4
Products and After-Sales Service processes

This chapter deals with the description of Step 1 and Step 2 of the procedure defined in Chapter 3. In particular, the work is addressed to propose a matrix which identifies the appropriate correspondence between product characteristics and the suitable AS processes, namely technical support processes, to carry out after a customer's inquiry. Once identified the right match, further work is turned to define the processes and activities that make up the technical support. The definition of these AS processes leads to improve and apply the XCOR methodology and thus to map the business processes of a company.

4.1 Step 1: identify product-processes relation

Manufacturers can use different service support strategies that vary according to the customers' needs and willingness to pay, available and affordable technology and equipment design. According to Lele (1997), the characteristics of customers' costs and expectations help to determine the most cost-effective design and support strategy for a given situation.

Any product can be assigned to a service support: considering variable costs and costs related to replacing or repairing an item, four categories of product can be identified and associated to appropriate service supports.

More in detail:

- *variable costs* (VC) refer to those opportunity costs sustained by the customer when a product/service does not work properly or does not suit his/her needs and requires assistance to be fixed; the higher they are, the more remarkable the losses are for the customer;
- *α* represents the ratio *replace costs/repair costs*; it is a balance that indicates what is more convenient between a substitution and a repair of a product when a problem occurs. For example, if $\alpha = 1$ it means that the product can be either swapped or fixed, if $\alpha < 1$ the product is advisable to be fully replaced and, finally, if $\alpha > 1$ the product is economically repairable.

According to these two dimensions, products can be classified as it follows (Figure 4.1):

- *commodity* - refers to products with low replace costs and low variable costs; it includes goods that are normally not fixed once broken down or, if necessary, just repaired by the customer; it includes small household appliances and inexpensive office equipment; sales contracts are not stipulated with the customer, generally just commercial invoices are exchanged;
- *conventional* - belongs to the cost-sensitive product category, that is represented by goods with a high α ratio (which thus need to be repaired) and little influenced by variable costs fluctuations; it is the case of some domestic appliances like home PCs provided also with adequate documentation, warranty schemes and regulated by simple transactional contracts;
- *essential* - refers to products very sensitive to variable costs which imply a fast repair when inactive; this category includes more sophisticated appliances like office PCs or industrial equipment; these products need technical support but also detailed documentation, installation, training, spare parts supply and logistics, product upgrading and customised commercial contracts;
- *vital* - includes products with a very high α ratio and very high variable costs (both tending to infinite); it refers to products of crucial importance, as the case of medical equipment, which can never malfunction; this is the most complex category where assistance support plays a fundamental and irreplaceable role.

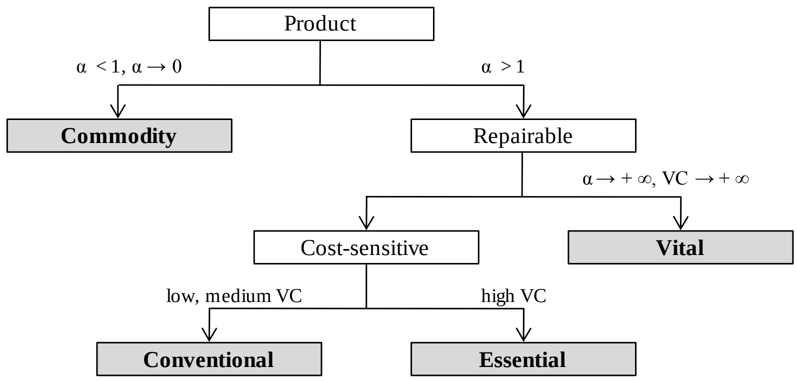


Figure 4.1 - Classification of a product according to its service requirements

In conclusion, α represents the boundary between commodities ($\alpha < 1$ and tending to zero) and repairable products (when $\alpha > 1$) which can be further split into vital (when both α and VC tend to infinite) and cost-sensitive products. Cost-sensitive products present a wide α range, thus they can be classified according to the sustained variable costs: when the amount is low-medium they are considered as conventional, when it is high as essential products.

According to the first step of the procedure, it is important to clarify the relation between product characteristics and the most suitable typologies of assistance support. From the analysis of different case studies, three categories of assistance support have been identified[3]. The processes are:

- *passive (or indirect) assistance* – when the company provides an appropriate documentation to the customer who is able to autonomously perform the diagnosis, identification and application of the solution;
- *collaborative assistance* – when the customer autonomously sorts out the problem with the help of an expert through a remote connection;
- *turn-key assistance* – when the customer is not able to fix the problem and needs the support of an expert who solves the issue. This support can be of two types:
  - off-site, when the company collects the faulty product through its assistance channel, repairs and gives it back to the customer;
  - on-site when the intervention is performed at the location where the defective item is installed.

[3] A more detail explanation of these processes and the related activities is provided in paragraph 4.2.2.

Figure 4.2 reports a matrix which highlights the match between products and service support and it helps companies in detecting their placement. The diagram is filled with a different shade of blue according to the intensity of the correspondence between products and appropriate assistance processes.

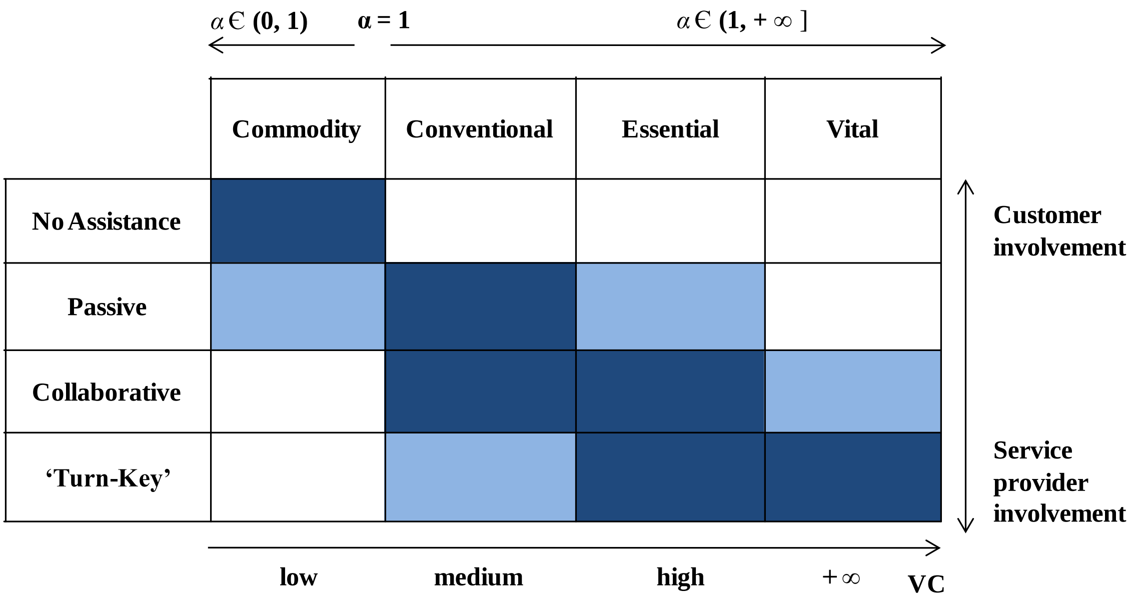


Figure 4.2 – The product-process matrix

Along the diagonal of this matrix there is a proper fit between products and technical support processes. More specifically, it turns out that:

- commodity products can require a passive support even if in most of the cases their low value generally do not lead to any assistance request.
- conventional products mainly include passive and collaborative supports and sometimes also a turn-key one; though products belonging to this group have a quite high α ratio, a repair is normally required but not necessarily immediate because the associated variable costs are not very considerable.
- essential products refer to goods with a high α ratio which need to be fixed promptly since they have high variable costs. Turn-key and collaborative assistance are mainly performed, including in some cases also the passive mode.
- vital products embrace mainly a turn-key support, since they have a very high α ratio and variable costs; collaborative assistance is also performed at times.

Once a company has assessed the position of its products along this grid, a further step consists in defining the actions to accomplish for each type of assistance support identified.

The formalisation of the operational processes and activities to carry out for each support is built according to the XCOR methodology. More details are provided in the next paragraphs.

4.2 Step 2: map After-Sales processes

When analyzing a company, understanding and modelling its business processes represent an important starting point (Stadtler and Kilger 2005). Concerning this purpose, it has been decided to use the methodology and formalism proposed by the Supply Chain Council (SCC) in its reference models. In particular, given the necessity to improve these models with the introduction of processes related to the AS area, some work has been carried out in collaboration with the SCC in order to define the assistance processes and the related activities. Mapping using the combination of the different SCC reference models refers to the XCOR methodology. Next paragraphs explain this methodology and describe in detail the defined AS processes.

4.2.1 XCOR methodology

Examining the business of a company implies a deep analysis and understanding of different processes that relate to product development, product design, customer relations and supply networks. This means that to map and evaluate a specific area of a business (such as the AS one), it is crucial to consider all those processes and activities that add value to the company and its network. This normally concerns various business units and external actors, like suppliers, customers and third-party operators.

The Supply Chain Council (SCC), a global non-profit consortium of private companies, government organizations and academicians, born in 1996, has developed a methodology to support organizations in thinking through their value-added processes.

This methodology is called XCOR, since it is the combination of different reference models proposed by council, namely SCOR, CCOR, DCOR and MCOR[4].

These four models present similar characteristics since they link in a unique and standard format process elements, metrics, best practices and features that describe the business activities associated with all phases of satisfying a customer's demand.

Each of the four model contains several sections and it is organized around five primary management processes. The four models are:

- *SCOR (Supply Chain Operations Reference) model* - it analyzes the supply network and it is organized around the primary management processes of Plan, Source, Make, Deliver and Return.
- *DCOR (Design Chain Operations Reference) model* - it covers the whole design process, from the research to the industrialization of a product. It is organized around the primary management processes of Plan, Research, Design, Integrate and Amend.
- *MCOR (Market Chain Operations Reference) model* - it concerns the processes that drive the business development. It is organized around the primary management processes of Plan, Analyze, Create, Launch and Revise.
- *CCOR (Customer Chain Operations Reference) model* – it refers to the relations between the company and its customers, from the negotiations during the sale to the AS services provided. It is organized around the primary management processes of Plan, Relate, Sell, Contract and Assist.

Figure 4.3 shows the interrelations among these four models which constitute the framework of the XCOR methodology.

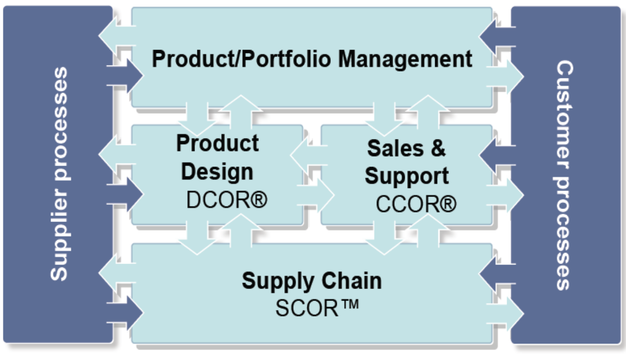


Figure 4.3 - XCOR framework (SCC, 2008)

[4] XCOR represents the combined use of the four reference models. Thus X stands for S-, C-, D-, M-COR applications.

By describing businesses combining these process building blocks, the XCOR methodology can be used to describe networks that are very simple or very complex using a common set of definitions. As a result, disparate industries can be linked to describe the depth and breadth of virtually any networks.

These four reference models have the same hierarchical structure with three different levels of detail, both for processes and metrics. Figure 4.4 reports the process architecture[5].

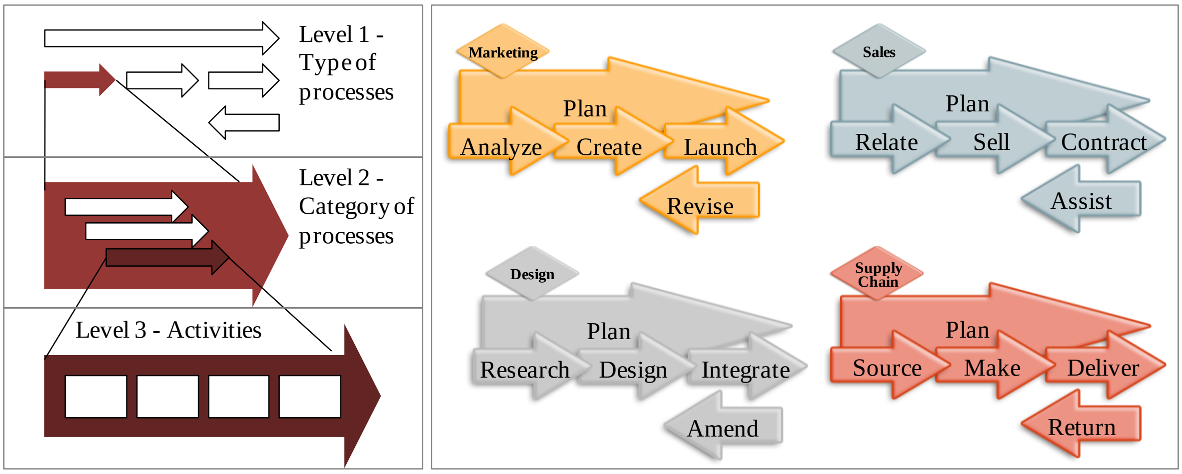


Figure 4.4 – The hierarchical structure of the four reference models

The ***first level (Level 1)***, also known as top level, defines the scope, the addressed areas and the content of each reference model. It describes the five main types of processes that characterize each model.

The ***second level (Level 2)*** is about the process categories, that is the configuration that companies choose to implement their operations strategy. These categories include *planning* processes, primary processes (*executive*) and secondary processes (*enable*).

In the ***third level (Level 3)*** each process category identified at Level 2 is analyzed in detail regarding all the activities which make them up. Every single element is characterized by a definition, inputs and outputs, performance metrics to measure it and best practices, if applicable. This level is the lowest defined by the XCOR framework and it communicates the operations strategies implemented by the company.

[5] The metrics architecture is described in next chapter.

Since the SCC has not defined any standards for levels following the third one, each company is free to map activities and measure their performance. For this reason, it might be defined a fourth level where the main management practices implemented by the company are analyzed.

The notation used to identify processes or elements in the four models of the XCOR methodology is the same. It is as follows:

- a lower-case letter which characterizes the reference model, such as s for SCOR, c for CCOR, d for DCOR and m for MCOR;
- a capital letter which identifies the Level 1 processes (e.g. cA = CCOR model, Assist);
- a number which identifies the Level 2 processes (e.g. cA1 = CCOR model, Passive Assist). In case of Enable or Planning type of processes the Level 2 is identified respectively by E and P followed by the Level 1 process acronym (e.g. cEA = CCOR model Enable Assist; cPA = CCOR model Planning Assist);
- two numbers identifies the Level 3 processes (e.g. cA1.01 = CCOR model, Passive Assist, Receive inquiry/request).

The first model developed by the SCC is the SCOR model which was first created in 1996. The model has been subject to several revisions and at the moment the Version 10.0 is currently in use. It has been recognized as an excellent reference model to support globalized supply chains, since it provides an easy language to describe material flow, workflow and transaction flow among companies, and a set of metrics to measure performance of different processes.

The other three models of the SCC are still in a development phase. The DCOR and CCOR model are at their first releases while MCOR is still at a conceptual phase. In particular, in the recent years the CCOR model has been attracting great attention given the necessity to examine also the sales and post-delivery customer support activities. Concerning this purpose, some work has been personally carried out in collaboration with the SCC to define the Assist module of the CCOR model, which is just about the provision of technical support to customers. The work was conducted in the form of conference calls and working group activities with practitioners and others academicians expert on the field. The project lasted two years during which Assist processes and relative metrics[6] have been designed and defined.

The main advantage of the XCOR methodology is the possibility to describe various business through the combination of the different process blocks belonging to the four models, using a common set of definitions. In Chapter 7 the AS business of a company is described by the joint use of the some modules of the SCOR model and the Assist module of the CCOR model.

4.2.2 After-Sales processes: the assistance support

In order to facilitate companies in mapping their AS processes, a detailed description of the main assistance supports and their relative activities is defined according to the XCOR formalism.

The design and the definition of these processes have been carried out through the CCOR working group, within the SCC, and the analysis of different case studies belonging to various industries. More in detail, the examined case studies are about: i) a company which provides machines and services for folding carton, corrugated board and flexible materials markets; ii) a company involved in the high-tech industry and operating both in the hardware and in the software markets; iii) a company which operates in the consumer and professional electronics industry; iv) a company which makes heating and air-conditioning systems; and v) a company which produces machine tools for shaving removal.

Processes are structured into three different levels of detail, starting from the most aggregate (Level 1), which depicts the process type, moving through process categories (Level 2), till process elements and activities (Level 3).

As reported in Table 4.1, the Assist process (cA - Level 1) is made up of three different primary process categories, namely Passive Assist (cA1), Collaborative Assist (cA2) and Turn-Key Assist (cA3), and a secondary category, called Enable Assist (cEA), which enables the execution of the Assist process (Level 2). At Level 2 there is also the Planning process which determines the requirements and corrective actions necessary to achieve the objectives of the AS business unit.

[6] AS metrics are defined in the next chapter.

Each process category is then further detailed into the operational activities to carry out (Level 3).

Level 1	cA: Assist				
Level 2	Execution			Enable	Planning
	cA1: Passive Assist	**cA2: Collaborative Assist**	**cA3: Turn-Key Assist**	**cEA: Enable Assist**	**cPA: Planning Assist**
Level 3	cA1.01: Receive inquiry/request	cA2.01: Receive inquiry/request	cA3.01: Receive inquiry/request	cEA.01: Manage Assist Business Rules	cPA.01: Gather Assist Requirements
	cA1.02: Authorize request	cA2.02: Authorize request	cA3.02: Authorize request	cEA.02: Manage Assist Performance	cPA.02: Gather Assist Resources
	cA1.03: Route request to identify solution	cA2.03: Route request	cA3.03: Route request	cEA.03: Manage Assist Information	cPA.03: Balance Assist Requirements with Resources
	cA1.04: Propose solution	cA2.04: Identify solution	cA3.04: Scheduling	cEA.04: Manage Warranty	cPA.04: Publish Assist Plan
	cA1.05: Release solution to customer	cA2.05: Propose solution	cA3.05: Identify solution	cEA.05: Manage Assist Capital Assets	
	cA1.06: Close request	cA2.06: Distribute solution	cA3.06: Distribute solution	cEA.06: Manage Assist Knowledge Transfer	
		cA2.07: Release solution to the customer	cA3.07: Obtain materials	cEA.07: Manage Assist Network	
		cA2.08: Close request	cA3.08: Repair product or obtain customer agreement	cEA.08: Manage Assist Regulatory Compliance	
			cA3.09: Dispose materials		
			cA3.10: Close request		

Table 4.1 – After-Sales processes: the assistance support

For each of these processes and activities an explanation has been provided. Definitions are reported in detail in Annex I.

4.3 Conclusions

This chapter describes in detail Step 1 and Step 2 of the procedure. These two steps help companies in detecting the suitable technical support to provide according to the characteristics of the product sold to their customers and in mapping the processes related to the AS business unit. Mapping is made exploiting the XCOR methodology and, since this methodology was lacking the AS processes, a consistent work has been done in order to define them according to the SCC formalism. An application of this methodology is provided in Chapter 7 where a case study is analyzed.

However, the defined list of AS processes as well as the other processes reported in the SCC models want to be a sort of reference guide that companies should follow when they have to revise, re-engineer and map their business processes. This means that according to the specific problem that a company wants to model, using the XCOR methodology it is possible to pick up just those processes critical for the problem to analyze and adapt them to the specific industrial context.

According to Andersen and Fagerhaug 2002, managing processes provides a better foundation for measuring and controlling performance levels. For this reason, Step 1 and Step 2 give a basic understanding of the business processes and they lay the foundation for proceeding with the design of a PMS.

Chapter 5
After- Sales Service performance measures

This chapter deals with the description of Step 3 and Step 4 of the procedure defined in Chapter 3. The work is directed to define a PMS specific for measuring the results of the AS area and a relative dashboard for monitoring and visualizing the actual performance.

5.1 Step 3: measure performance

Goal of this section is to introduce a Performance Measurement System (PMS) which is defined considering the challenges reported in Chapter 2, related to the features and supporting infrastructure that a PMS should present to measure the results of the AS service area.

The PMS has been developed and tested according to the following steps:

1. Collection of information through literature analysis, focused group activities and seminars with academicians and practitioners members of the Supply Chain Council (SCC), for understanding the main gaps regarding applications of PMSs in the AS area;
2. Development of a suitable and specific PMS for the AS area;
3. Testing of the PMS through a case study (as suggested by Voss 2009) that is thoroughly described in Chapter 7;
4. Analysis of the feedbacks gathered during the testing phase and further refinement of the PMS.

The PMS is designed considering a proper equilibrium between strategic and operational objectives, financial and non-financial indicators, efficiency and effectiveness dimensions.

It is conceived to measure and monitor the overall results that a single company, which operates through a vertical structure, or an entire service supply chain perform when dealing with their respective final customers. Relational indicators which measure the quality of the links between the different actors of the service supply chain are not considered.

The PMS presents two different arrangements:

- a *hierarchical structure* which measures the overall results of the AS area through a set of performance categories;
- a *process-diagnostics structure* which measures the results of the single process/activity carried out in the AS area.

The suggested PMS and the relative proposed list of metrics are designed to be general, as a reference guide for those companies which need to develop, implement and use adequate performance indicators to evaluate their AS results. Each company can adapt the PMS according to its necessities, selecting from the list those indicators which best suit its requirements and possibly define new ones specific to its needs.

5.1.1 Hierarchical structure

A multi-levelled set of performance indicators is built using the same semantic structure and formalism adopted by the XCOR methodology. This methodology provides a hierarchical architecture to map processes belonging to different business areas and it also specifies the appropriate set of indicators to use. Metrics are organised in a hierarchical structure, ranging from strategic indicators used to monitor the overall performance of a company to more diagnostic measures, which are then used to identify the relative beneath critical processes.

The PMS is structured as it follows:

- *performance attributes*, which are groupings for metrics used to explain company's strategies and to analyze and evaluate them for performing internal or external benchmarking;
- *level 1 metrics*, which are strategic indicators (Key Performance Indicators - KPIs) used to monitor the overall performance of the company according to the performance attribute to which they are associated;
- *level 2* and *level 3 metrics*, respectively tactical and operational indicators, which serve as diagnostic measures to identify critical processes and variations in performance against the plan.

Regarding the notation used to identify metrics, it is the same in the four models of the XCOR methodology. It is as follows:

- a lower-case letter which characterizes the reference model, such as s for SCOR, c for CCOR, d for DCOR and m for MCOR;
- the acronym of the performance attribute;
- a number which identifies the metrics Level (e.g.: 1 for Level 1; 2 for Level 2; 3 for Level 3);
- a sequential number used to list and identify the specific metrics.

Taking advantage of this structure, within the CCOR project team, six performance categories have been identified to measure the AS area[7]: Reliability, Responsiveness, Agility, Assets, Costs and Growth. These categories encompass both internal-facing (Costs, Asset, Growth) and customer-facing perspectives (Reliability, Responsiveness, Agility). Their relative definitions are reported in Table 5.1 together with the corresponding Level 1 metrics (KPIs).

[7] According to the CCOR model structure, the model should present indicators to measure pre-sales, sales and after-sales activities. Since the main goal of this thesis is to analyze the AS business and since my major work within the CCOR project was in this area, just AS metrics are reported.

PERFORMANCE ATTRIBUTES	**DEFINITION**	**LEVEL 1 METRICS (KPIs)**
Reliability (RL)	The performance of the service network to offer the right products/services at the right time, to generate the right contractual agreements in place, to provide the right answers to customer enquiries.	cRL.1.1: Perfect Assist Completion
Responsiveness (RS)	The speed at which customer enquiries are resolved by the service network.	cRS.1.1: Assist Cycle Time for Turn-Key assist cRS.1.2: Assist Cycle Time for Collaborative assist
Agility (AG)	The agility of a service network in responding to marketplace changes to gain or maintain competitive advantage.	cAG.1.1: Reaction time to unplanned events cAG.1.2: Adaptability to the increase of unplanned requests for Collaborative assist cAG.1.3: Adaptability to the increase of unplanned requests for Turn-Key assist cAG.1.4: Adaptability to customized requests
Costs (CO)	The costs reported by a company and associated with operating the service network in order to resolve customer enquiries.	cCO.1.1: Total Assist Cost
Asset Management (AM)	The effectiveness of a company in managing fixing and working capital assets to resolve customer enquiries.	cAM.1.1: Return on Assist Assets cAM.1.2: Assist Cash-to-Cash Cycle Time cAM.1.3: Return on Assist Working Capital
Growth (GR)	Ability of a company to grow along the time and generate a net income on a consistent and sustainable basis.	cGR.1.1: Assist operating margin growth cGR.1.2: Customer loyalty cGR.1.3: Growth of maintenance contracts cGR.1.4: Call variance

Table 5.1 – AS performance attributes and relative Level 1 metrics

For each Level 1 metrics, appropriate and suitable Level 2 and Level 3 indicators have been defined according to their different levels of detail.

As a result, six hierarchical structures have been created to synthetically evaluate the associated performance attribute categories. As an example, Figure 5.1 shows the hierarchical structure of indicators which measure the Reliability attribute.

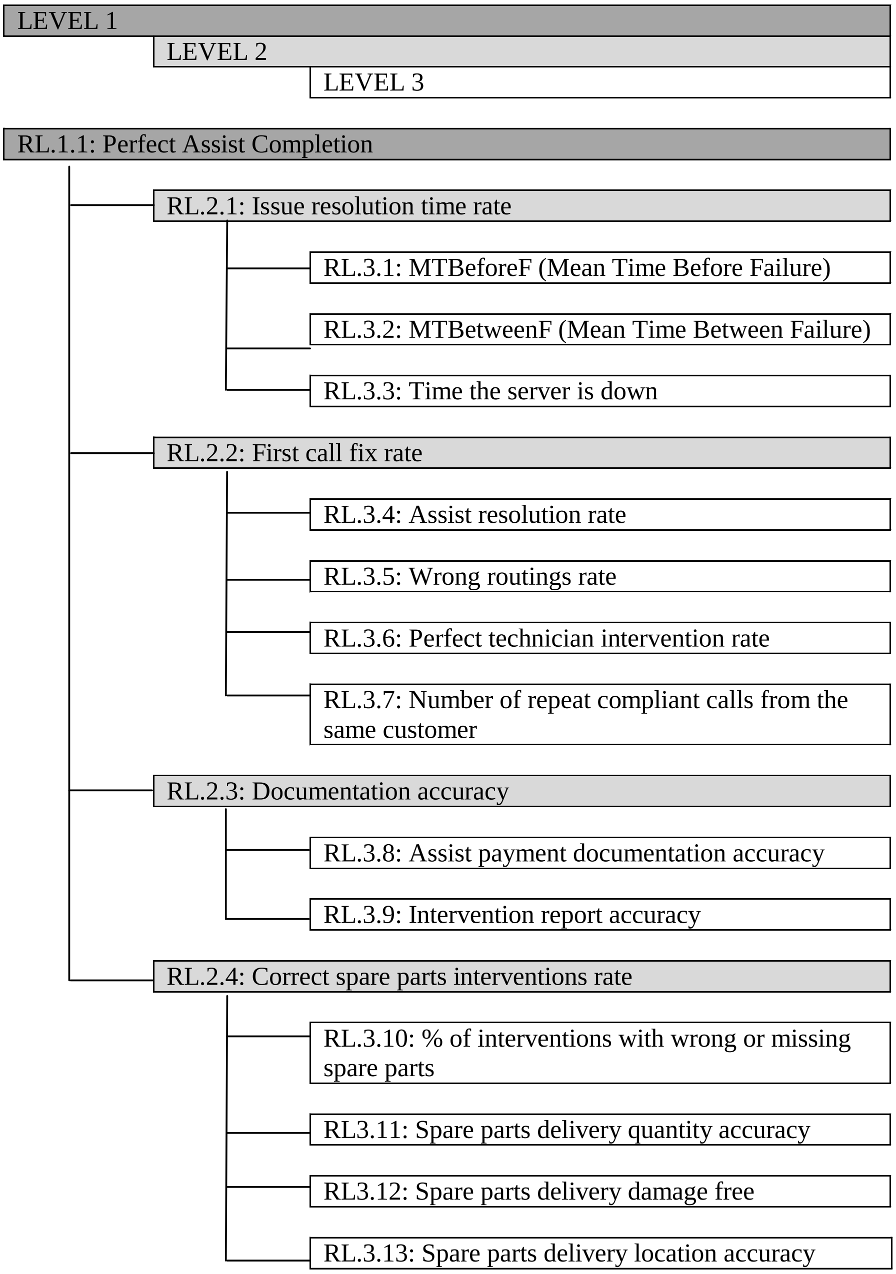


Figure 5.1 – Reliability: hierarchical structure

For each metrics, at whatever level is, a definition and a calculation method are also proposed. For instance, Table 5.2 reports the definition and calculation for the Level 1 metrics *Perfect Assist Completion* related to the Reliability attribute.

RL.1.1: Perfect Assist Completion
A Perfect Assist is a customer assist which meets all of the following standards: - Issue/Request responded to within agreed upon time - Issue/Request resolved within agreed upon time - Problem is completely resolved - Problem is resolved during the first customer contact - Customer satisfied with resolution - Resolution is documented - Product issue information communicated back to rest of the business (Design Chain, Supply Chain)
Calculation
(# of perfect assists / # of assists) * 100

Table 5.2 - Definition and calculation for *Perfect Assist Completion*

The hierarchical structures and detailed definitions of all the indicators are reported in Annex II.

The main advantage of this hierarchical structure is its multi-faceted nature, since it provides aggregate and strategic information, normally useful to the management, and at the same time more detailed and specific information which is measurable and understandable by all the process decision makers operating through a service supply chain.

5.1.2 Process-diagnostics structure

In addition to the hierarchical arrangement, there is another kind of classification which lies in associating the diagnostic indicators (mainly Level 2 and 3 indicators of the hierarchical structure) with the specific activities belonging to each process mapped.

Efforts have been addressed to identify a link within Assist Level 3 processes (defined in Chapter 4) and the diagnostic metrics identified in the hierarchical structure (Level 2 and 3).

This metrics arrangement helps companies in identifying those crucial processes associated to critical values of the performance indicators.

In Annex II this process-diagnostics structure is reported for each assistance process identified in Chapter 4, namely Passive Assist, Collaborative Assist and Turn-Key Assist. As an example, Figure 5.2 reports the process-diagnostics structure for the Passive Assist process.

A1.01	RL	cRL.3.7: N° of repeat compliant calls from the same customer cRL.3.3:Time the server is down	RS	cRS.2.1: Call center waiting time		
A1.02				cRS.2.2: Average authorization request time		
A1.03		cRL.3.5: Wrong routings rate		cRS.2.3: Average routing time cRS.2.5: Average time for diagnosis		
A1.04				cRS.2.6: Average time to propose a solution		
A1.05		cRL.3.4: Assist resolution rate				
A1.06		cRL.3.8: Assist payment documentation accuracy cRL.3.9: Intervention report accuracy		cRS.2.11: Average time to close requests		
A1.01	AG		CO		AM	
A1.02		cAG.2.6: N°of contract-conditions modified				
A1.03						
A1.04						
A1.05						
A1.06						

Figure 5.2 – Process – diagnostics structure for the Passive Assist process

5.2 Step 4: display metrics through a dashboard

Dashboards are recognized as vital tools for monitoring the health of an organization and turn data into useful information for decision making.

A business dashboard shows the key information that managers need to monitor the process they are responsible for, enabling them to find quickly out problems and take action in order to improve the performance of their organizations. According to Eckerson (2003), *"a performance dashboard is a multilayered application built on a Business Intelligence and data integration infrastructure that enables organizations to monitor, analyse and manage business performance more efficiently"*.

This definition passes on the idea that a business dashboard is more than just a screen populated with fancy performance graphics, but it is a real business information system designed to help organization to optimize performance and achieve strategic objectives.

A dashboard uploads data from the company's database, calculates metrics based on a PMS and creates synthetic reports to summarize their values and display their trends.

The ideas and benefits of a business dashboard are very much the same as an automobile or aircraft dashboard where all the vital information about the speed, oil pressure and temperature is available in front of the driver. Gauges, red and green lights, and odometers are strategically positioned so that a quick glance, without losing the focus on where the car is going, allows the driver to know if everything is under control (or not) and to take decisions accordingly.

If a company implements a dashboard, everyone can get benefits in an organization, from executives to managers to staff. In particular a dashboard helps to:

Communicate strategies	Performance dashboards translate corporate strategy into measures, targets and initiatives that are customized to each group in an organization and sometimes to every individual.
Refine strategy	Executives use dashboards like a steering wheel to tune corporate strategy as they go along. Instead of veering drastically from one direction to another in response to internal issues, executives can use performance dashboards to make a series of minor corrections along the way to their destination.
Increase visibility	Dashboards give executive and managers greater visibility into daily operations. This helps companies to avoid being surprised by unforeseen problems that might affect bottom-line results.
Increase coordination	By publishing performance data, dashboards encourage staff from different departments to work more closely together and they foster dialogue between managers and staff about how to improve performance.
Increase motivation	By publicizing performance measures and results, dashboards increase the motivation of business people to excel in the areas being measured.
Give a consistent view of the business	Dashboards consolidate and integrate corporate information using common definitions, rules and metrics.
Reduce costs and redundancy	By consolidating and standardizing information, dashboards can eliminate the need for redundant silos of information that undermine a single version of business information.
Empower users	Dashboards empower users by giving them self-access to information.

Table 5.3 – Typical benefits of using a performance dashboard (Eckerson 2003)

Regarding the purpose of this PhD thesis, it has been decided to design a performance dashboard structured according to the PMS defined in Section 5.1 and with the following characteristics:

- *accessibility* - users can access to the dashboard from the web;
- *modularity (in programming)* – the software architecture on which the dashboard is based has to enable easy customization and maintenance activities;
- *readability* – the dashboard has to present a user-friendly interface which allows through a quick glance to see immediately the most important metrics and performance trends.

There are different software and programming language that allows to build such a dashboard. In this project the software selected is a WAMP application. It is an open source package of programs installed on computers that use a Microsoft Windows operating system. WAMP is an acronym formed from the initials of the operating system Windows and the principal components of the package: Apache (web server), MySQL (database management software) and PHP (programming language). PHP is a scripting language that can manipulate information held in a database and generate web pages dynamically each time the content is requested by a browser.
According to these requirements and the selected software, a performance dashboard has been developed for Orkel, the main case study of this thesis. The structure and graphical interface of the dashboard are reported in Chapter 7.

5.3 Conclusions

This chapter describes in detail Step 3 and Step 4 of the procedure. These two steps lead to the development of a PMS specific to measure the results generated by the AS business and to the design of a dashboard that enhances data acquisition, analysis and reporting of the current performance of a company. The PMS and the dashboard are two of the three main outcomes of this PhD thesis and they are tools designed to evaluate and monitor the AS-IS situation of a company. An example of their application is reported in Chapter 7 where a Norwegian company operating in the agri-machine industry is examined. The application of the PMS to this case study has led to refine the PMS: the final version is the one presented in this chapter. In the next chapter work is addressed to explore the causal relations which lie within the defined PMS in order to understand the non-linear relations among all those processes that are involved when providing assistance support.

Chapter 6
Assessing future After-Sales Service scenarios

This chapter deals with the description of Step 5 and Step 6 of the procedure defined in Chapter 3. Conversely to the previous steps that are directed to assess the AS-IS situation of a company which operates in the After-Sales context, these steps are addressed to analyze and improve the TO-BE situation. Starting from the PMS defined in Chapter 5, System Dynamics is the methodology used to explore the causal relations among the defined performance indicators and to evaluate, through different scenarios, the impact that the introduction of a new policy might have on the performance results. This analysis leads to the definition of a management cockpit as a supporting tool for handling decision making processes.

6.1 Step 5: make a dynamic analysis

A system consists of distinguishable elements which are linked to each other in a certain structure. The nature of the relations can be flows of material, information as well as cause and effect loops. Complex systems are made up of a great variety of elements having specialized functions. These elements belong to different hierarchical levels which are linked by a great variety of non linear relationships (De Rosnay 1977). Moreover, complex systems change their status over time and they are made up of many components or agents interacting in infinite ways, whose behaviour is not given by summing up the behaviours of their constituent elements, but it is highly dependent on their interactions (De Toni and Comello 2005).

According to these definitions, the provision of AS services can be seen as a *complex system* since it includes a series of primary and supporting processes and involves independent organisations with very often conflicting objectives and behaviours. The strong interaction among these different actors is the key for managing AS activities and achieving high performance results. Traditional performance measurement models are able to evaluate the effects of complexity on the behavior of the many and different AS elements and actors. Nevertheless, very few models suggest structured approaches to analyze the causes determining the values of the monitored performance indicators, that is the causes of complex AS system behavior which is reflected by the indicators. Several authors, in fact, claim that efforts should be addressed to identify the relationships between measures (Flapper *et al.* 1996; Neely 1999; Bititci *et al.* 2000). In reality, in spite of the recognised importance of understanding the relationships among the various performance indicators in developing a comprehensive measurement system, too many organisations still define their measurement systems without understanding the dynamic interdependencies and trade-offs between measures and, ultimately, the process underlying the performance generation (Santos *et al.* 2002). Thus an appealing challenge is to highlight the causal relationships existing among performance indicators and explore the effect that they exert on the management of the main processes and on the enhancement of the overall company results. The analysis should aim at emphasizing the causal-loop relationships existing within the main performance indicators of the AS system.

In order to do that, Systems Thinking (ST) capabilities need to be developed to understand how things influence one another within a whole. ST is defined as an approach to problem solving and it is different from the traditional forms of analyses. While traditional analyses focus on separating the parts of what is being studied, ST focuses on how the studied object interacts with other constituents of the system. This means that instead of isolating smaller and smaller parts of the system, ST works by expanding its view in order to take into account larger and larger interactions. According to Sterman (2000), many advocate the development of ST as the ability to see the world as a complex system where everything is connected to everything else. It is argued that if people had a holistic worldview, they would act in consonance with the long-term best interests of the system as a whole, identify high leverage points and avoid policy resistance. An action of one element causes effects on other elements altering the state of the system and, therefore, leading to further actions to restore the balance. These interactions or feedbacks are usually the main reasons for the complex behaviour of a system.

The development of ST capabilities need to be translated into successful approaches to learn about complex systems. This requires: i) tools to represent the mental models that the mind creates to approach difficult problems and ii) formal models and simulation methods to test and improve the mental models, design new policies and practice new skills.

System Dynamics is a tool to enhance learning in complex systems.

6.1.1 System Dynamics

Formal modelling of systems has been carried out via mathematical models which attempt to find analytical solutions enabling the prediction of the system behaviour from a set of parameters and initial conditions. For many systems, however, simple closed form analytic solutions are not applicable and thus computer simulation models are necessary. Simulation generates a sample of representative scenarios for a model in which a complete enumeration of all possible states would be prohibitive or impossible (Crespo 2010). Modelling multifaceted, interactive and dynamic structures, like those involved in the AS services provision, requires a powerful tool or method which helps to understand complexity, to design better operating AS service polices and to guide changes. System Dynamics (SD) modelling as well as Discrete Event Simulation (DES) can be both used to model corporate business decisions.

For the purpose of this research, it has been decided to apply a SD approach as it is the most suitable method to enhance learning in compound systems (Sterman 2000). It is a method used to represent, analyse and explain the dynamics of complex systems along the time. Its main goal is to understand, through the use of qualitative and quantitative models, how the system behaviour is produced and to exploit this understanding to predict the consequences over time of policy changes to the system (Santos *et al.* 2002).

Moreover, SD is suited to problems associated with continuous processes where behaviour changes in a non-linear fashion and where extensive feedback occurs.

DES models, in contrast, more often represent particular processes, not entire systems, and they are better at providing a detailed analysis of systems involving linear processes and modelling discrete changes in system behaviour (Sweetser 1999).

According to Crespo (2010), to make a dynamic analysis through SD, it is necessary to carry out the following activities (which represent sub-steps of Step 5):

- Step 5.1 - identify a critical problem which needs to be analyzed within the company;
- Step 5.2 - make the modelling, and in particular
  - develop a dynamic hypothesis explaining the cause of the problem and the logical and causal relations within the variables (using Causal Loop Diagrams);
  - build a computer simulation model of the system at the root of the problem (using Stock and Flow Diagrams);
- Step 5.3 - test the model to be certain that it reproduces the behaviour seen in the real world;

In order to develop a dynamic hypothesis and build a simulation model (Step 5.2), Causal Loop Diagrams (CLDs) and Stock and Flow Diagrams (SFDs) are used as practical devices.

CLDs are flexible and useful tools for diagramming the feedback structure of systems in any domain. CLDs are simply maps showing the causal links among variables with arrows from a cause to an effect. Each causal link is assigned a polarity, either positive or negative, to indicate how the dependent variable changes when the independent variable is modified.

Positive causal links mean that the two nodes move in the same direction (e.g. if the node in which the link starts decreases, then the other node also decreases. Vice versa, if the node in which the link starts increases, then the other node also increases). Negative causal links are those in which the nodes change in opposite directions (e.g. an increase causes a decrease in another node, or a decrease causes an increase in another node).

Moreover, the important loops are highlighted by a loop identifier which shows whether the loop is a positive (R = reinforcing) or negative (B = balancing) feedback.

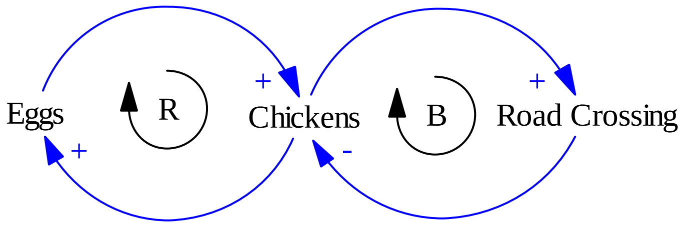


Figure 6.1 – Example of a Causal Loop Diagram (Sterman 2000)

SFDs are ways of representing the structure of a system with more detailed information than is shown in a CLD. CLDs emphasize the feedback structure of a system. SFDs emphasize their underlying physical structure. Stocks and flows track accumulation of material, money and information as they move through a system. Stocks include inventories of product, populations and financial account such as debt, book value and cash and they are represented as boxes. Flows are the rates of increase or decrease in stocks, such as production and shipments, births and deaths, and they are represented as valves. Stocks characterize the state of a system and generate the information upon which decisions are based. The decisions then alter the rates of flow, altering the stocks and closing the feedback loops in the system.

Figure 6.2 – Example of a Stock and Flow Diagram

The mathematical notation behind the application of SFDs, implies the use of some variables:

- *stock or level variables* – they express the level of stocks in the system. They accumulate or integrate the value of their incoming and outgoing flows. They are assigned initial values which allow the simulation to start;
- *flow variables or rates* - they define the rates of flow between two stocks of the system;
- *auxiliary variables* - often a rate equation is very complex if it is actually formulated only from stocks. Furthermore, a flow may often be best defined in terms of one or more concepts having independent meaning and, in turn, arising from the stocks of

the system. Thus, it is often convenient to break down a rate equation into component equations called auxiliary. Auxiliary variables are a great help in keeping the model formulation in close correspondence with the actual system, since they can be used to define separately the many factors that enter decision making;

- *exogenous variables* – they express exogenous values that are independent from any company decision. They are normally input values and they can be represented either by a function or a constant value;
- *internal variables* – they define internal values that are normally decided by the company. They are normally input values and they can be represented either by a function or a constant value.

On the market there are several software that contribute to make dynamic analyses and allow model builders to concentrate on conceptualizing the system rather than on the technicalities of the model building (Dutta and Roy 2002). The most popular commercial software packages are Powersim, iThink, Vensim. For the scope of this thesis, it has been decided to use Vensim.

Given the aforesaid potential of SD, in this PhD thesis SD is used to:

- qualitatively understand and represent, through the study of the causal relations between the service metrics, the non-linear relations among all those processes that are involved when providing AS services (using CLDs);
- quantitatively evaluate how introducing new policies (or services) for handling AS service significantly affects the company performance (using SFDs);
- attribute the appropriate organizational changes to the processes thanks to the answers (feedbacks) given by the simulation study with regard to the changes adduced to the service performance (this is the management cockpit described in the next paragraph).

In order to show the potential of the SD methodology, a specific application using Vensim is reported for Orkel, the case study analysed in Chapter 7. Annex III reports the model developed for Orkel and its mathematical formulation.

6.2 Step 6: control the system through a management cockpit

Once a SD model is built, both in the form of CLDs and SFDs, and it is verified that it reproduces the behaviour seen in the real world, according to Crespo (2010), it is necessary to:

- Step 6.1 – analyze different scenarios, namely devise and test in the model alternative policies that alleviate the problem;
- Step 6.2 –implement the solution and keep the system under control.

Through the dynamic analysis of different scenarios, it is possible to understand the main factors and causal relations that generate changes in the provision of AS services and the impact that these changes have on the company performance results.

Making what-if considerations on the basis of a simulation model, and especially of a SD one which allows to analyze linear and non-linear relations, helps to understand which are the input (exogenous or internal) variables to the model whose variation mostly affects the performance results of the modelled system.

These input variables are kind of knobs on a control panel: their change positively or negatively modifies the final performance outcomes. Knowing how these input variables affect the system allows to understand which is their best combination in order to monitor and manoeuvre the system under analysis. This is a management cockpit.

A management cockpit is different from a management dashboard: the difference is in the control. Referring to a metaphor, a dashboard can be seen as a set of gauges, a management cockpit as a joy stick which controls the gauge trends.

A management cockpit is a useful tool for maintaining decisions under control and checking the effect that future operational decisions have on the performance of a company, and in this specific analysis on the AS business.

6.3 Conclusions

This chapter aims at providing some guidelines in order to approach Step 5 and Step 6 of the procedure defined in Chapter 3. Goal of these steps is to explore the causal relations which lie within the defined PMS (Chapter 5) in order to understand the non-linear relations among all those processes that are involved when providing AS service. To study and manage such complex relations, the methodology chosen is SD.

By performing a SD analysis, in fact, it is possible to understand the main factors and causal relations that generate changes in the AS service systems and the impact that these changes could exert on the company results. These considerations can be arranged in a management cockpit where the effect of future operational decisions on the performance of AS service systems can be visible and adjustable as knobs on a control panel.

An application of SD modelling is reported in the following chapter where the results achieved testing the application of a new service are shown. Mathematical formulas behind this specific model are reported in Annex III.

Chapter 7
The case study: Orkel AS

This chapter shows an application of the six-step procedure. It has been applied to Orkel, a Norwegian manufacturer of farm machineries with the need to control and improve the provision of its AS services. This case study allows to test and validate the soundness and the solidity of the defined procedure.

After a brief introduction to Orkel, the chapter reports how each step of the procedure has been developed and the results which have been achieved. All the values related to Orkel's performance have been distorted for non-disclosure agreements.

7.1 Orkel's description

Orkel is situated in Norway and it is one of the biggest manufacturers of farm machinery, leader in baler and trailer manufacturing. It is well-known for the excellence and reliability of its products and it has a considerable export network; more than 80% of the company's products, in fact, are sold to export markets in Europe and the rest of the world.

A part from producing and selling dumper trailers, which however constitutes a considerable share of its profits, its main market regards the production, selling and repairing of three different types of round balers: GP1260, GP1260 Agronic, MP 2000 Compactor. Round balers are traditionally used to compress greater amounts of grass and maize feed for cows; however, the company long experience in this field, has led to enter new markets in order to bale and wrap industrial waste and garbage.

Figure 7.1 – Examples of round baler - hiQ smartbaler (left) and MP 2000 Compactor (right)

Sales of round balers count around 50% of the turnover and another considerable part is given by its AS activities; around 240 balers are manufactured a year and almost 50% of them are exported. Its main customers are farmers, either contractors or little homesteaders. To support its worldwide business Orkel makes use of a tight network of technical assistance centres and dealers spread around the world.

AS support is a pillar for Orkel’s success: its mission is to assist its customers whenever they have problems, especially during high peak season, which is normally between the beginning of May and the end of August.

The company provides maintenance and spare parts supply and one of its key issues is to improve and optimize the provision of these services related to the sales of round balers. A round baler standing idle might cause losses for the customers: the harvest season has to be completely exploited and a quick repair has to be assured by the company. This means that, since the company encompasses a series of primary and supporting processes and involves different departments and independent organisations, its goal is to enhance its AS structure in order to increase the profits coming from this business and retain its customers to secure itself with future sales.

7.2 Step 1: identify product-processes relation

The first step of the procedure proposes to clarify the relation between the characteristics of the products sold by Orkel and the typologies of assistance support.

The analysis reported hereafter is about the round balers, which are considered the most important and critical products for Orkel’s business. Round balers have high variable costs and are typical products which need to be promptly fixed when a failure happens, especially during the harvest season.

According to these characteristics, the product-process relation matrix (Figure 7.2) suggests that the round balers can be classified as essential products.

The matrix indicates that the most suitable types of assistance are Collaborative and Turn-Key Assist, while Passive Assist is performed just in some cases. This considerations find a match with the technical support actually carried out by Orkel, which is of both Collaborative and Turn-Key nature.

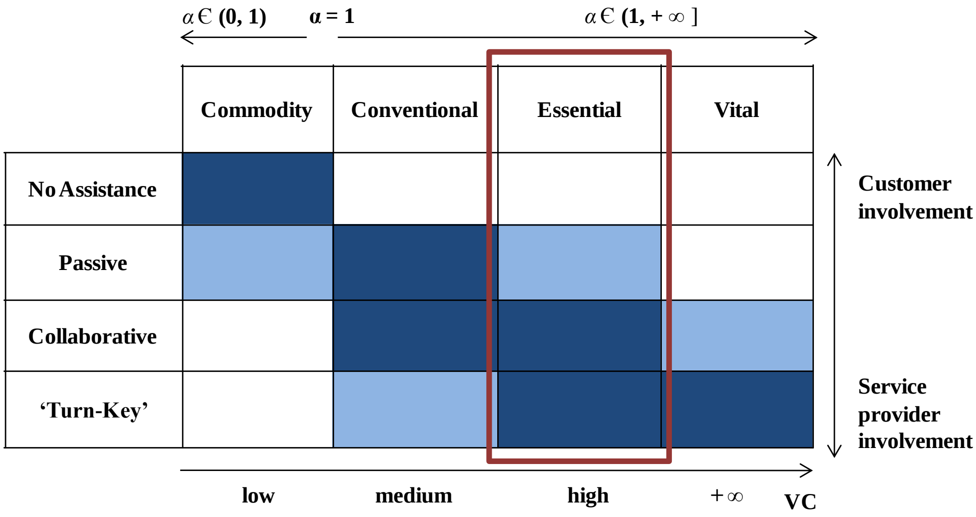


Figure 7.2 – Match with the product – process relation matrix

7.3 Step 2: map processes

According to Step 2 of the procedure, the AS area of Orkel, which deals mainly with spare parts management and assistance support, is mapped through the application of the XCOR methodology. The processes that have been analyzed, in fact, do not belong just to the SCOR model but also to the Assist module of the CCOR model.

Figure 7.3 reports an overview of Orkel's service supply chain which is mapped using Level 1 processes of the SCOR (red boxes) and CCOR models (blue boxes). The chart highlights that the provision of AS services is carried out by a complex system which encompasses a series of primary and supporting processes and involves different departments and independent organizations.

Orkel's service supply chain is made up by:

- Orkel itself, that provides assistance support and sells spare parts both to its customers and its satellites;
- satellites (around 14 in Norway) and dealers (outside Norway), which are authorized technical support centers that sell spare parts bought from Orkel and provide assistance support to final customers. They are located in different areas in order to guarantee a total coverage and they receive training by Orkel;
- suppliers of spare parts, that provide Orkel with either ready-to-sell spare parts or components which are then assembled by Orkel to make finished spare parts;
- customers, who are mainly farmers, either contractors or little farmers.

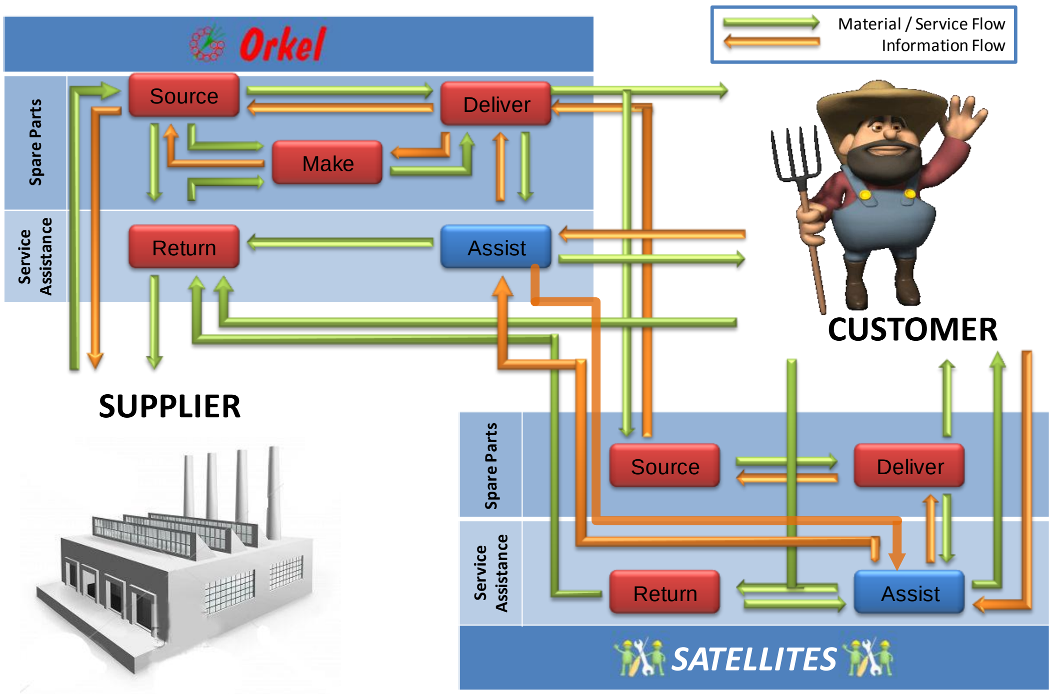


Figure 7.3 – Orkel's service supply chain (XCOR methodology, Level 1 processes)

Regarding the process mapping, here follows a brief description of the Level 1 process that have been adapted from the SCOR and CCOR models and their main interrelations with the other processes.

Process	**Model**	**Process description**	**Link with other processes**
ASSIST	CCOR	This process includes all the activities to be carried out in order to provide After-Sales support for all products/services offered to the customer, such as responding to customer inquiries, solving customer issues, assigning support resources and managing warranty claims. Based on a customer’s request, Orkel (or one of its satellites), responds to the customer providing technical support: in some cases the issue is solved remotely, in other cases on-site or off-site.	DELIVER - to fix customers’ problems, spare parts might be required. A request of delivery is sent to the finished spare parts warehouse. RETURN - during an intervention technicians might be required to take care of the material disposal. ASSIST (satellites) – in some cases Orkel helps its satellites in providing assistance to customers (e.g. for odd issues to solve).
SOURCE	SCOR	The procurement and receipt from suppliers of subassemblies or spare parts.	DELIVER – when Orkel buys finished spare parts from suppliers, these parts are delivered to the spare parts warehouse and sent to the customers when required. MAKE – when Orkel buys components from its suppliers, then it assembles parts to make finished spare parts. RETURN – when Orkel buys defective parts from suppliers, these parts are returned back.
MAKE	SCOR	The process of manufacturing or assembling spare parts. This process is carried out just by Orkel, its satellites do not manufacture spare parts.	SOURCE –in order to make spare parts Orkel procures some components from its suppliers. DELIVER – when finished spare parts are made, they are sent to the spare parts warehouse awaiting to be delivered to customers.

			RETURN – some disposal material can be refurbished and reused to make new spare parts.
DELIVER	SCOR	The process of delivering spare parts that are maintained in a finished goods state prior to the receipt of a customer order.	SOURCE – when spare parts are not available at the finished spare parts warehouse, a request is sent to the procurement department. SOURCE (satellites) – when a request of spare parts comes from the satellites, then parts are delivered from Orkel directly to customers or to the satellites. MAKE – delivery of finished spare parts from the manufacturing department to the warehouse of finished spare parts. ASSIST – delivery of spare parts to the technicians in order to allow assistance operations.
RETURN	SCOR	The process, initiated by the customer, of returning material deemed defective or to be refurnished.	RETURN (satellites) – return of defective components or parts to be refurnished from satellites. ASSIST – return of disposal material.

Table 7.1 – Level 1 processes and their interrelations

The following charts show, with a deeper detail than what reported in Figure 7.3, how Orkel performs assistance support and manages requests of spare parts.
Elements of the SCOR model and of the Assist module of the CCOR model have been picked up and combined in order to give the most reliable mapping of Orkel's processes.

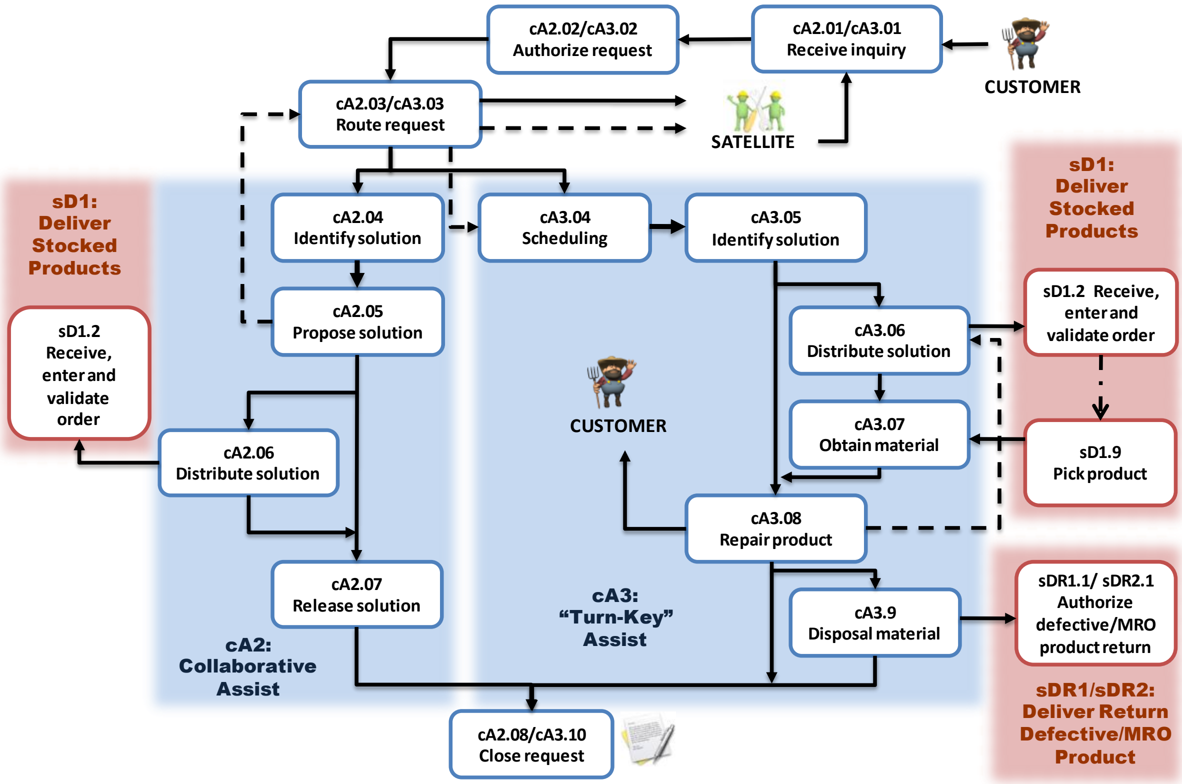


Figure 7.4 – ASSIST Level 2 and Level 3 mapping and interrelations with other SCOR processes

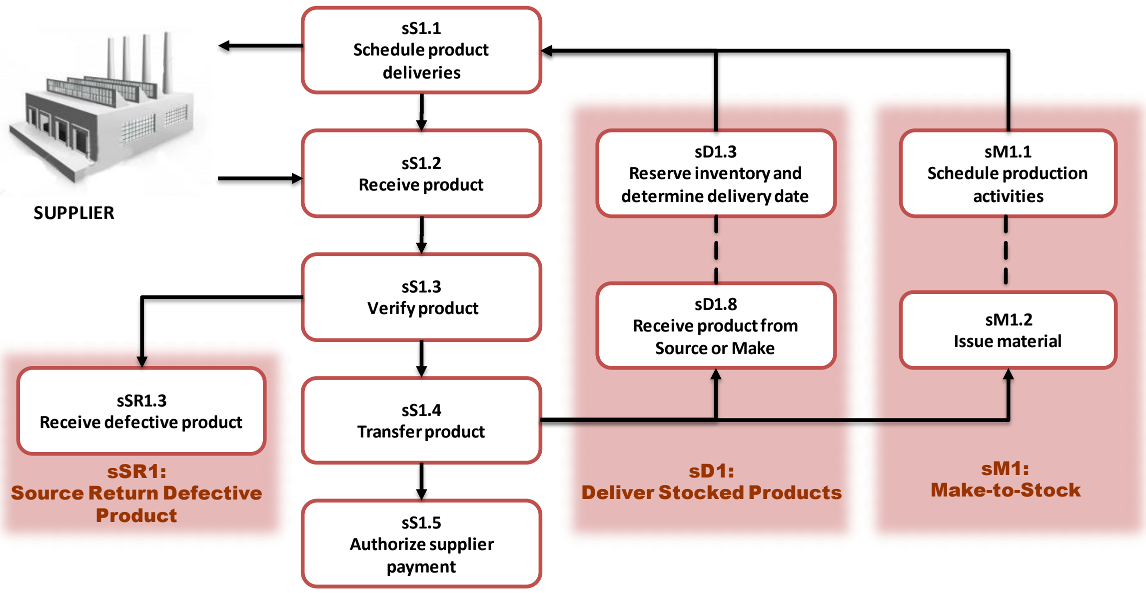


Figure 7.5 - SOURCE Level 2 and Level 3 mapping and interrelations with other SCOR processes

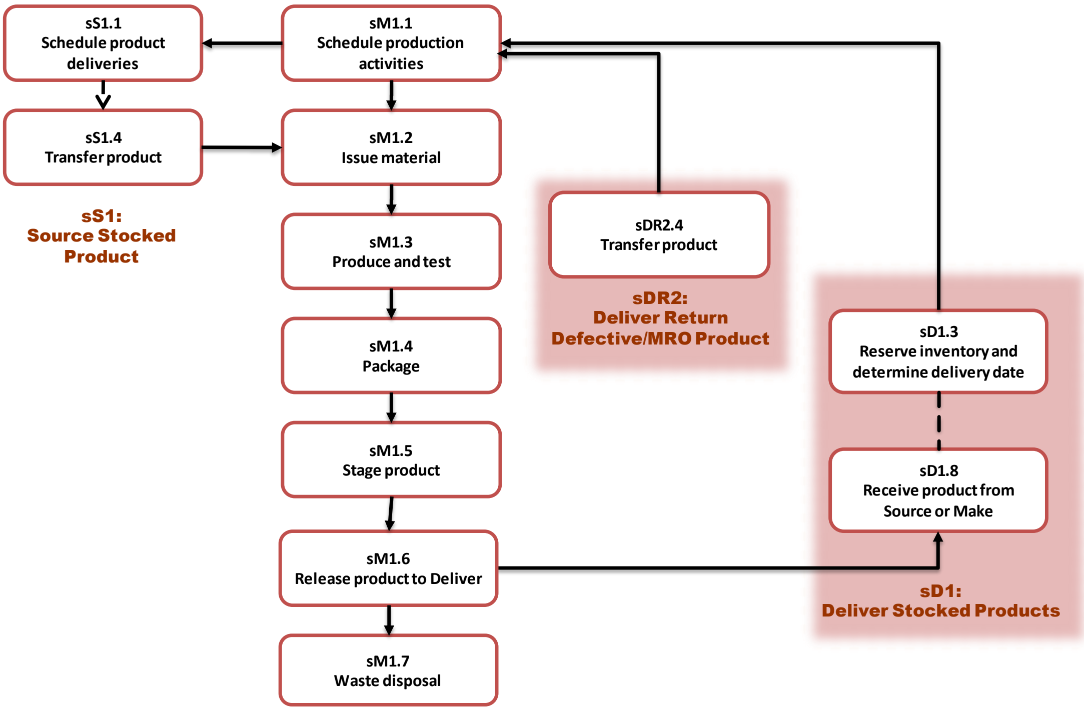


Figure 7.6 - MAKE Level 2 and Level 3 mapping and interrelations with other SCOR processes

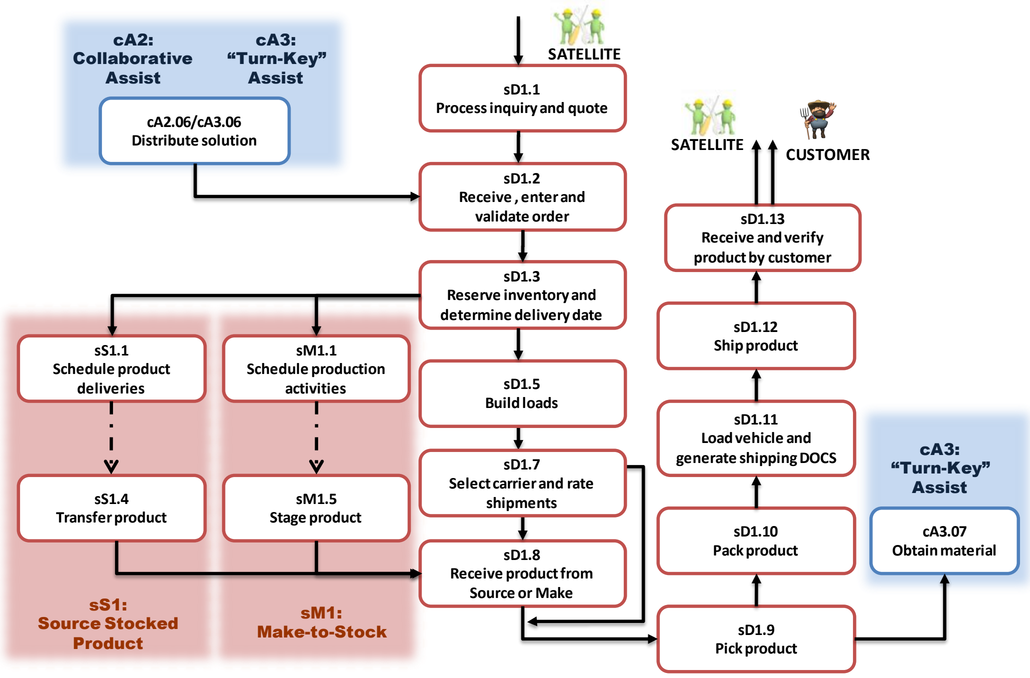


Figure 7.7 - DELIVER Level 2 and Level 3 mapping and interrelations with other SCOR-CCOR processes

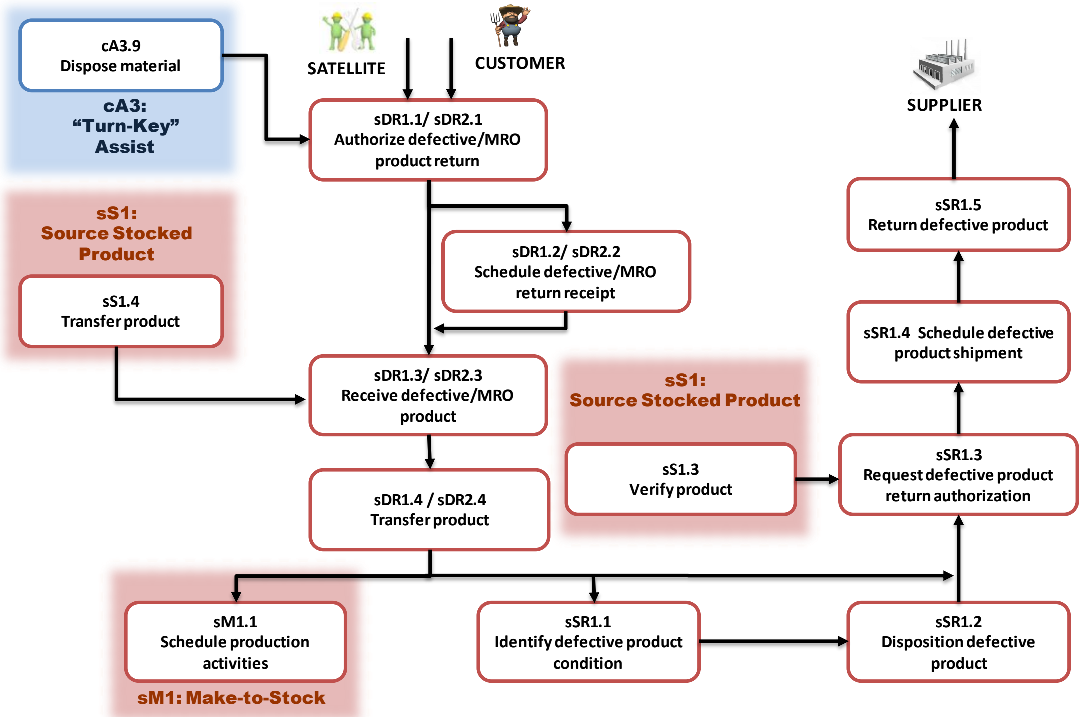


Figure 7.8 – RETURN Level 2 and Level 3 mapping and interrelations with other SCOR-CCOR processes

In order to accomplish these mappings, several interviews have been made at Orkel. The constant presence of Orkel service manager helped to refine little by little the work.

7.4 Step 3: measure performance

In order to measure Orkel’s performance the PMS defined in Chapter 5 has been applied. Among all the indicators proposed in the PMS, just those suitable with Orkel’s strategy and requirements have been selected. In some cases some indicators and definitions have been tailored according to Orkel’s needs.

Regarding the hierarchical structure, the six performance attributes of the PMS have assumed a different shade of meaning in the developed set of measures for Orkel.

In order to shows this nuance, Table 7.2 reports the two different definitions for each performance attribute: the first definition is the standardized one proposed in the PMS, the second definition is the one tailored to Orkel.

Reliability	The performance of the service network to offer the right products/services at the right time, to generate the right contractual agreements in place, to provide the right answers to customer enquiries.
	The expected reliability of the round balers in terms of produced bales.
Responsive-ness	The speed at which customer enquiries are resolved by the service network.
	The quickness at which the inquiries of technical support from customers are closed.
Agility	The agility of a service network in responding to marketplace changes to gain or maintain competitive advantage.
	The ability in handling the increase of technical support inquiries in the harvest season (peak season).
Costs	The costs reported by a company and associated with operating the service network in order to resolve customer enquiries.
	All the costs related to provide technical support to the customers for round baler malfunctions.
Asset Management	The effectiveness of a company in managing fixing and working capital assets to resolve customer enquiries.
	The ability in exploiting the assets to provide technical support to generate profits. This includes the management of fixed and working capital assets.
Growth	Ability of a company to grow along the time and generate net income on a consistent and sustainable basis.
	The attempt to increase the operating margin especially through the growth in the sale of maintenance contracts.

Table 7.2 - Attribute definitions from Orkel's perspective

The six hierarchical structures reported in Annex II have been adapted to Orkel. A selection of indicators have been done following Orkel's management specifications and they are as it follows:

Reliability

- cRL.2.3: Documentation accuracy
  - cRL.3.1: Mean number of bales before failure (MNBBeforeF)
  - cRL.3.2: Mean number of bales between failures (MNBBetweenF)

cRL3.1 and cRL3.2 have been modified from the standardized version to accomplish Orkel's requirements.

Responsiveness

- cRS.1.1: Assist cycle time for turn-key assist
  - cRS.2.8: MTTR (Mean Time To Repair) a machine type both for corrective and preventive maintenance
  - cRS.2.9: MTTR (Mean Time To Repair) each machine per technician both for corrective and preventive maintenance
  - cRS.2.14: Average number of turn-key interventions during out of peak season (in a day)
    - cRS.3.1: Number of average turn-key interventions per technician during out of peak season (in a day)

- cRS.1.2: Assist cycle time for collaborative assist
  - cRS.2.7: Waiting time for delivery spare parts
  - cRS.2.15: Average number of collaborative interventions during out of peak season (in a day)
    - cRS.3.2: Number of average collaborative interventions per technician during out of peak season (in a day)

<u>Agility</u>

- cAG.1.2: Adaptability to the increase of unplanned requests for collaborative assist
  - CAG2.3: Average number of collaborative interventions during peak season (in a day)
    - cAG.3.1: Number of average collaborative interventions per technician during peak season (in a day)

- cAG.1.3: Adaptability to the increase of unplanned requests for turn-key assist
  - cAG.2.4: Average number of turn-key interventions during peak season (in a day)
    - cAG.3.2: Number of average turn-key interventions per technician during peak season (in a day)

<u>Costs</u>

- cC.1.1: Total assist cost
  - cCO.2.1: Cost of turn-key assist
    - cCO.3.4: Average repair intervention cost
  - cCO.2.2: Cost of passive and/or collaborative assist
  - cCO.2.3: Cost of spare parts sold
  - cCO.2.4: Warranty cost
    - cCO.3.6: Warranty cost as % of revenue
  - cCO.2.5: Cost of maintenance interventions
  - cCO.2.6: Cost of spare parts inventory
  - cC0.2.7: Cost of spare parts backlog
  - cC0.2.8: Cost of assistance personnel

Growth

- cGR.1.1: Assist operating margin growth
    - cGR.2.1: Assist operating margin
        - cGR.3.1: Assist operating revenue
        - cGR.3.2: Assist operating income (or profit)
- cGR.1.3: Growth of maintenance contracts
- cGR.1.4: Call variance (= collaborative or turn-key calls)

Regarding the process-diagnostics structure, Table 7.3 and Table 7.4 reports the indicators that have been chosen for Orkel. The complete versions of these tables are reported in Annex II.

The metrics associated to the Collaborative Assist support are:

A2.01	RL		RS	
A2.02				
A2.03				
A2.04				
A2.05				
A2.06				cRS.2.7: Waiting time for delivery spare parts
A2.07		cRL.3.1: Mean number of bales before failure cRL.3.2: Mean number of bales between failures		
A2.08				cRS.2.15: Average number of collaborative interventions during out of peak season cRS.3.2 Average number of collaborative assist calls for technician during out of peak season

A2.01	AG		CO		AM	
A2.02						
A2.03						
A2.04						
A2.05						
A2.06						
A2.07						
A2.08		cAG.2.3: Average number of collaborative interventions during peak season cAG.3.1: Number of average collaborative interventions for technician during peak season				cAM.2.2: Spare Parts Inventory Days of Supply (IDS) cAM.3.1: Spare part Inventory turns in the warehouse

Table 7.3 – Process-diagnostics structure for Collaborative Assist

The metrics associated to the Turn-Key Assist support are:

A3.01	RL		RS	
A3.02				
A3.03				
A3.04				
A3.05				
A3.06				
A3.07				
A3.08		cRL.3.1: Mean number of bales before failure cRL.3.2: Mean number of bales between failures		cRS.2.8: MTTR (Mean Time To Repair) a machine cRS.2.9: MTTR (Mean Time To Repair) each machine per technician
A3.09				
A3.10				cRS.2.14: Average number of turn-key interventions during out of peak season cRS.3.1: number of average turn-key interventions for technician during out of peak season

A3.01	AG		CO		AM	
A3.02						
A3.03						
A3.04						
A3.05						
A3.06						
A3.07						cAM.2.2: Spare Parts Inventory Days of Supply (IDS) cAM.3.1: Spare part Inventory turns in the warehouse cAM.3.2: Spare part Inventory turns on the van
A3.08				cCO.3.4: Average repair intervention cost		
A3.09						
A3.10		cAG.2.4: Average number of turn-key interventions during peak season cAG.3.2: Number of average turn-key interventions for technician during peak season				

Table 7.4 - Process-diagnostics structure for Turn-Key Assist

7.5 Step 4: display metrics through a dashboard

According to Orkel's requirements, a tailored dashboard has been created to display the metrics identified to evaluate the performance of the technical support.

The dashboard has been developed using a WAMP (Windows, Apache, MySql, Php) application and it has been designed in order to upload data from the company's database, calculate metrics and create synthetic reports to summarize their values and show their trends.

The dashboard interface has been organized according to the PMS structure defined in Chapter 5, and it is made up by:

- the *Metrics* section, which presents the metrics grouped by performance attributes and arranged in the hierarchical structure;

- the *Process* section, which displays the metrics linked with the activities of the Assist processes;
- the *MainView* section, which exhibits the graphical trends of the main KPIs.

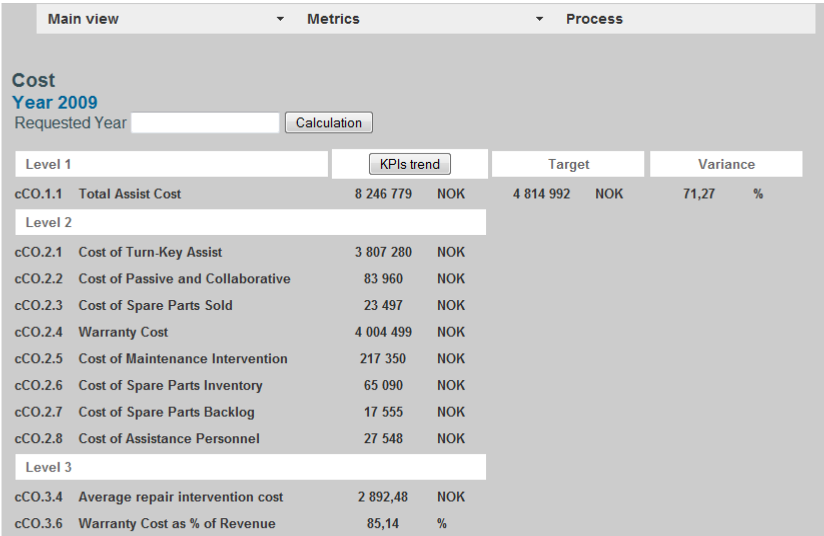
All values have been distorted for non-disclosure agreements.

The Metrics section

It is organized in six pages, one for each performance attribute: Growth, Cost, Responsiveness, Reliability, Agility and Asset Management. For each attribute, metrics are listed in three levels according to the PMS hierarchical structure.

The KPIs (Level 1 metrics) present also a target value and a variance value which measures the difference between the target value and the actual value.

As an example, in Figure 7.9 the *Cost* page is reported.



Main view | Metrics | Process

Cost
Year 2009
Requested Year [Calculation]

Level 1		KPIs trend		Target		Variance	
cCO.1.1	Total Assist Cost	8 246 779	NOK	4 814 992	NOK	71,27	%
Level 2							
cCO.2.1	Cost of Turn-Key Assist	3 807 280	NOK				
cCO.2.2	Cost of Passive and Collaborative	83 960	NOK				
cCO.2.3	Cost of Spare Parts Sold	23 497	NOK				
cCO.2.4	Warranty Cost	4 004 499	NOK				
cCO.2.5	Cost of Maintenance Intervention	217 350	NOK				
cCO.2.6	Cost of Spare Parts Inventory	65 090	NOK				
cCO.2.7	Cost of Spare Parts Backlog	17 555	NOK				
cCO.2.8	Cost of Assistance Personnel	27 548	NOK				
Level 3							
cCO.3.4	Average repair intervention cost	2 892,48	NOK				
cCO.3.6	Warranty Cost as % of Revenue	85,14	%				

Figure 7.9 - Metrics section: Cost page

The Process section

It refers to the process-diagnostics structure of the PMS where the diagnostic indicators (mainly Level 2 and 3 indicators of the hierarchical structure) are associated with the specific activities belonging to each process mapped.

As an example, in Figure 7.10 the activity *cA3.8 Repair product* of the *Turn-Key* process is measured through a list of suitable indicators grouped on the basis of the performance attribute they refer to.

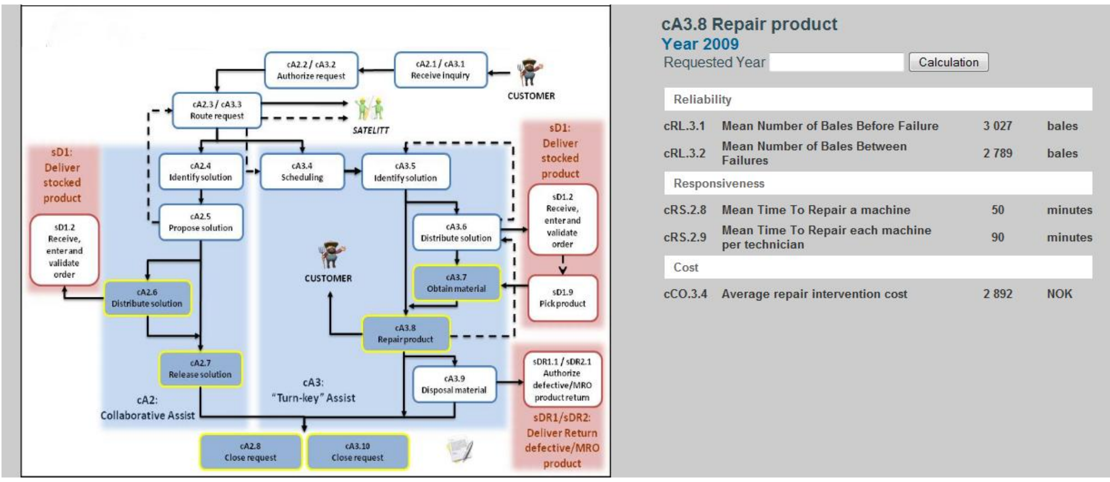


Figure 7.10 - Process section: cA3.8 Repair Product (Turn-Key) page

The MainView section

It is the page that groups some of the KPIs recognized as strategic for monitoring the AS area. This section is tailored to Orkel's requirements and it is arranged in three pages: *Accounting*, *Annual growth* and *Season comparison*.

- The *Accounting* page shows both numerically and graphically the operating revenue, the total cost and the operating income made by the AS business unit.
- The *Annual growth* page displays the values of the Growth attribute, such as the operating margin growth, the growth of maintenance contracts, etc.
- The *Season comparison* page is specifically created for Orkel in order to compare its performance during the peak season (May – August) and out of the peak season.

As an example, in Figure 7.11 the *Annual Growth* page is reported.

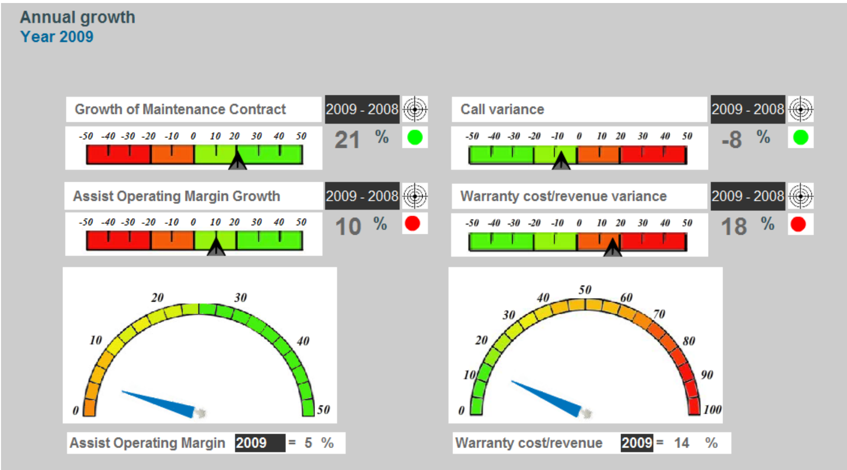


Figure 7.11 - MainView section: Annual Growth page

7.6 Step 5: make a dynamic analysis

According to what reported in Chapter 6, in order accomplish a dynamic analysis it is necessary to approach this step through different sub-steps.

Step 5.1 - identify a critical problem which needs to be analyzed within the company

Orkel has recently decided to approached a new strategy to keep down the number of maintenance interventions, especially during the harvest season: since these corrective repair services are completely unplanned and difficult to handle, it is thinking to move towards the additional provision of a preventive support to be performed with more regularity.

According to Djamaludin *et al.* (2001), maintenance can be defined as a series of actions either to (i) prevent the deterioration process leading to the failure of a system or (ii) restore the system to its operational state through corrective actions after a failure. The former is called Preventive Maintenance (PM) and the latter Corrective Maintenance (CM). CM actions are unscheduled activities intended to restore a system from a fault state to a working state. This involves either repair or replacement of fault components. In contrast, PM actions are scheduled actions carried out to either reduce the likelihood of a failure or prolong the life of a component. Normally, the regularly scheduled downtime provided by the application of PM activities could imply higher direct costs to the manufacturer than operating the equipment until repair is absolutely necessary. However, it is important to compare not only direct costs but the long-term benefits and savings deriving from opportunity or indirect costs associated with PM (e.g. decrease of the system downtime, better spare parts inventory management, improved system reliability, etc.). Moreover, from the manufacturer's perspective, the role of PM assumes more relevance during the warranty period: in general, a customer pays for having a PM contract, thus the costs of repairing item failures through CM can be reduced for the manufacturer. However, for a myopic buyer, who does not consider the impact that investments in PM during the warranty and the post warranty periods have on the total life cycle maintenance cost of a product, there is no incentive to invest any effort into PM, especially during the warranty period when the buyer can claim any repairs on the product. For this reason, it is worthwhile for the manufacturer to promote a PM policy only if the expected extra costs are more than balanced by an overall positive return.

Regarding this case study, due to the recent decision to introduce PM contracts, the management of Orkel needs to better assess the main pros and cons related to their adoption. In particular, for this specific case, PM interventions are about planned and scheduled on-site interventions (namely turn-key assistance) while CM are about unscheduled on-site interventions and remote support (namely turn-key and collaborative assistance supports).

The simulation, based on a SD model, tries to provide some valuable answers. In particular, the SD model has been developed to understand and represent, through the study of the causal relations amid the service metrics, the non-linear relations among all those processes that are involved when providing AS services (in particular CM, PM and spare parts supply).

The boundary diagram reported in Figure 7.12 is built according to the ISO/DIS 14-224 standard and it displays the main processes involved for the resolution of the above mentioned problem. It highlights the boundaries and the main inputs and outputs requested by the model to give an answer to this specific problem.

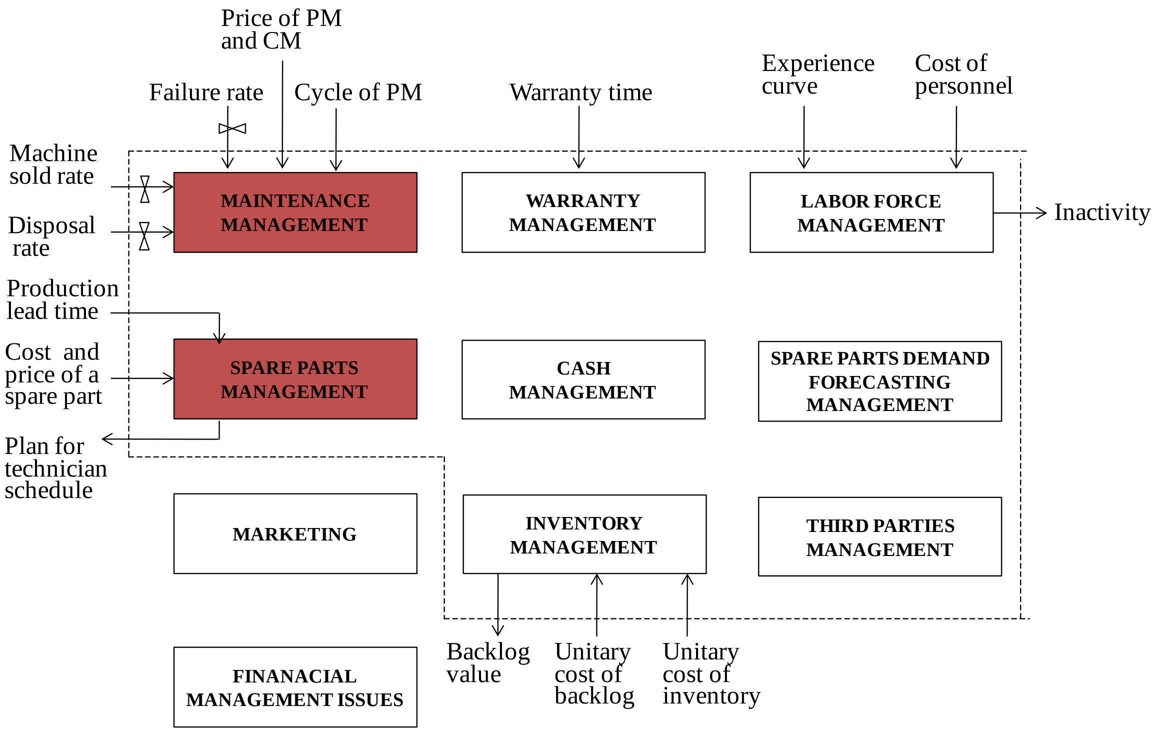


Figure 7.12 – The boundary model

Maintenance management and spare parts management are the focal processes on which the analysis has been concentrated. Their handling depends on other processes with which they are related through non-linear relations. Marketing management (in terms of customer repurchasing attitudes) and the management of financial constraints are out of the scope of this study.

Step 5.2 - make the modelling, and in particular

- *develop a dynamic hypothesis explaining the cause of the problem and the logical and causal relations within the variables (using Causal Loop Diagrams);*
- *build a computer simulation model of the system at the root of the problem (using Stock and Flow Diagrams).*

Causal Loop Diagrams (CLDs) are used to explore the cause of the problem and the logical and causal relations within the variables. Stock and Flow Diagrams (SFDs), instead, are used to quantitatively evaluate the abovementioned causal and non-linear relations and the impact that introducing a new policy may exert on the improvement of Orkel's results.

The aggregate view of Orkel's AS area is reported in a CLD model (Figure 7.13). It logically describes the causal relations that come out when providing maintenance service and the related spare part supply. The model aims at emphasizing the causal-loop relationships existing within the main KPIs of the AS system (those reported in the PMS defined in Chapter 5, such as reliability, responsiveness, agility, cost, asset management and growth). The model explores the effect that these KPIs exert on the management of the main processes and on the enhancement of the overall company performance.

More in detail, regarding the CLD reported hereafter:

- the green arrows represent those causal relations that have been translated into SFDs: they mainly refer to the causal relations that come out from Orkel's operational activities and which are involved in the resolution of the identified problem (and they also correspond to the boundary model of Figure 7.12).
- the dotted lines stand for those relations that have been detected for providing a complete overview of the AS service system but have not been translated into SFDs:

they are out of the scope of this study and they represent chance for further developments.

- the red words are the KPIs identified in the PMS described in Chapter 5 and in the Annex II.

The CLD has been built through the observation of the main processes taking place at Orkel's and it has also been justified through some literature contributions (Table 7.5). More in detail, the AS business has been examined under different perspectives:

- the customer's perspective, in terms of customer perceived value and repurchasing attitudes;
- the company's perspective in terms of operational activities, investments to carry out and economical results to achieve.

Perspective	**Causal relations**	**Contributions**
Customer	Customer value → customer satisfaction	Zeithaml *et al.* 1990 Sawhney *et al.* 2004 Kingman-Brundage *et al.* 1995 Raimondi 2005 McDougall and Levesque 2000
	Product-service quality perceived → customer value	Sweeney *et al.* 1997 Cohen *et al.* 1997 Woodruff 1997 Gummesson 1993 Reichheld and Sasser 1990
	Customer satisfaction → customer loyalty → selling rate	Schneider and Bowen 1995 Rust and Metters 1996 Heskjett *et al.* 1994 Anderson and Fornell 1994 Raimondi 2005
Company (and its network)	Personnel → agility/responsiveness	InCoCo's 2007 Gaiardelli *et al.* 2007 Sterman 2000
	Profit → growth	Kingman-Brundage *et al.* 1995
	Profit → investments	Camerinelli and Cantu 2006 Crespo and Blanchar 2006 Spohrer *et al.* 2007

Table 7.5 – Literature contributions

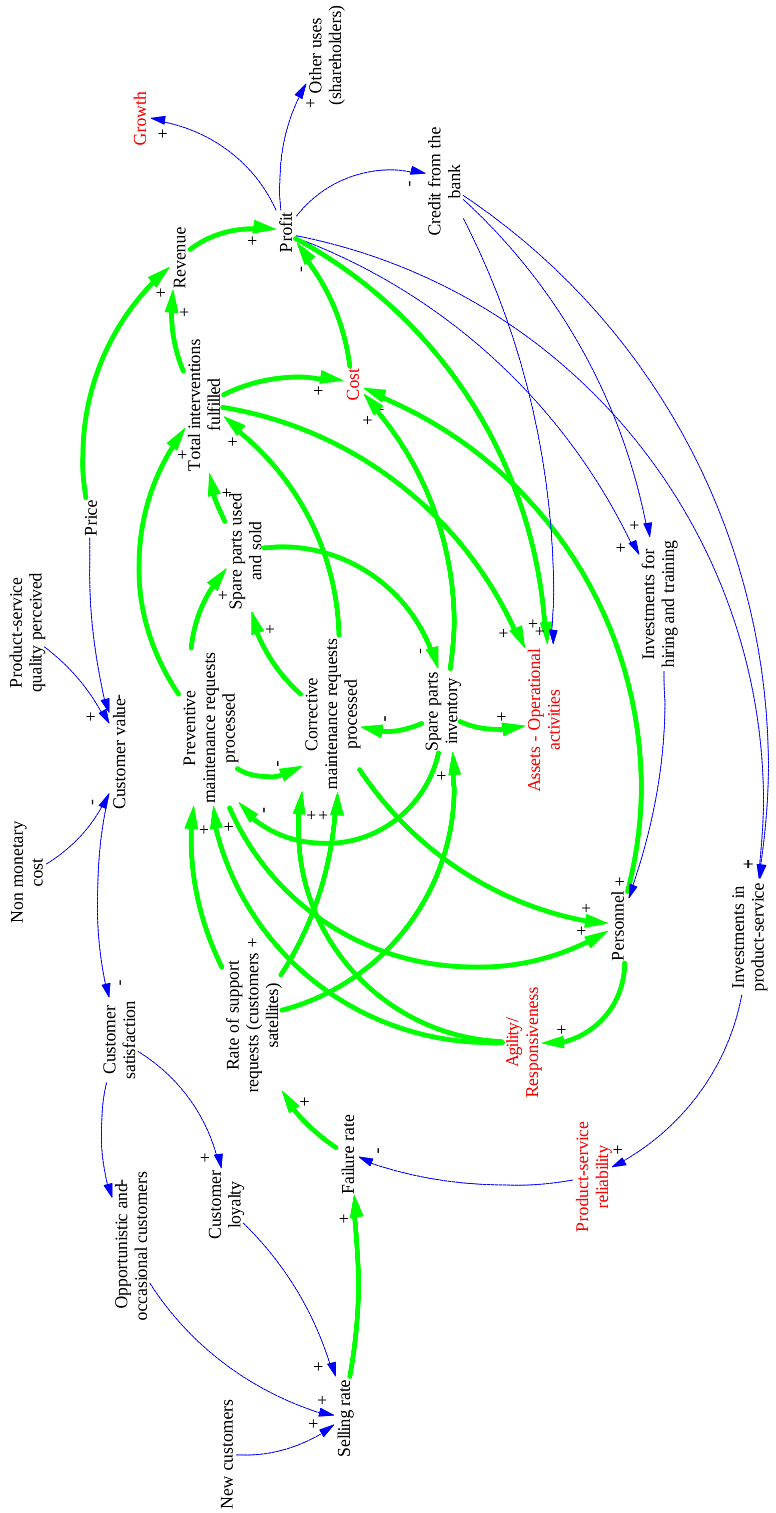


Figure 7.13 - Orkel's AS service provision (maintenance and spare parts supply) – aggregate view

The above CLD model (the green arrows) is translated into SFDs which quantitatively represent the causal relation and constitute the base for the simulation analyses. The models have been built partially from scratch and partially adapting to the specific case some SFD modules found in literature (Oliva 1996; Sterman 2000; Crespo 2010).

The SFDs have been developed according to the following different conceptual views:

1. Portfolio of sold machines which are under warranty, during the extended warranty and out of the warranty periods.

   This view gives an outlook of the installed base of machines sold by Orkel and currently on the market. These are the machines that require maintenance and provision of spare parts during their life cycle.

2. Number of requested maintenance interventions.

   This view shows the main maintenance interventions (both preventive and corrective) required by the machines on the market according to their different state of life. They are classified as:

   a) Preventive and corrective maintenance interventions under warranty;

   b) Preventive and corrective maintenance interventions during the extended warranty;

   c) Preventive and corrective maintenance interventions out of warranty.

3. Forecasting and spare parts inventory management.

   This view shows how the consumption of spare parts is forecasted and how their inventory is managed according to the different types of maintenance and states of the machines:

   a) Corrective maintenance interventions under and during the extended warranty;

   b) Corrective maintenance interventions out of warranty;

   c) Preventive maintenance interventions under and during the extended warranty;

   d) Preventive maintenance interventions out of warranty;

   e) Satellites' requests (namely the requests of spare parts from the technical assistance centres). The focus of this SD model is just on Orkel while the relations with third parties are roughly considered. It is assumed that there is some spare part consumption from Orkel's satellites and it is modelled as an input parameter.

4. Number of requested technicians, hiring and laying off rates.

   This view is about the estimation of the requested labour force according to the different types of maintenance interventions to carry out. It is assumed that technicians are all hired following the same procedure and they all receive the same training. When hired, then they work for collaborative assistance, turn-key assistance or preventive maintenance.

   a) Corrective maintenance interventions - turn – key type;
   b) Corrective maintenance interventions – collaborative calls type;
   c) Preventive maintenance interventions.

5. Costs, revenues and profit.

   This view shows the main costs, revenues and profits that come from Orkel's AS business.

   They are grouped as:

   a) Costs and revenues made on the installed based of machines under and during the extended warranty;
   b) Costs and revenues made on the installed based of machines out of warranty;
   c) Other costs and revenues made on all the installed based of machines;
   d) Total After-Sales service profit.

   Analyses are performed considering only the company's point of view and not the customer's one. Opportunity costs that the customer can save thanks to the introduction of PM contracts are not taken into account.

6. Working capital requirements and asset value.

   This SD model has been developed following the operational manager's view. Financial constraints and how money has to be collected and financed is out of the scope of this model. More in detail, this view shows the value of the AS assets and the requirements of money needed to run the AS business.

For each view, the SFDs and their related formulas are reported in Annex III.

Step 5.3 - test the model to be certain that it reproduces the behaviour seen in the real world

In order to test the validity of the model, a simulation campaign has been carried out on a sample of 100 machines. Since Orkel does not have historical data about its AS business, the validation of the model has been done through meetings with Orkel's management. The tested scenario represents the current situation at Orkel's where no preventive maintenance contracts are in use (it is the scenario A defined in the following paragraph). The results achieved from the simulation have shown trends similar to the real behaviour according to key indicators of costs, revenues and profits. Based on this results, it has been assumed that the other tested scenarios (scenarios B and C defined in the following paragraph) show a realistic trend as well. Moreover, on these scenarios some robustness analyses have been performed. Extreme conditions have been tested and the model has shown reasonable behaviours: physical quantities, such as inventories and backlogs, never get negative values.

7.7 Step 6: control the system through a management cockpit

The accomplishment of Step 6 is also split up into some sub-steps.

Step 6.1 – analyze different scenarios, namely devise and test in the model alternative policies that alleviate the problem

In order to assess how the introduction of Preventive Maintenance (PM) contracts impacts on Orkel's service performance, the analyses have been conducted assuming three different scenarios (Figure 7.14):

- <u>Scenario A</u> – PM contracts are not applied, either under or out of warranty (it represents the actual situation at Orkel's). If there is a failure, it is of CM nature and it is paid by Orkel under the warranty period and by the customer out of the warranty period.
- <u>Scenario B</u> – PM contracts are purchased by the customers just during the warranty period. The customer buys a contract for 1 PM intervention whose price includes the cost of the PM intervention and of the replacement of the rotor cutter. If there are other failures during the warranty time, they are of CM nature and they are paid by

Orkel. Failures out of the warranty period are of CM nature and are paid by the customer.

- Scenario C – PM contracts are purchased throughout the whole life cycle of the product, both under and out of the warranty periods. The customer buys contracts for yearly PM interventions whose price includes the PM intervention and the replacement of the failed part. If there are other failures, they are of CM nature and they are paid by Orkel during the warranty time and by the customer out of the warranty time.

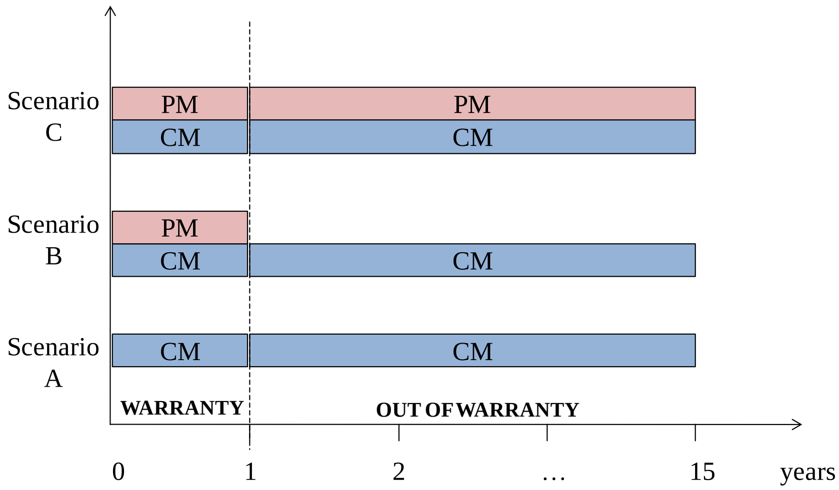


Figure 7.14 – Simulation scenarios

The analyses have been performed considering the manufacturer's perspective (namely Orkel's perspective in terms of revenues and costs) and considering a life cycle temporal horizon. The simulation time has been set on a monthly base and simulations have been run for 30 years, in order to analyze the entire life cycle of a round baler, which normally accounts for 10-15 years. After this time, machines are disposed. The model has been initialized considering the current company's installed base which is made up of machines under warranty and machines out of the warranty period (Figure 7.15).

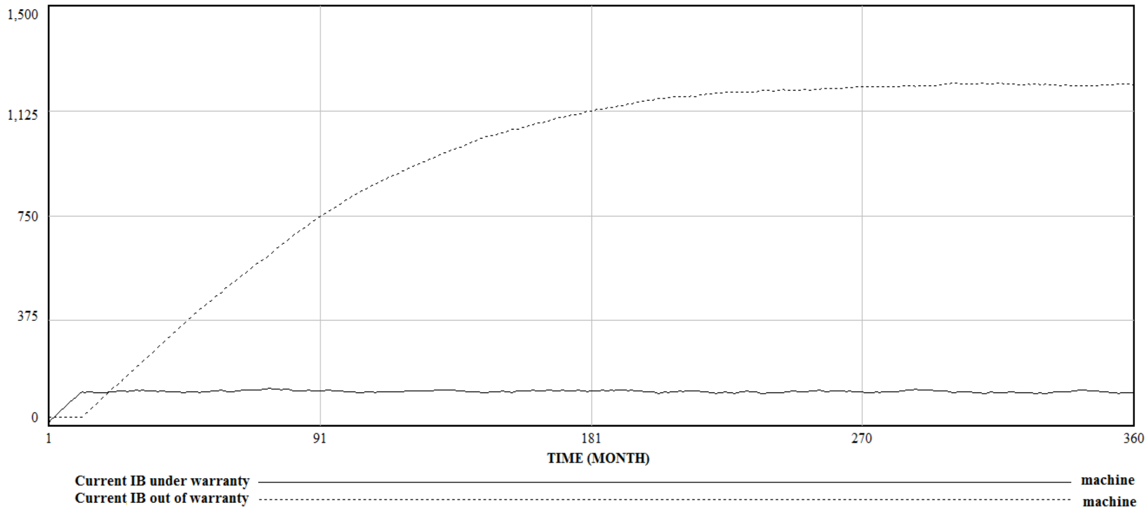


Figure 7.15 – Installed base of machines under and out of the warranty period

The model has been based on the following assumptions:

- whenever a failure happens, it is due to a component malfunctioning and it occurs on all the installed base of machines on the market;
- just one type of component is considered (i.e. the rotor cutter);
- the part failure rate has been estimated constant during the useful life of the component and increasing after a certain number of bales produced (Figure 7.16);

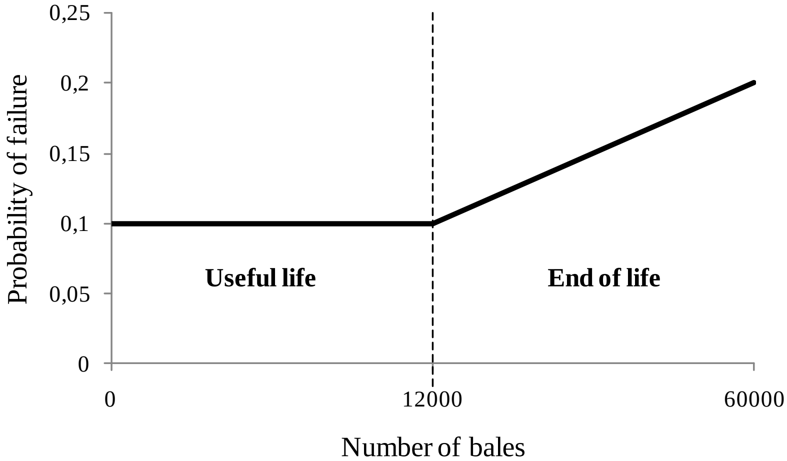


Figure 7.16 – Rotor cutter failure rate

- the customer purchases a PM contract paying a quota which includes the price of the PM intervention and of the part replaced, both during and out of the warranty periods;

- PM actions are time-cyclical, being carried out at predetermined time intervals (of 12 months);
- both PM and CM interventions are performed assuming that the restored component works as good as new.

In order to run the SD model, different input parameters (both exogenous and internal parameters) have been introduced and their values have been provided by the company or estimated to realistic values (Table 7.6).

Input parameter	**Value**	**Measure**
Demand rate of round balers	normal standard distribution ($\mu = 10$; $\sigma = 2$)	machine/month
Life cycle of round balers	10	year
Warranty time	12	month
Cycle time of a PM intervention	12	month
Part failure rate under warranty	$\begin{Bmatrix} P(0 < x \leq 12000) = 0{,}1 \\ P(x > 12000) = 0{,}2 \end{Bmatrix}$ where x = number of bales P = probability of failure	dimensionless
Price of a PM intervention under warranty	6500	nok/machine
Price of a PM intervention out of warranty	7000	nok/machine
Price of a CM intervention out of warranty	5500	nok/machine
Unitary cost of personnel	18000	nok/(month*technician)
Unitary cost of spare parts backlog	400	nok/part
Unitary cost of inventory	200	nok/part
Unitary price of spare parts	18000	nok/part
Unitary cost of spare	12000	nok/part

<table>
<tr><td>parts</td><td></td><td></td></tr>
<tr><td>Supply lead time (for spare parts)</td><td>2</td><td>weeks</td></tr>
<tr><td>Experience curve for CM</td><td>
<table>
<tr><th>Years of work experience</th><th>Hours to make the CM intervention</th></tr>
<tr><td>0 – 2</td><td>8</td></tr>
<tr><td>2 – 3</td><td>7,5</td></tr>
<tr><td>3 – 4</td><td>7</td></tr>
<tr><td>4 – 5</td><td>6,5</td></tr>
<tr><td>5 – 6</td><td>6</td></tr>
<tr><td>> 6</td><td>5,5</td></tr>
</table>
</td><td>hours</td></tr>
<tr><td>Experience curve for PM</td><td>
<table>
<tr><th>Years of work experience</th><th>Hours to make the PM intervention</th></tr>
<tr><td>0 - 2</td><td>12</td></tr>
<tr><td>2 – 3</td><td>11,5</td></tr>
<tr><td>3 - 4</td><td>11</td></tr>
<tr><td>4 - 5</td><td>10,5</td></tr>
<tr><td>5 - 6</td><td>10</td></tr>
<tr><td>6 - 7</td><td>9,5</td></tr>
<tr><td>7 - 8</td><td>9</td></tr>
<tr><td>8 - 9</td><td>8,5</td></tr>
<tr><td>> 9</td><td>8</td></tr>
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</td><td>hours</td></tr>
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Table 7.6 – Input parameters to the model

To assess the impact of introducing PM contracts, analyses have been addressed to evaluate:

- *Total life cycle cost* – it is the sum of all the costs that Orkel supports to maintain its installed base of machines during their life cycle. It is the sum of the following cost items:
    - Cost for answering to corrective collaborative calls +
    - Cost of inactive personnel +
    - Cost of spare parts sold to satellites +
    - Cost of spare parts backlog +

  - Cost of spare parts inventory +
  - Cost of spare parts sold out of warranty +
  - Cost of spare parts sold under warranty for preventive maintenance +
  - Cost out warranty for corrective interventions +
  - Preventive maintenance cost out warranty +
  - Preventive maintenance cost under warranty +
  - Warranty cost +
  - Cost of backlog of corrective maintenance requests out of warranty +
  - Cost for hiring and training personnel +
  - Cost of backlog of preventive maintenance requests out of warranty +
  - Cost of backlog of corrective collaborative calls
- *Total life cycle profit* – it is the difference between all the revenues and all the costs that Orkel supports to maintain its installed base of machines during their life cycle. It is the difference of the following revenue and cost items:
  - Preventive maintenance revenue out of warranty +
  - Preventive maintenance revenue under warranty +
  - Revenue of spare parts sold to satellites +
  - Revenue of spare parts sold out of warranty +
  - Revenue of spare parts sold under warranty for preventive maintenance +
  - Revenue out warranty for corrective interventions –
  - Total life cycle cost
- *Spare parts backlog cost* – it is the penalty cost for spare part backlogs related to corrective and preventive maintenance both under and out of the warranty periods.
- *Cost of inactive personnel* – it is the cost associated to the inactivity of the personnel, namely when the technicians are not involved in corrective or preventive maintenance interventions.

The following graphs present the main results achieved through the simulation performed on Orkel’s installed base of machines.

Figure 7.17 and Figure 7.18 report the trends of the total life cycle cost and profit for all the installed base of machines, for scenarios A, B and C.

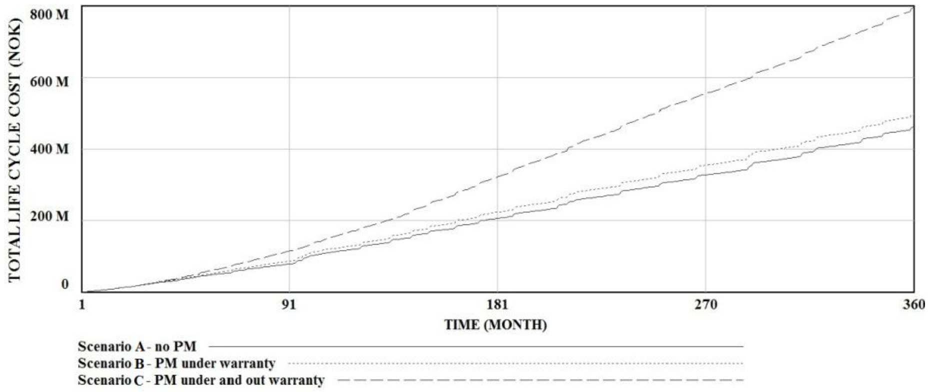


Figure 7.17 - Total life cycle cost for the three simulated scenarios for all the installed base

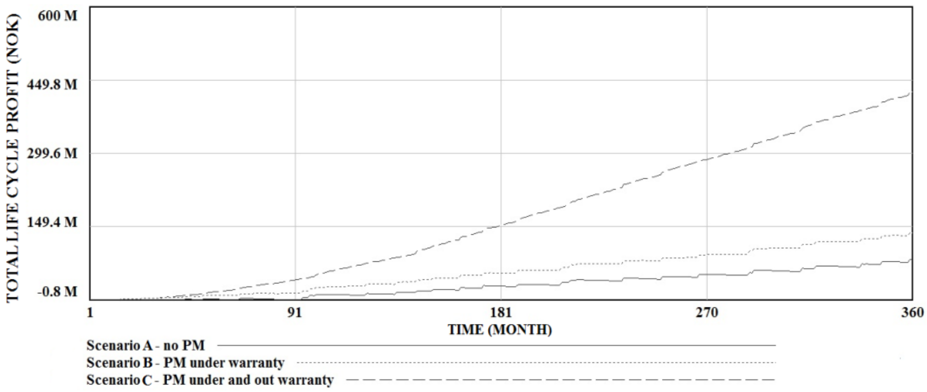


Figure 7.18 - Total life cycle profit for the three simulated scenarios for all the installed base

Limiting the PM just to the warranty period is less convenient than extending it to the entire life cycle of the round balers. Even though following this strategy makes the company incur in higher operational costs (due to the necessity of performing both CM and PM interventions and, consequently, due to the presence of more personnel who accomplishes these interventions), this is more than balanced by the profit made along the product life cycle.

Figure 7.19 shows the trend of the spare parts backlog costs accumulated during the product life cycle for each simulated scenario.

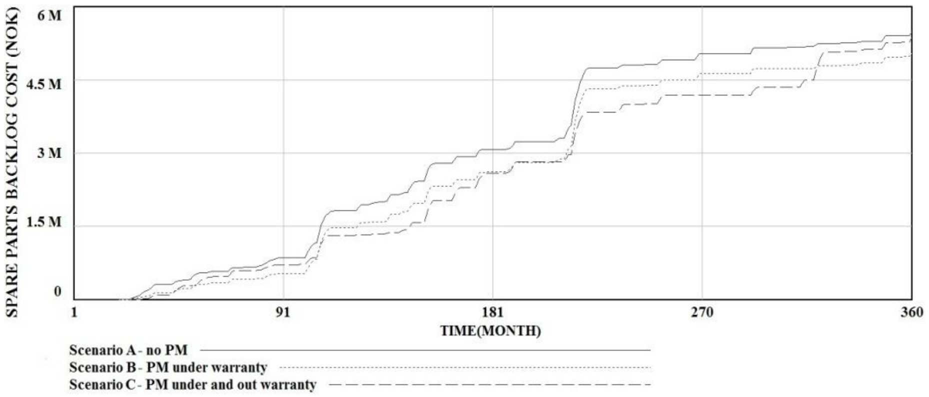


Figure 7.19 - Spare parts backlog cost in the product life cycle for the three simulated scenarios for all the installed base

It is interesting to note that introducing PM contracts lead to a reduction of the spare parts backlog. This is due to the fact that PM interventions are regularly scheduled and this reduces the uncertainty in forecasting the desired level of spare parts.

Finally, Figure 7.20 shows the trend that the costs for the inactivity of the personnel accumulate during the product life cycle.

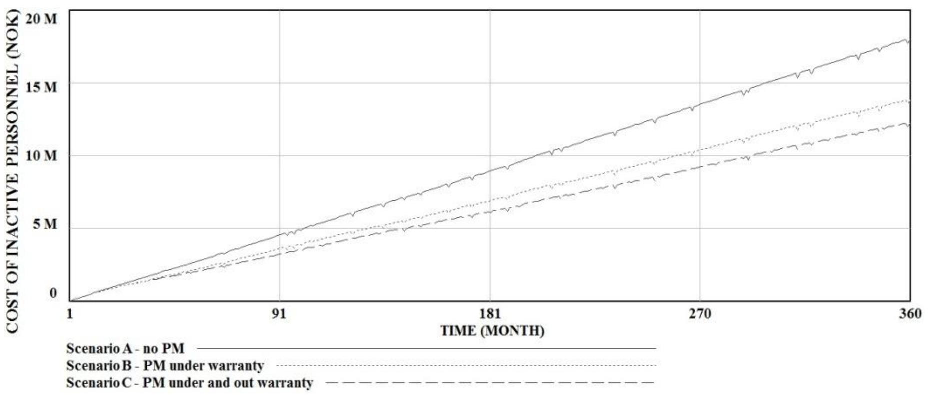


Figure 7.20 - Cost of inactive personnel in the product life cycle for the three simulated scenarios for all the installed base

It is evident that the costs of the inactive personnel decreases when the incidence of the PM increases. This is due to the fact that PM interventions are regularly planned compared to those of CM, thus the working time of the personnel can also be planned and better exploited.

The crucial outcome of the analysis is that Orkel can get benefits from the introduction of PM contracts. In particular, the higher the use of PM is, the higher Orkel's service performance is.

Step 6.2 – implement the solution and keep the system under control

Different scenarios have been examined to evaluate how the introduction of PM contracts may affect the total service performance of Orkel. For this particular case, given the initial assumptions made for the analysis and the input data provided by the manufacturer and used for the simulations, it comes out that introducing PM contracts is advantageous to the company. The number of PM contracts is one of the levers whose change can modify Orkel's performance and thus, for this specific situation, it constitutes the main knob of Orkel's management cockpit. In particular, it turns out that the higher the application of PM is, the higher the expected results are: even though the company incurs in higher operational costs, this is more than balanced by the improvement of several results, such as the increase of the overall service profit, the reduction of the inactive personnel costs and the reduction of the spare parts backlog costs.

It has to be remarked that the developed SD model (both the CLD and the SFDs) takes into consideration different elements of the AS area, which allows to make other analyses besides the specific problem examined. This has been done to create an overall SD model which analyses the entire AS area and the causal relations amid all the indicators proposed in the PMS of Chapter 5. As a consequence, this SD model has the potential to consider and evaluate other issues related to the AS business in addition to the particular problem proposed in this chapter. Further analyses can be conducted on this case study in order to define which is the best maintenance strategy to adopt, the optimal number of preventive cycles to carry out during the warranty period, the benefit of extending the warranty period, etc.

7.8 Conclusions

This chapter has shown an application of the six-step procedure. The use has permitted to control and improve the provision of Orkel's AS services. In particular, the procedure has allowed to create:

- a product-process matrix, a PMS and a dashboard for measuring the actual results carried out by Orkel;
- a management cockpit to evaluate the impact that the introduction of preventive maintenance contracts might have on Orkel's actual performance.

Regarding the management cockpit, the chapter shows how to manoeuvre Orkel's results through the variation of the number of preventive maintenance contracts.

In conclusion, it can be stated that the application of the procedure has been successful and has led to reach the expected outcomes of this research work. As shown, this procedure is made up of repeatable steps that can serve as guidelines and can be followed anytime it is required to support a company in designing (or reviewing), controlling and improving the provision of AS services.

Chapter 8

Conclusions

In several manufacturing industries service is recognised as a key of competitive success. Hence, companies need to move from a pure product orientation to a product-service one. It is proved that this shift is very challenging and it can be very difficult if companies do not develop an appropriate service culture and the capability to design and deliver services in an effective and efficient way. A key issue is to monitor and control all the processes and activities which are carried out to provide a product-service: service measures need to be implemented and applied consistently by all the parties involved in the service network in order to enhance its overall effectiveness.

Goal of this work is to contribute to fill this gap. It proposes a procedure to finally develop applicable tools to help companies in designing (or reviewing), controlling and improving the provision of After Sales services.

Regarding the scientific value and originality of this work, it adds up research to the field of Servitization, which is a still quite relatively new topic and not yet consolidated. In particular, the work is addressed to study how effectively providing Product-Service Systems, and more in detail, AS services.

More precisely, the project aims at:

- defining the main processes that make up the AS area and matching them in accordance with the characteristics of the product sold;
- defining the main requirements and the architecture of a Performance Measurement System specific to assess the results coming from the provision of AS services;

- exploring and representing the causal relations between the service metrics and thus the non-linear relations among all those processes that are involved when providing AS services.

This research has also some practical implications since it aims at providing usable and supportive tools to help companies in managing the supply of AS services. A procedure, made up of 6 steps, is provided as a guideline to follow in order to:

- identify the right correspondence between product characteristics and suitable technical support processes through a product-process matrix;
- develop a specific Performance Measurement System (Key Performance Indicators and diagnostic indicators) to evaluate company results;
- come up with a structured and organised dashboard which monitors the actual results of a company;
- develop a management cockpit to control and manoeuvre the future operational decisions of a company.

The application of the work to a real case study has been successful and of utility for the analysed company.

The results achieved through this work may be extended and applied to other companies which operate in the service business and have to deal with AS service issues. Companies which do not have a structured organization of their service supply chain processes, do not have a proper Performance Measurement System or are investing in extending their service offerings, but are incurring in higher costs without getting back the expected returns.

In order to implement this research work a maturity level assessment model has been created (Figure 8.1).

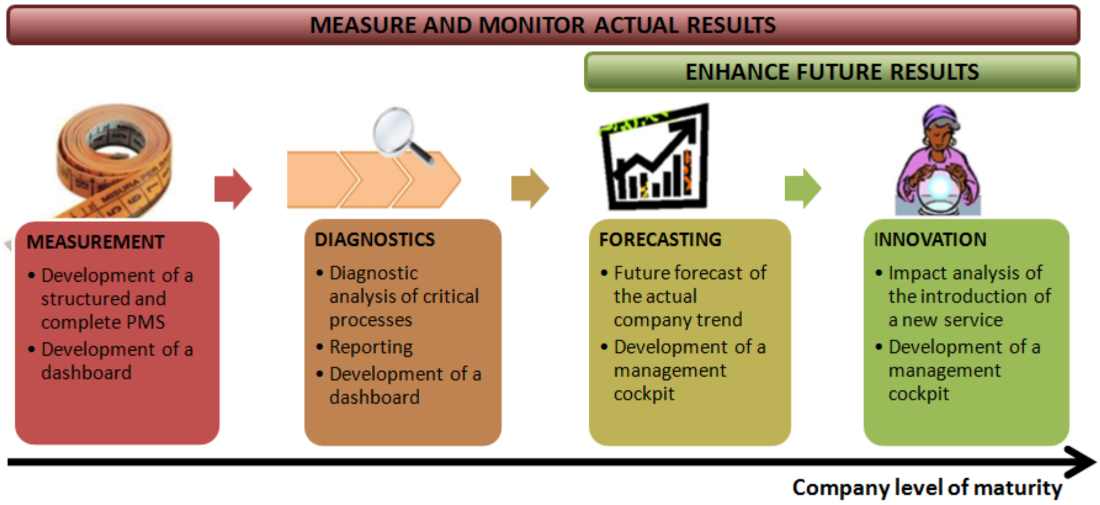


Figure 8.1 – Maturity level assessment model

According to this model, this work can be addressed to companies which deal with AS and are in different maturity levels. More in detail:

- Measurement stage - it refers to those companies which have just started to provide AS service, which have a very basic service culture and almost no tools for managing their AS service provision. These companies, which are normally Small and Medium Enterprises, are mainly interested in measuring their current performance results, thus they need a PMS tailored to their requirements and a dashboard to visualize the achieved results.
- Diagnostics stage - it refers to companies which have already implemented a PMS to evaluate their current performance and need to make diagnostics analyses on the underlying processes. These companies are interested in having a PMS which reflects critical trends of the beneath processes in order to possibly re-engineer them. They are interested in having a process-diagnostics PMS, a reporting system and a dashboard which visualizes the achieved results.
- Forecasting stage - it refers to companies which have already implemented a system to assess their results and they need tools to make forecasting analyses to evaluate, in the near future, the company's trends. They require a simulation tool to predict the future performance based on their current strategies and a management cockpit to understand which are the variables that mostly affect their results.

- Innovation stage – it refers to companies which are interested in introducing new services and are addressed to make innovation. They need a simulation tool which assesses the impact of the introduction of new policies and a management cockpit to manoeuvre those variables that influence the results of these new scenarios.

Regarding future developments, this work can be further extended.

Firstly the two main hypotheses on which the work is based can be relaxed. Research can be expanded beyond AS services and include the other categories of Product-Service System, namely Product-Utility services and Product-Result services. Moreover, research should be addressed to analyse the service network and all the relations with the service providers and the technical assistance centres.

This research can be further extended to consider sustainability, environmental and social issues with the definition of specific processes and performance indicators. Metrics which evaluate the customer satisfaction and the value creation for customers should be also included.

Regarding the System Dynamics model, this thesis proposes just an application of the model in order to analyse the impact of introducing preventive maintenance contracts at Orkel’s. However, this SD model has the potential to consider and evaluate other issues related to the AS business: further analyses can be conducted on this case study in order to define which is the best maintenance strategy to adopt, the optimal number of preventive cycles to carry out during the warranty period and the benefit of extending the warranty period.

References

Agnihothri S., Sivasubramaniam N., Simmons D., 2002. Leveraging technology to improve field service, *International Journal of Service Industry Management*, 13 (1): 47-68.

Alexander W.L., Dayal S., Dempsey J.J., Vander Ark J.D., 2002. The secret life of factory service centers, *The McKinsey Quarterly*, 3: 106 – 115.

Amaratunga D., Baldry D., 2002. Moving from performance measurement to performance management, *Facilities*, 20 (5/6): 217 – 223.

Andersen B., Fagerhaug T., 2002. Performance measurement explained – Designing and implementing your State-of-the-Art System, ASQ Quality Press.

Anderson E.W., Fornell C., 1994. A customer satisfaction research prospectus. In: Rust, R.T., Oliver R. (eds.) Service Quality: new directions in theory and practice. Sage Publications, 241 - 268, Thousand Oaks, CA.

Anderson K.A., Kerr C.J., 2001. Customer Relationship Management, McGraw-Hill.

Anderson J.C., Narus J.A., 1995. Capturing the value of supplementary services, *Harvard Business Review*, 73 (1): 75 - 83.

Armistead C., Clark G., 1991. A Framework for Formulating After-sales Support Strategy, *International Journal of Operations & Production Management*, 11 (3): 111 - 124.

Artto K.A., 1994. Life Cycle Cost Concepts and Methodologies, Cost Management, Fall.

Asugman G., Johnson J., McCullough J., 1997. The role of after-sales service in international marketing, *Journal of International Marketing*, 5 (4): 11 – 28.

Aurich J. C., Fuchs C., Wagenknecht C., 2006. Life cycle oriented design of technical Product-Service systems, *Journal of Cleaner Production*, 14 (17): 1480 - 1494.

Baines T.S., Lightfoot H.W., Evans S., Neely A., Greenough R., Peppard J., Roy R., et al., 2007. State-of-the-art in product-service systems, *Journal of Engineering Manufacture*, 221: 1543 - 1552.

Baines T.S., Lightfoot H.W., Benedettini O., Kay J., 2009. The servitization of manufacturing: A review of literature and reflection on future challenges, *Journal of Manufacturing Technology Management*, 20 (5): 547-567.

Bartolomeo M., Dal Maso D., De Jong P., Eder P., Groenewegen P., Hopkinson P., et al., 2003. Eco-efficient producer services e what are they, how do they benefit customers and the environment and how likely are they to develop and be extensively utilised?, *Journal of Cleaner Production*, 11: 829 - 37.

Baveja S.S., Gilbert J., Ledingham D., 2004. From products to services: why it's not so simple, *Harvard Management Update*, 9 (4): 3 - 5.

Beamon B., 1999. Measuring supply chain performance, *International Journal of Operations and Production Management*, 19 (3): 275 – 292.

Behrend S., Jasch C., Kortman J., Hrauda G., Firzner R.,Velte D., 2003. Eco-service development. Reinventing supply and demand in the European Union, Greenleaf Publishing Ltd. Sheffield.

Bijvank M., Koole G., Vis I.F.A., 2010. Optimising a general repair kit problem with a service constraint, *European Journal of Operational Research*, 204 (1): 76 - 85.

Bititci U.S., Turner T., Begemann C., 2000. Dynamics of performance measurement system, *International Journal of Operations & Production Management*, 20 (6): 692 - 704.

Bourne M., Neely A., Mills J., Platts K., 2003. Implementing performance measurement systems: a literature review, *International Journal of Business Performance Management*, 5 (1).

Brandstotter M., Haberl M., Knoth R., Kopacek B., Kopacek P., 2003. IT on demand – towards an environmental conscious service system for Vienna (AT). In: Third International Symposium on Environmentally conscious design and inverse manufacturing – EcoDesign, 799 – 802.

Brewer P.C., Speh T.W., 2000. Adapting the balanced scorecard to supply chain management, *Supply Chain Management Review*, 5 (2): 48 – 56.

Brun A., Novakova G., Gaiardelli P., Corti D., Pinto R., 2004. Design of a performance measurement architecture for integrated after-sales processes, In: Proceedings of Performance Measurement Association (PMA'04) Conference, EICC, Edinburgh (UK), 28-30 July, 163 - 170.

Bullinger H.J., Kühner M., Van Hoof A., 2002. Analysing supply chain performance using a balanced measurement method, *International Journal of Production Research*, 40 (15): 3533 - 3543.

Bundschuh R.G., Dezvane T.M., 2003. How to make after sales services pay off, *The McKinsey Quarterly: The Online Journal of McKinsey & Co*, 4.

Camerinelli E., Cantu A., 2006. Linking supply chain measures with financial performance: a framework, Technical Report, Supply Chain Council Research.

Campbell A.J., 2003. Creating customer knowledge competence: managing customer relationship management programs strategically, *Industrial Marketing Management*, 32 (5): 375 - 383.

Cavalieri S., Corradi E., 2002. L'evoluzione del servizio di assistenza del post-vendita: modelli di supporto, aspetti logistici ed opportunità IT (in Italian), in: Atti del XXVIII Convengo Nazionale ANIMP, Spoleto, 25-26 Ottobre 2002.

Chan F., 2003. Performance Measurement in a Supply Chain, *International Journal of Advanced Manufacturing Technology*, 21: 534 – 548.

Ciceri D.N., Garetti M., Terzi S., 2009. Product lifecycle management approach for sustainability, In: Proceedings of the 19th CIRP Design Conference.

Cohen M.A., Lee H.L., 1990. Out of touch with customer needs? Spare parts and after sales service, *Sloan Management Review*, Winter, 55 – 66.

Cohen M.A., Whang S., 1997. Competing in product and service: a product life-cycle model, *Management Science*, 43 (4): 535-45.

Cohen M.A., Zheng Y.S., Agrawal V., 1997. Service parts logistics: a benchmark analysis. *IEE Transactions*, 29: 627 - 639.

Cohen M.A., Agrawal N., & Agrawal V., 2006. Winning in the Aftermarket, *Harvard Business Review*.

Cooper R., 1995. When Lean Enterprises Collide. Competing through Confrontation, Harvard Business School Press, Boston, MA.

Cooper R., Slagmulder R., 1999. Supply Chain Development for the Lean Enterprise: Interorganisational Cost Management, Productivity Press, Portland.

Cooper R., Slagmulder R., 2003. Strategic cost management: expanding scope and boundaries, *Journal of Cost Management*, January–February.

Corti D., Gaiardelli P., Legnani E., Saccani N., 2009. Managing and controlling processes in product-based service networks, In: Proceedings of 11th International Conference MITIP, Bergamo, Italy, 15-16 October.

Craemer-Kühn D., Junghans M., Krönig J., 2002. BER revised – The aftermarket battle, a McKinsey presentation.

Crespo M.A., Blanchar C., 2006. A decision support system for evaluating operations investments in high-technology business, *Decision Support Systems*, 41: 472 – 487.

Crespo Marquez A., 2010. Dynamic modelling for supply chain management – Dealing with front-end and back-end and integration issues, Springer-Verlag, London.

De Rosnay J., 1977. Il macroscopio. Verso una visione globale (in Italian), Dedalo, Bari, Italy.

De Toni A.F., Comello L., 2005. Prede o Ragni. Uomini e Organizzazioni nella Ragnatela della Complessità (in Italian), Utet Libreria, Torino, Italy.

Dinning J., 1996. Measuring Performance (A Reference Guide) – Part One, Alberta Government, Canada, retrieved from: http://www.finance.gov.ab.ca/publications/measuring/measupgu/guide1.html

Dixon J.R., Nanni Jr. A.J., Vollmann T.E., 1990. The New Performance Challenge: Measuring Operations for World-Class Manufacturing, Business One Irwing, Homewood (Ill.).

Djamaludin I., Murthy N.P., Kim C.S., 2001. Warranty and preventive maintenance. *International Journal of Reliability, Quality and Safety Engineering*, 8 (2): 89 – 107.

Dutta A., Roy R., 2002. System Dynamics, OR/MS Today, The Institute for Operations Research and the Management Sciences, June.

Eccles R.G., 1991. The Performance Measurement Manifesto, *Harvard Business Review*, January-February.

Eckerson W.W., 2006. Performance dashboards: measuring, monitoring, and managing your business, John Wiley & Sons.

Edvardsson B., Gustafsson A., Roos I., 2005. Service portraits in service research: a critical review, *International Journal of Service Industry Management*, 1 (1): 107 - 121.

EFQM -European Foundation for Quality Management, 1998. EFQM self-assessment guidelines.

Ehinlanwo O.O., Zairi M., 1996. Best practice in the car after-sales service: an empirical study of Ford, Toyota, Nissan and Fiat in Germany – Part 1, *Business Process Re-engineering and Management Journal*, 2 (2).

Elima, 2003. Environmental life cycle information management and acquisition, retrieved from http://www.shu.ac.uk/design-research/elima/.

Ellram L.M., 1995. Total cost of ownership. An analysis approach for purchasing, *International Journal of Physical Distribution and Logistics Management*, 25 (8): 4 – 23.

Fabrychy W.J., Blanchard B.S., 1991. Life-Cycle Cost and Economic Analysis, Prentice Hall, Englewood Cliffs, NJ.

Fitzgerald L., Johnston R., Brignall S., Silvestro R., Voss C., 1991. Performance measurement in service businesses, CIMA.

Fitzgerald L., Moon P., 1996. Performance measurement in service industries: making it work, CIMA, London.

Flapper S.D., Fortuin L., Stoop P.P., 1996. Towards consistent performance management systems, *International Journal of Operations & Production Management*, 16 (7): 27 - 37.

Forza C., Salvador F., 2000. Assessing Some Distinctive Dimensions of Performance Feedback Information in High Performing Plants, *International Journal of Operations & Production Management*, 20 (3): 359 - 385.

Frambach R.T., Wels-Lips I., Gundlach A., 1997. Proactive product service strategies, *Industrial Marketing Management*, 26: 341 - 352.

Gaiardelli P., Saccani N., Songini L., 2007. Performance measurement systems in the after-sales service: an integrated framework, *International Journal Business Performance Management*, 9 (2): 145 - 171.

Gallagher T., Mitchke M.D., Rogers M.C., 2005. Profiting from spare parts, *The McKinsey Quarterly*.

Gebauer H., Fleisch E., Friedli T., 2005. Overcoming the Service Paradox in Manufacturing Companies, *European Management Journal*, 23 (1): 14 - 26.

Gebauer H., Benke P., Fleisch E., 2008. Service performance strategies in companies producing capital goods, ZWF Zeitschrift fuer Wirtschaftlichen Fabrikbetrieb, 102 (2): 865 - 869.

Ghalayini, A.M., Noble J.S., 1996. The Changing Basis Of Performance Measurement, *International Journal of Operations & Production Management*, 16 (8): 63 - 83.

Goedkoop M., Van Halen C., Te Riele H., Rommens P., 1999. Product service systems: ecological and economic basics, VROM, The Hague.

Goffin K., 1999. Customer support: a cross-industry study of distribution channels and strategies, International Journal of Physical Distribution & Logistics Management, 29 (6).

Gummesson E., 1993. Quality management in service organizations: an interpretation of the service quality phenomenon and a synthesis of international research. International Service Quality Association.

Gunasekaran A., Patel C., Tirtiroglu E., 2001. Performance measures and metrics in a supply chain environment, *International Journal of Operations & Production Management*, 21 (1/2): 71 – 87.

Hausman W.H., 2003. Supply chain performance metrics, in: Harrison T.P., Lee H.L., Neale J.J. (Eds.), The practice of supply chain management: Where theory and application converge, Boston.

Heiskanen E., Jalas M., 2000. Dematerialization through services e a review and evaluation of the debate, Helsinki, Finnish Ministry of the Environment.

Heskett J.L., Jones T.O., Loveman G.W., Sasser W.E., Schlesinger L.A., 1994. Putting the service-profit chain to work, *Harvard Business Review*, March-April, 164 - 174.

Hewitt P., 2002. The Government’s manufacturing strategy, Department of Trade and Industry. 4 April.

Hockerts K., Weaver N., 2002. Towards a theory of sustainable product service systems, INSEAD-CMER Research Workshop on Sustainable Product Service Systems.

Hopp W.J., Zhang R.Q., Spearman M.L., 1999. An easily implementable hierarchical heuristic for a two-echelon spare parts distribution system, *IEEE Transactions*, 31: 977 – 988.

Huiskonen J., 2001. Maintenance spare parts logistics: Special characteristics and strategic choices, *International Journal of Production Economics*, 71: 125 – 133.

InCoCo’s, 2007. EU-funded project, www.incoco.net.

Islam A.E., 2010. Investigating Governmental (Public Sector) Performance Management in Egypt, Doctoral Thesis, University of Strathclyde, Glasgow, UK.

ISO/DIS 14 224, 2004, Petroleum, petrochemical and natural gas industries — Collection and exchange of reliability and maintenance data for equipment.

iThink. High Performance Systems Inc., Hanover, NH 03755, http://www.hps-inc.com.

Johnson H.T., 1992. Relevance Regained, The Free Press, New York.

Johnson, H.T., Kaplan R.S., 1987. Relevance Lost: the Rise and Fall of Management Accounting, Harvard Business School Press, Boston, MA.

Kaplan R.S., Johnson H.T., 1987. Relevance Lost – The Rise and Fall of Management Accounting, Harvard Business School Press, Boston.

Kaplan R.S., Norton D.P., 1992. The Balanced Scorecard. Measures that Drive Performance, *Harvard Business Review*.

Kaplan R.S., Norton D.P., 1996. The Balanced Scorecard. Translating Strategy into Action, Harvard Business School Press, Boston.

Karlsson U., 2007. Service based manufacturing strategies implications for product development, productions and service operations in global companies, In: Proceedings of POMS College of Service Operations and EurOMA Conference.

Keegan D.P., Eiler R.G., Jones C.R., 1989. Are your performance measures obsolete?, *Management Accounting*, June, 45 – 50.

Kim B., Park S., 2008. Optimal pricing, EOL (end of life) warranty, and spare parts manufacturing strategy amid product transition, *European Journal of Operations Research*, 188 (3): 723 - 745.

Kingman-Brundage J., George W.R., Bowen D.E., 1995. “Service logic”: achieving service system integration, *International Journal of Service Industry Management*, 6 (4): 20.

Lange I., Schnetzler M., Schneider O., Osadsky P., 2007. Design of a performance measurement system for industrial service operations, In: Proceedings of 2nd International Conference on Changeable, Agile, Reconfigurable and Virtual Production (CARV 2007), July, Toronto, Ontario, Canada.

Lapide L., 2000. What about measuring supply chain performance, retrieved from: http://lapide.ascet.com.

Lebas M.J., 1995. Performance Measurement and Performance Management, *International Journal of Production Economics*, 41 (1/3): 23 - 35.

Legnani E., Cavalieri S., 2008. Measuring the performance of after-sales service processes. A hierarchical approach, In: Proceedings of APMS 2008, International Conference on Advances in Production Management Systems, Espoo, Finland, 14-17 September, 359 - 368.

Legnani E., Cavalieri S., Ierace S., 2009. A framework for the configuration of after-sales service processes, *Production Planning and Control*, (20) 2: 113 - 124.

Legnani E., Cavalieri S., 2009. Exploring the causal relationships of key performance indicators in after sales service systems, In: Proceedings of APMS 2009, International Conference on Advances in Production Management Systems, Bordeaux, France, 19-23 September.

Legnani E., Cavalieri S., Crespo A.M., González V.D., 2010. System Dynamics modeling for Product-Service Systems. A case study in the agri-machine industry, In: Proceedings of APMS 2010, International Conference on Advances in Production Management Systems, Cernobbio, Como, Italy, 9-13 October.

Lele M., 1997. After-Sales service-necessary evil or strategic opportunity?, *Managing Service Quality*, 7 (3): 141 - 145.

Lorino P., 1995. Comptes et récits de la performance (in French), Les Editions d'Organisation, Paris.

Löfberg N., Witell L., Gustafsson A., 2010. Service strategies in a supply chain, *Journal of Service Management*, 21 4: 427 - 440.

Lynch R.L., Cross K.F., 1991. Measure Up – The Essential Guide to measuring Business Performance, Mandarin, London.

Manzini E., Vezzoli C., Clark G., 2001. Product service-systems: using an existing concept as a new approach to sustainability, *Journal of Design Research*, 1.

Manzini E., Vezzolli C., 2003. A strategic design approach to develop sustainable product service systems: examples taken from the 'environmentally friendly innovation' Italian prize, *Journal of Cleaner Production*, 11: 851 – 857.

Maskell B.H., 1991. Performance Measurement for World Class Manufacturing, Productivity Press, Inc., Portland, OR.

Mathieu V., 2001. Service strategies within the manufacturing sector: benefits, costs and partnership, *International Journal of Service Industry Management*, 12 (5): 451-475.

McAdam R., Bailie B., 2002. Business Performance Measures and alignment impact on Strategy - The role of business improvement model, *International Journal of Operations & Production Management*, 22 (9): 972 - 996.

McClusky M., 2002. Service Lifecycle Management (Part 1): The Approaches and Technologies to Build Sustainable Advantages for Services, AMR Research, August.

McDougall G.H.G, Levesque T., 2000. Customer satisfaction with services: putting perceived value into the equation, *Journal of Services Marketing*, 14 (5): 392 - 410.

Mont O., 2001. Introducing and developing a PSS in Sweden, IIIEE, Lund University, 6.

Neely A.D., Mills J.F., Gregory M.J., Platts K.W., 1995. Performance measurement system design–a literature review and research agenda, *International Journal of Operations and Production Management*, 15 (4): 80 – 116.

Neely A.D., 1998. Measuring business performance: why, what and how, The Economist and Profile Books Ltd., London, UK.

Neely A., 1999. The performance measurement revolution: why now and what next?, *International Journal of Operations & Production Management*, 19 (2): 205 - 228.

Neely A., Mills J., Platts K., Richards H., Gregory M., Bourne M., 2000. Performance measurement system design: developing and testing a process-based approach, *International Journal of Operations & Production Management*, 20 (10): 1119 - 1145.

Neely A., 2009. Exploring the financial consequences of the servitization of manufacturing, *Operations Management Research*, 1 (2): 103-118.

Oliva R., 1996. A dynamic theory of service delivery: implications for managing service quality, Doctoral Thesis, Massachusetts Institute of Technology.

Oliva R., Kallenberg R., 2003. Managing the transition from products to services, *International Journal of Service Industry Management*, 14 (2): 160 - 172.

Olve N., Roy J., Wetter M., 1999. Performance Drivers: a Practical Guide to Using the Balanced Scorecard, John Wiley and Sons, UK.

Orkel SA, http://www.orkel.no.

Osadsky P., Garg A., Nitu B., Schneider O., Schleyer S., 2007. Improving service operation performance by a cross-industry reference model, in: Proceedings of the

IFIP International Federation for Information, Advances in Production Management Systems, eds. Olhager J., Persson F., Springer, Boston, 246: 397 - 404.

Panizzolo R., 2008. A methodology to measure the value of services provided to customers in manufacturing firms, *Measuring Business Excellence*, 12 (3): 3 - 15.

Papadopoulos H.T., 1996. A Field Service Support System Using a Queuing Network Model and the Priority MVA Algorithm, *Omega*, 24: 195 – 200.

Patelli L., Pistoni A., Songini, L., 2004a. The appraisal of after-sales service contribution to value creation. A conceptual framework, 27th Annual Congress of the European Accounting Association, Prague, April.

Patelli L., Pelizzari M., Pistoni A., Saccani N., 2004b. The after-sales service for durable consumer goods. Methods for process analysis and empirical application to industrial cases, In: Pre-Prints of 13th International Working Seminar on Production Economics, Igls (Innsbruck), Austria, 16-20 February, 3: 289-299.

Patton J.D., Bleuel W.H., 2000. After the sale, The Solomon Press, New York.

Persson F., Saccani N., 2007. Managing the after sales logistic network – a simulation study of a spare parts supply chain, IFIP International Federation for Information Processing, 246: 313 - 320.

Pezzotta G., Cavalieri S., Gaiardelli P., 2009. Product-Service Engineering: State of the Art and Future Directions, In: Proceedings of 13th IFAC Symposium on INformation COntrol problems in Manufacturing (INCOM), June, Moscow.

Piccinini P., Spinella G., 2010. Measuring the performance of the After-Sales area: the Orkel case study, Master thesis, University of Bergamo, Italy.

Pilkington A., Liston-Heyes K., 1998. Defining production and operations management: a citation/co-citation study, in: P. Coughlan, A. Dromgoole and J. Peppard (Eds.) Operations Management: Future Issues and Competitive Responses, Papers from the 5th International Conference of the European Operations Management Association, Dublin, Ireland, 14-17 June, published by the School of Business Studies, University of Dublin, Eire, 366 – 371.

Powersim. Powersim Corp, Bergen, Norway, http://www.powersim.com

Raimondi M., 2005. Marketing del prodotto-servizio – Integrare tangibile e intangibile per offrire valore al cliente (in Italian), Hoepli.

Reichheld F.F., Sasser W.E., 1990. Zero Defections: Quality Comes to Services. In: Reichheld, F.F., Cook, S.D.: The Quest for Loyalty, 129 - 141. Harvard Business School Publishing, Boston.

Ren G., Gregory M., 2007. Servitization in Manufacturing Companies. Paper presented at Cranfield Product-Service Systems Seminar (November), Cranfield, UK.

Roy R., Shehab E., 2009. Industrial Product Service Systems, Cranfield, Cranfield University Press.

Rust R.T., Metters R., 1996. Mathematical models of service, *European Journal of Operational Research*, 91: 427 - 439.

Santos M.F., Kennerley M., Micheli P., Martinez V., Mason S., Marr B., Gray D., Neely A., 2007. Towards a definition of a business performance measurement system, *International Journal of Operations and Production Management*, 27 (8): 784 – 801.

Santos S.P., Belton V., Howick S., 2002. Adding value to performance measurement by using system dynamics and multicriteria analysis, *International Journal of Operations & Production Management*, 22 (11): 1246 - 1272.

Sawhney M., Balasubramanian S., Krishnan V.V., 2004. Creating growth with services, *MIT Sloan Management Review*.

Schneider B., Bowen D.E., 1995. Winning the service game, Harvard Business School Press, Boston, MA.

Shields M.D., Young S.M., 1991. Managing product life cycle costs: an organizational model, Cost Management. Fall, 39 – 52.

Spohrer J., Maglio P.P., Bailey J., Gruhl D., 2007. Steps toward a science of service systems. Computer, *IEEE Computer Society Press*, 40 (1): 71 - 77.

Stadtler H., Kilger C., 2005. Supply Chain Management and Advanced Planning – Concepts, Models, Software and Case Studies, Berlin: Springer - Verlag.

Sterman J., 2000. Business dynamics: system thinking and modelling for a complex world, McGraw-Hill.

Stewart G.B., 1991. The Quest for Value: The EVATM Management Guide, HarperCollins Publishers, Inc.

Supply Chain Council (SCC), 2010. Supply Chain Operations Reference model (SCOR), version 10.0, Customer Chain Operations Reference model (CCOR), Design

Chain Operations Reference model (DCOR), Market Chain Operations Reference model (MCOR), www.supply-chain.org.

Sweeney J., Soutar G., Johnson L.W., 1997. Retail service quality and perceived value, *Journal of Retailing and Consumer Services*, 4 (1): 39 - 48.

Sweetser A., 1999. A Comparison of System Dynamics (SD) and Discrete Event Simulation (DES). In: Proceedings of 17th International Conference of the System Dynamics Society and 5th Australian & New Zealand Systems Conference. Wellington, New Zealand.

Thoben K.D., Jagdev H., Eschenbaecher J., 2001. Extended products: evolving traditional product concepts, In: Proceedings of the 7th International Conference on Concurrent Enterprising: Engineering the Knowledge Economy through Co-operation, Bremen (Germany), 27 - 29 June, 429 - 439.

Tukker A., 2004. Eight types of product-service: eight ways to Sustainability?, *Business Strategy and the Environment*, Summer.

Urbaniak A.J., 2001. What really happen to customer service, The American Salesman, Burlington, 46 (2): 14 – 17.

Vandermerwe S., Rada J., 1988. Servitization of business: adding value by adding services, *European Management Journal*, 6 (4): 314 - 324.

Vensim, Ventana Systems Inc., Harvard, MA 01451, http://www.vensim.com

Visnjic I., Van Looy B., 2009. Manufacturing firms diversifying into services: A conceptual and empirical assessment, Working Paper. Faculty of Business and Economics, K.U.Leuven.

Voss C., 2009. Case research in operations management, in: Researching operations management, edited by Karlsson C., Routledge, New York.

Williams A., 2007. Product service systems in the automobile industry: contribution to system innovation?, *Journal of Cleaner Production*, 15: 1093 - 1103.

Wise R., Baumgartner P., 1999. Go Downstream - the New Profit Imperative in Manufacturing. *Harvard Business Review*, September-October.

Woodruff R.B., 1997. Customer value: the next source for competitive advantage, *Journal of the Academy of Marketing Science*, 25 (2): 139 – 153.

Wright P.D., Keegan D.P., 1997. Pursuing Value: the Emerging Art of the Reporting on the Future, PW Papers, Price Waterhouse LLP.

Yamashina H., Otani S., 2001. Cost-optimized maintenance of the elevator – single unit case, *Journal of Quality in Maintenance Engineering*, 7 (1): 49 - 70.

Zeithaml V.A., Parasuraman A., Berry L.L., 1990. Delivering quality service: balancing customer perceptions and expectations, Free Press, New York.

Zhang R.Q., Hopp W.J., Supatgiat C., 2001. Spreadsheet Implementable Inventory Control for a Distribution Center, *Journal of Heuristics*, 7: 185 – 203.

Annex I – The assistance processes

The definitions of each process and activity that belong to the Assist process of the CCOR model are reported hereafter.

cA: Assist process

The set of processes which provide AS support for all products/services offered to the customer, and include resolving any contractual issues. Assistance processes include assigning support resources and responding to customer inquiries, (warranty) claims, contractual issues, and quality feedback for business transactions and products/services life performance.

cA1: Passive-Assist

Contract-related information are updated and monitored, performance expectations are documented and pre-packaged solutions to products/ services inquiries or issues are offered; inquiries are diagnosed solely by the customer.

- **cA1.01: Receive inquiry/request**

  The receipt and logging of Assist requests from the customer. Passive Assist can be received through internet and/or automated phone services (Requests can be either of proactive or of reactive nature).
- **cA1.02: Authorize request**

  The process of validation and authorization of the Assist request. For example the user of an automated service might be asked to provide a code or a user-name and a password.
- **cA1.03: Route request to identify solution**

  The automated process of analyzing the Assist request to determine where/how the request can be best supported in order to identify a solution. Solution(s) could be verification and/or extension of warranty term limitations as well as automated user-diagnosis for technical support. Solutions are defined according to the defined business model.

- **cA1.04: Propose solution**

  The automated interaction with the customer to offer the identified solution(s) and acceptance of the response from the customer on the proposed solution(s). A negative response might trigger the request for additional information and the rerouting of the Assist request or the release of the Assist Request to Collaborative Assist.
- **cA1.05: Release solution to customer**

  The actual transfer of the solution to the customer. This can be performed using one or more of the following media: automated fax services, internet downloads, internet redirection, automated voice response, etc.
- **cA1.06: Close request**

  The activities associated with closing the Assist request. This may include offering the customer to provide feedback on the effectiveness of the assist offering, sending a signal to the financial department that the internal or external billing process should begin for the services provided (warranty), and archiving the Assist request in support of analyzing the performance of the Assist process.

cA2: Collaborative-Assist

Contract-related information are updated and monitored, performance expectations are documented and pre-packaged or custom solutions to products/ services requests or issues are provided; inquiries are diagnosed jointly by the customer and the assistance provider.

- **cA2.01: Receive inquiry/request**

  The receipt and logging of Assist requests from the customer. Collaborative Assist requests can be received through (electronic) mail, phone, fax or in store. (Requests can be either of proactive or of reactive nature)
- **cA2.02: Authorize request**

  The process of validation and authorization of the Assist request. This includes warranty/contracts verification.
- **cA2.03: Route request**

  The process of analyzing the Assist request to determine where/how the request can be best supported.

- **cA2.04: Identify solution**
  The process of identifying a proposed solution to the Assist request based on the information provided by the customer. Solution(s) could be re-definition of warranty term limitations as real-time product performance diagnostics for technical support.
- **cA2.05: Propose solution**
  The interaction with the customer to offer the identified solution and acceptance of the response from the customer on the proposed solution(s). A negative response might trigger the request for additional information and the rerouting of the Assist request or the release of the Assist Request to a “Turn-key” Assist.
- **cA2.06: Distribute solution**
  The process of passing the solution on to the appropriate organizations. (An example scenario is the engagement with the supply chain process to issue an RMA (Return Merchandise Authorization) for return product and creation of a customer order to replace the product).
- **cA2.07: Release solution to the customer**
  The actual transfer of the solution to the customer. This can be performed using one or more of the following media: phone, fax, other electronic media, etc. Implementation of solutions may be the responsibility of the customer or may be shared with the assistance provider.
- **cA2.08: Close request**
  The activities associated with closing the Assist request. This may include offering the customer to provide feedback on the effectiveness of the assist offering, sending a signal to the financial department that the internal or external billing process should begin for the services provided (warranty), and archiving the Assist request in support of analyzing the performance of the Assist processes.

cA3: ‘Turn-Key’-Assist

Contract-related information are updated and monitored, performance expectations are documented and mainly custom solutions are implemented; diagnosing activities are performed primarily or solely by the assistance-provider.

- **cA3.01: Receive inquiry/request**

  The receipt and logging of Assist requests from the customer. "Turn-Key" Assist requests can be received through electronic mail, phone or fax. (Requests can be either of proactive or of reactive nature)
- **cA3.02: Authorize request**

  The process of validation and authorization of the Assist request. This includes warranty/contracts validation.
- **cA3.03: Route request**

  The process of analyzing the Assist request to determine where/how the request can be best supported.
- **cA3.04: Scheduling**

  Assist resources are identified and reserved for a "Turn-key" Assist event based on service levels agreements (contract rules, time, location, competences).
- **cA3.05: Identify solution**

  The process of identifying a proposed solution to the Assist request based on diagnosis performed by the assistance-provider.
- **cA3.06: Distribute solution**

  The process of passing the solution on to the appropriate organizations. (An example scenario is the engagement with the supply chain process to issue an RMA (Return Merchandise Authorization) for return product and creation of a customer order to replace the product).
- **cA3.07: Obtain materials**

  The identification of materials (expected to be) required for the Assist event and activities associated with expediting the materials. (The procurement process to replace spare parts is not within the scope of the Assist process).
- **cA3.08: Repair product or obtain customer agreement**

  The process of preparing, decomposing the product, replacing the part and re-assembling the product. The product is fully operational upon completion. In case the request is a re-negotiation of the assist contract, it is necessary to refine the counter offer within constraints and obtain agreements with the customer.

- **cA3.9: Dispose materials**

  The disposition of materials replaced during the assist event. This process can link to a supply chain process trying to salvage replaced materials (in terms of return process but also to retrieve technical data from the product).

- **cA3.10: Close request**

  The activities associated with closing the Assist request. This may include offering the customer to provide feedback on the effectiveness of the Assist offering, sending a signal to the financial department that the internal or external billing should begin for the services provided (warranty), and archiving the Assist request in support of analyzing the performance of the Assist processes.

cEA: Enable Assist

Enable Assist is the collection of processes to prepare, maintain, and manage information or relationships upon which Assist execution processes rely.

- **cEA.01: Manage Assist Business Rules**

  The process of defining, maintaining, and enforcing rules which affect the post sales and post delivery support for products and services. The Assist business rules provide criteria that are translated into guidelines, policies and business models for post sales and post delivery support. Assist business rules include: warranty validation and solution offering guidelines.

- **cEA.02: Manage Assist Performance**

  The process of defining the requirement and monitoring the performance of providing post sales and post delivery support for products and services against internal and/or external standards and goals of customer retention, customer satisfaction and financial performance

- **cEA.03: Manage Assist Information**

  The process of collecting, maintaining, and communicating information to support post sales and post delivery support planning and execution processes. The information to be managed includes: warranty status, ordering and credit history, product/services information, etc.

- **cEA.04: Manage Warranty**
  The process of defining, maintaining and enforcing warranty information. This includes collecting, maintaining and distributing warranty information. The Supply Chain inputs shipment/delivery information.
- **cEA.05: Manage Assist Capital Assets**
  The acquisition, maintenance, and disposition of support capital assets (spare parts, resources, means of transport, equipment). This includes support call centers, call center automation tools, etc.
- **cEA.06: Manage Assist Knowledge Transfer**
  The process of defining a Assist knowledge transfer strategy and maintaining the information, which characterizes total Assist knowledge management requirements. This includes creation and maintenance of training materials, delivery of training, and availability and accessibility of training and warranty information.
- **cEA.07: Manage Assist Network**
  The process of defining, establishing, and maintaining the support business model for a specific combination of product line, customer (group), market and geographic location. And the process of defining and maintaining a network of relationships with internal and/or external process groups required to provide satisfactory customer support. (e.g. Spare part fulfillment, Supply Chain for returns and replacements, Sales for quotation for additional products or services).
- **cEA.08: Manage Assist Regulatory Compliance**
  The process of identifying and complying with regulatory documentation and process standards set by external entities (e.g. government).

cPA: Plan Assist

The development and establishment of courses of action for specified time periods to ensure alignment of resources to requirements and identification of gaps. E.g. Support call centre staff planning, infrastructure (web server/telecom) capacity planning, repair staff planning (warranty).

- **cPA.01: Gather Assist Requirements**
  The process of identifying, prioritizing, and considering as a whole with constituent parts, all sources of demand for post sales or post delivery support.

- **cPA.02: Gather Assist Resources**

  The process of identifying, evaluating, and considering, as a whole with constituent parts, all resources that add value in post sales or post delivery support.

- **cPA.03: Balance Assist Requirements with Resources**

  The process of developing a time-phased course of action that commits Assist resources to meet post sales and post delivery support requirements. This may include: support call centre planning, repair (staff) planning, materials demand planning (as an input to support supply chain), etc.

- **cPA.04: Publish Assist Plan**

  The process of establishing and communicating the Assist plan.

Annex II – The Performance Measurement System

According to the PMS architecture defined in Chapter 5, the hierarchical structure, the process-diagnostics structure and the relative performance indicators are hereafter reported.

Hierarchical structure

RELIABILITY (RL)

LEVEL 1

cRL.1.1: Perfect Assist Completion

A Perfect Assist is a customer assist which meets all of the following standards:

- Issue/Request responded to within agreed upon time
- Issue/Request resolved within agreed upon time
- Problem is completely resolved
- Problem is resolved during the first customer contact
- Customer satisfied with resolution
- Resolution is documented
- Product issue information communicated back to rest of the business (Design Chain, Supply Chain)

(# of perfect assists / # of assists) * 100

LEVEL 2

cRL.2.1: Issue resolution time rate

Rate of issues solved within the original commitment date

(# of issues solved within the original commitment date/total assist issues solved)*100

cRL.2.2: First call fix rate

Rate of issues solved at the first customer contact

(# of issues solved at first customer contact/total assist requests received)*100

cRL.2.3: Documentation accuracy

Rate of issues solved by the customer through complete and clear documentation. It is useful mainly for Passive Assist. If Assist is performed through a web site, it measures also how reliable and useful is the web. (# of issues solved through documentation/total assist requests received)*100

(# of issues solved through the web site/total visits received)*100

cRL.2.4: Correct spare parts interventions rate

Rate of interventions performed with correct spare parts

(# of interventions performed with correct spare parts/total assist requests received with spare parts usage)*100

LEVEL 3

cRL.3.1: MTBeforeF (Mean Time Before Failure)

Indicator which measures the reliability of the product sold. It gives useful information to Assist personnel to approximately forecast when a problem will occur. It measures time between first product start up and first failure

(first product start up - first assist intervention) [time]

cRL.3.2: MTBetweenF (Mean Time Between Failure)

Elasped time between two assist interventions. Lower is the value, more reliable is the performed assistance

(assistance request at time t - assistance request at time t-1) [time]

cRL.3.3: Time the server is down

Number of minutes (or seconds) the server is down and does not work

cRL.3.4: Assist resolution rate

% of requests resolved/assist inquiries

(# of assist resolved/# of Assist inquiries or requests)*100

cRL.3.5: Wrong routings rate

Rate of wrong routings which return back to the call center unresolved

(# of issues back to the call center/ total assist requests received)*100

cRL.3.6: Perfect technician intervention rate

Rate of interventions correctly performed by technicians at first time (correct diagnosis, right spare parts, etc.)

(# of interventions correctly performed at first time/total assist requests received)*100

cRL.3.7: Number of repeat compliant calls from the same customer

cRL.3.8: Assist payment documentation accuracy

Number of Assist interventions performed with the right payment documentation

cRL.3.9: Intervention report accuracy

Number of Assist interventions performed with the right reporting documentation

cRL.3.10: % of interventions with wrong or missing spare parts

cRL3.11: Spare parts delivery quantity accuracy

Number of spare parts delivered with right quantities

cRL3.12: Spare parts delivery damage free

Number of spare parts delivered without any damage

cRL.3.13: Spare parts delivery location accuracy

Number of spare parts delivered at the right place

- cRL.1.1: Perfect Assist Completion
  - cRL.2.1: Issue resolution time rate
    - cRL.3.1: MTBeforeF (Mean Time Before Failure)
    - cRL.3.2: MTBetweenF (Mean Time Between Failure)
    - cRL.3.3: Number of minutes the server is down
  - cRL.2.2: First call fix rate
    - cRL.3.4: Assist resolution rate
    - cRL.3.5: Wrong routings rate
    - cRL.3.6: Perfect technician intervention rate
    - cRL.3.7: Number of repeat compliant calls from the same customer
  - cRL.2.3: Documentation accuracy
    - cRL.3.8: Assist payment documentation accuracy
    - cRL.3.9: Intervention report accuracy
  - cRL.2.4: Correct spare parts interventions rate
    - cRL.3.10: % of interventions with wrong or missing spare parts
    - cRL3.11: Spare parts delivery quantity accuracy
    - cRL3.12: Spare parts delivery damage free
    - cRL.3.13: Spare parts delivery location accuracy

RESPONSIVENESS (RS)

LEVEL 1

cRS.1.1: Assist Cycle Time for turn-key assist

Average Time from receipt of customer inquiry, to resolve customer problems on-site and to close request.

$$\frac{\sum(\text{close assist request date} - \text{receive assist request date})}{\#\text{ of interventions}}$$

cRS.1.2: Assist Cycle Time for collaborative assist

Average Time from receipt of customer inquiry and to close request

$$\frac{\sum(\text{close assist request date} - \text{receive assist request date})}{\#\text{ of collaborative assist calls}}$$

LEVEL 2

cRS.2.1: Call center waiting time

Average time customers wait on the phone before talking with the operator at the call center

cRS.2.2: Average authorization request time

cRS.2.3: Average routing time

cRS.2.4: Average time for scheduling technical assistance

cRS.2.5: Average time for diagnosis

cRS.2.6: Average time to propose a solution

cRS.2.7: Waiting time for delivery spare parts

Average Time from receipt of customer inquiry to delivering of spare parts.

$$\frac{\sum(\text{delivery spare parts date} - \text{receive spare parts request date})}{\#\text{ of deliveries}}$$

cRS.2.8: MTTR (Mean Time To Repair) a machine

Average time to repair or fix a problem for each type of machine

$$MTTR_k = \frac{\sum \text{Time to repair machine}_\text{k}}{\text{\# of machine}_\text{k}\text{ repaired}}$$

k = machine type

cRS.2.9: MTTR (Mean Time To Repair) each machine per technician

Average time to repair or fix a problem for each type of machine per single technician

$$MTTR_{k,w} = \frac{\sum \text{Time spent by technician}_\text{w}\text{ to repair machine}_\text{k}}{\text{\# of machine}_\text{k}\text{ repaired by technician}_\text{w}}$$

k = machine type

w = technician

cRS.2.10: Average time for material disposal

cRS.2.11: Average time to close requests

cRS.2.12: Frequency to update solutions on web site

cRS.2.13: Average time to prepare documentation for a new solution

cRS.2.14: Average number of turn-key interventions during out of peak season

$$\frac{\text{\# of turn key interventions during out of peak season}}{\text{\# of working day during out of peak season}}$$

cRS.2.15: Average number of collaborative assist calls during out of peak season

$$\frac{\text{\# of collaborative assist calls during out of peak season}}{\text{\# of working day during out of peak season}}$$

LEVEL 3

cRS.3.1: Average number of turn-key interventions for technician during out of peak season

$$\frac{\text{cRS. 2.14}}{\text{\# of technicians working on site during out of peak season}} =$$
$$= \frac{\text{Average number of turn key interventions during out of peak season}}{\text{\# of technicians working on site during out of peak season}}$$

cRS.3.2: Average number of collaborative assist calls for technician during out of peak season

$$\frac{\text{cRS. 2.15}}{\text{\# of technicians in the call center during out of peak season}} =$$
$$= \frac{\text{Average number of collaborative assist calls during out of peak season}}{\text{\# of technicians in the call center during out of peak season}}$$

- cRS.1.1: Assist Cycle Time for turn-key assist
  - cRS.2.1: Call center waiting time
  - cRS.2.2: Average authorisation request time
  - cRS.2.3: Average routing time
  - cRS.2.4: Average time for scheduling technical assistance
  - cRS.2.5: Average time for diagnosis
  - cRS.2.6: Average time to propose a solution
  - cRS.2.7: Waiting time for delivery spare parts
  - cRS.2.8: MTTR (Mean Time To Repair) a machine
  - cRS.2.9: MTTR (Mean Time To Repair) each machine per technician
  - cRS.2.10: Average time for material disposal
  - cRS.2.11: Average time to close requests
  - cRS.2.12: Frequency to update solutions on web site
  - cRS.2.13: Average time to prepare documentation for a new solution
  - cRS.2.14: Average number of turn-key interventions during out of peak season
    - cRS.3.1: Number of average turn-key interventions for technician during out of peak season

- cRS.1.2: Assist Cycle Time for collaborative assist
  - cRS.2.1: Call center waiting time
  - cRS.2.2: Average authorisation request time
  - cRS.2.3: Average routing time
  - cRS.2.5: Average time for diagnosis
  - cRS.2.6: Average time to propose a solution
  - cRS.2.7: Waiting time for delivery spare parts
  - cRS.2.11: Average time to close requests
  - cRS.2.12: Frequency to update solutions on web site
  - cRS.2.13: Average time to prepare documentation for a new solution
  - cRS.2.15: Average number of collaborative interventions during out of peak season
    - cRS.3.2: Number of average collaborative interventions for technician during out of peak season

AGILITY

LEVEL 1

cAG.1.1: Reaction time to unplanned events

Time required to achieve an unplanned sustainable increase in assist requests

cAG.1.2: Adaptability to the increase of unplanned requests for collaborative assist

The maximum sustainable % increase in assist requests that can be achieved in a fixed period time (ex. 30 days after a promotion)

$$\frac{(\mathrm{cAG.}\,2.3 - \mathrm{cRS.}\,2.15)}{\mathrm{cRS.}\,2.15} * 100 =$$

$$= \frac{\text{Average number of collaborative assist calls during peak season} - \text{Average number of collaborative assist calls during out of peak season}}{\text{Average number of collaborative assist calls during out of peak season}}$$

cAG.1.3: Adaptability to the increase of unplanned requests for turn-key assist

The maximum sustainable % increase in assist requests that can be achieved in a fixed period time (ex. 30 days after a promotion)

$$\frac{(\mathrm{cAG.}\,2.4 - \mathrm{cRS.}\,2.14)}{\mathrm{cRS.}\,2.14} * 100 =$$

$$= \frac{\text{Average number of turn key interventions during peak season} - \text{Average number of turn key interventions during out of peak season}}{\text{Average number of turn key interventions during out of peak season}}$$

cAG.1.4: Adaptability to customised requests

The maximum sustainable changes to accomplish customised assist requests

LEVEL 2

cAG.2.1: Time to manage urgent and unplanned spare parts requests

cAG.2.2: Time required to achieve unplanned sustainable increase in assists requests with assumption of incompliant resources (technicians injured, incompliant phone operators, etc.)

cAG.2.3: Average number of collaborative assist calls during peak season (in a day)

$$\frac{\text{\# of collaborative assist calls during peak season}}{\text{\# of working day during peak season}}$$

cAG.2.4: Average number of turn-key interventions during peak season (in a day)

$$\frac{\text{\# of turn key interventions during peak season}}{\text{\# of working day during peak season}}$$

cAG.2.5: Time required to perform a new and customised request

cAG.2.6: Number of contract conditions modified

LEVEL 3

cAG.3.1: Number of average collaborative assist calls for technician during peak season

$$\frac{\text{cAG. 2.3}}{\text{\# of technicians working on site during peak season}} =$$
$$= \frac{\text{Average number of turn key interventions during peak season}}{\text{\# of technicians working on site during peak season}}$$

cAG.3.2: Number of average turn-key interventions for technician during peak season

$$\frac{\text{cAG. 2.4}}{\text{\# of technicians in the call center during peak season}} =$$
$$= \frac{\text{Average number of collaborative assist calls during peak season}}{\text{\# of technicians in the call center during peak season}}$$

cAG.3.3: % of last minute interventions added in the scheduling

- cAG.1.1: Reaction time to unplanned events
  - cAG.2.1: Time to manage urgent and unplanned spare parts requests
  - cAG.2.2: Time required to achieve unplanned sustainable increase in assists requests with assumption of incompliant resources (technicians injured, incompliant phone operators, etc.)

- cAG.1.2: Adaptability to the increase of unplanned requests for collaborative assist
  - CAG2.3: Average number of collaborative interventions during peak season (in a day)
    - cAG.3.1: Number of average collaborative interventions for technician during peak season

- cAG.1.3: Adaptability to the increase of unplanned requests for turn-key assist
  - cAG.2.4: Average number of turn-key interventions during peak season (in a day)
    - cAG.3.2: Number of average turn-key interventions for technician during peak season
    - cAG.3.3: % of last minute interventions added in the scheduling

- cAG.1.4: Adaptability to customised requests
  - cAG.2.5: Time required to perform a new and customised request
  - cAG.2.6: Number of contract conditions modified

COSTS

LEVEL 1

cCO.1.1: Total Assist Cost (total)

The sum of the costs associated with customer inquiries resolution

Cost of Turn-Key Assist + Cost of Passive and Collaborative Assist + Cost of Spare Parts Sold + Warranty Cost + Cost of Maintenance Interventions+Cost of Spare Parts Inventory+Cost of Spare Parts Backlog+Cost of Assistance Personnel = cCO.2.1 + cCO.2.2 + cCO.2.3 + cCO.2.4+cCO.2.5+cCO.2.6+cCO.2.7+cC0.2.8

LEVEL 2

cCO.2.1: Cost of Turn-Key Assist (total)

Total cost to process customer inquiries/requests for assistance and resolve customer problems. It measures both direct and indirect costs related to the intervention. For instance hourly technician cost, technician travel expenses and cost of material used.

$$\sum_{i=1}^{n} \text{cost of turn} - \text{key assist out of warranty}_{i}$$

where i = 1...n is the number of turn-key interventions made out of the warranty period

cCO.2.2: Cost of Passive and/or Collaborative Assist (total)

Generally it is a fixed cost. It is the cost of technicians who perform collaborative interventions or responsible for the web site/automatic systems maintenance. It includes both direct and indirect costs (e.g. salary of the technicians who work at the call centre, phone fees...).

cCO.2.3: Cost of Spare Parts Sold (COSPS) (total)

The cost associated with buying spare parts or making them and selling them out of the warranty period. This cost includes direct costs (labor, materials) and indirect costs (overhead).

$$\sum \text{cost of spare part} * \text{ spare part out of warranty} \\ + \sum \text{cost of spare part} \\ * \text{spare part for maintenance intervention under warranty}$$

cCO.2.4: Warranty Cost (total)

Warranty costs include Cost of Assist and Cost of Spare Parts Sold covered by warranty agreement and Cost for mistaken interventions

$$\sum \text{cost of spare part} * \text{ spare part under warranty used for turn} - \text{key assist} \\ + \sum_{i=1}^{m} \text{cost of turn} - \text{key assist under warranty}_{\text{i}}$$

where i = 1...m is the number of turn-key interventions made under warranty period

cCO.2.5: Cost of Maintenance Interventions (total)

The cost associated with performing maintenance interventions (through the service form)

$$\sum \text{cost of maintenance interventions}$$

cCO.2.6: Cost of Spare Parts Inventory

The cost associated with the inventory of spare parts.

$$\sum \text{cost of spare part inventory} * \text{ spare part inventory}$$

cCO.2.7: Cost of Spare Parts Backlog

The cost associated with the backlog of spare parts.

$$\sum \text{cost of spare part backlog} * \text{ spare part backlog}$$

cCO.2.8: Cost of Assistance Personnel

The cost associated to the personnel working in assistance. (This is the cost spent for each technician when not involved in any kind of turn-key interventions and maintenance interventions).

$$\sum \text{timely cost of technicians} * \text{ number of technicians} \\ * \text{inactive time of technicians}$$

LEVEL 3

cCO.3.1: Average call center cost

Average of direct and indirect costs to manage the call center (personnel, phone fees, etc.) related to the number of turn-key calls received.

Total call center costs/# calls of turn-key support received

cCO.3.2: Assist outsourcing cost

Costs related to outsource assistance to authorised technical assistance centres.

cCO.3.3: Average cost to obtain spare parts

cCO.3.4: Average repair intervention cost (unit)

$$(\sum_{i=1}^{n} \text{cost of turn} - \text{key assist out of warranty}_i \\ + \sum_{i=1}^{m} \text{cost of turn} - \text{key assist under warranty}_i\ )/(n+m)$$

cCO.3.5: Average costs for disposal of material

cCO.3.6: Warranty Cost as % of Revenue (total)

It measures the total warranty expenses that are reflected in the company financial statements

(Warranty Cost / Assist Operating Revenue)*100 = (cCO.2.4/cGR.3.1)*100

cCO.3.7: Warranty Cost per Unit Shipped

Average warranty cost per unit shipped

(Warranty Cost/# of units shipped)*100

cCO.3.8: Cost of spare parts sold bought from the supplier (total)

The cost associated with buying spare parts. This cost includes direct material costs and indirect costs (overhead).

$$\sum_{i=1}^{n}(\text{ Direct material costs } + \text{ indirect costs related to buying parts})_{\mathrm{i}} * \text{ spare part}_{\mathrm{i}}$$

cCO.3.9: Cost of spare parts sold internally made (total)

The cost associated with making spare parts. This cost includes direct material costs, direct labor costs and indirect costs (overhead).

$$\sum_{i=1}^{n}(\text{Direct material costs} + \text{Direct labor cost} + \text{indirect costs related to making parts })_{\mathrm{i}} * \text{ spare part}_{\mathrm{i}}$$

cCO.3.10: Cost of spare parts sold during warranty bought from the supplier (total)

The cost associated with buying spare parts and selling to customers during warranty. This cost includes direct material costs and indirect costs (overhead).

$$\sum_{i=1}^{m}(\text{ Direct material costs } + \text{ indirect costs related to buying parts})_{\mathrm{i}} * \text{ spare part sold under warranty}_{\mathrm{i}}$$

cCO.3.11: Cost of spare parts sold during warranty internally made (total)

The cost associated with making spare parts and selling to customers during warranty. This cost includes direct material costs, direct labor costs and indirect costs (overhead).

$$\sum_{i=1}^{m}(\text{Direct material costs} + \text{Direct labor cost} + \text{indirect costs related to making parts })_{\mathrm{i}} * \text{ spare part sold under warranty}_{\mathrm{i}}$$

- cC.1.1: Total Assist Cost
  - cCO.2.1: Cost of Turn-Key Assist
    - cCO.3.1: Average call center cost
    - cCO.3.2: Assist outsourcing cost
    - cCO.3.3: Average cost to obtain spare parts
    - cCO.3.4: Average repair intervention cost
    - cCO.3.5: Average costs for disposal of material
  - cCO.2.2: Cost of Passive and/or Collaborative
  - cCO.2.3: Cost of Spare Parts Sold
    - cCO.3.8: Cost of spare parts sold bought from the supplier
    - cCO.3.9: Cost of spare parts sold internally made
  - cCO.2.4: Warranty Cost
    - cCO.3.6: Warranty Cost as % of Revenue
    - cCO.3.7: Warranty Cost per Unit Shipped
    - cCO.3.10: Cost of spare parts sold during warranty bought from the supplier
    - cCO.3.11: Cost of spare parts sold during warranty internally made
  - cCO.2.5: Cost of Maintenance Interventions
  - cCO.2.6: Cost of Spare Parts Inventory
  - cCO.2.7: Cost of Spare Parts Backlog
  - cCO.2.8: Cost of Assistance Personnel

ASSET MANAGEMENT

LEVEL 1

cAM.1.1: Return on Assist Assets

Measures the return an organisation receives on its invested capital in assistance fixed assets

$$\frac{\mathrm{cGR.}\,3.2}{\mathrm{cAM.}\,2.1} = \frac{\text{Assist Operating Income}}{\text{Assist Assets Value}}$$
$$= \frac{(\text{Assist Operating Revenue} - \text{Total Assist Cost})}{\text{Assist Assets Value}}$$

cAM.1.2: Assist Cash-to-Cash Cycle Time

The time from the point where a company pays for the resources consumed in the performance of a service to the time that the company received payment from the customer for those services.

$$\mathrm{cAM.}\,2.2 + \mathrm{cAM.}\,2.3 - \mathrm{cAM.}\,2.4 =$$
$$= \text{Spare Parts Inventory Days of Supply} + \text{Days of Sales Outstanding}$$
$$- \text{Days of Payables Outstanding}$$

cAM.1.3: Return on Assist Working Capital

Return on working capital is a measurement which assesses the magnitude of investment relative to a company's working capital position versus the revenue generated from assistance support and spare parts selling. Components include sales outstanding, payable outstanding, spare part inventory, assist operating revenue, cost of spare parts sold, cost of assist and warranty cost.

$$\frac{\mathrm{cGR.}\,3.2}{(\mathrm{cAM.}\,2.5 + \mathrm{cAM.}\,2.6 - \mathrm{cAM.}\,2.7)} =$$
$$= \frac{(\text{Assist Operating Revenue} - \text{Total Assist Cost})}{(\text{Spare Parts Inventory} + \text{Sales Outstanding} - \text{Payables Outstanding})}$$

LEVEL 2

cAM.2.1: Assist Assets Value

The current value of the customer chain assets used in the Assist process.

$$\text{Cash} + \text{cAM.2.5} + \text{cAM.2.6} + \text{Fixed Assets} =$$
$$= \text{Cash} + \text{Spare Parts Inventory} + \text{Sales Outstanding} + \text{Fixed Assets}$$

cAM.2.2: Spare Parts Inventory Days of Supply (IDS)

Number of days that cash is tied up as inventory. It measures how long a stock level of a certain material will be sufficient to match upcoming requirements. It is also the amount of spare parts inventory (stock) expressed in days of sales.

$$\frac{\text{cAM.2.5}}{\frac{\text{cCO.2.3} + \sum \text{cost of spare part} * \text{spare part under warranty}}{\text{\# days over the measurement period}}} =$$

$$= \frac{\text{Spare Parts Inventory}}{\frac{\sum \text{cost of spare part} * \text{spare part} + \sum \text{cost of spare part} * \text{spare part under warranty}}{\text{\# days over the measurement period}}}$$

cAM.2.3: Days of Sales Outstanding (DSO)

Average number of days the company takes to collect payments on goods sold. It is the amount of sales outstanding expressed in days.

Example: If \$5000 worth of sales were made per day and \$50,000 worth of sales were outstanding, this would represent 10 days' (\$50,000/\$5000) of sales outstanding.

$$\frac{\text{cAM.2.6}}{\frac{\text{cGR.3.1}}{\text{\# days over the measurement period}}} = \frac{\text{Sales Outstanding}}{\frac{\text{Assist Operating Revenue}}{\text{\# days over the measurement period}}}$$

cAM.2.4: Days of Payables Outstanding (DPO)

Average number of days the company takes to pay its bills, considering the time from purchasing materials, labour and/or conversion resources until cash payments. It is the amount of payables outstanding expressed in days.

$$\text{cAM. 2.7}$$

$$\frac{\text{Cost of material purchased over the measurement period}}{\text{\# days over the measurement period}} = \frac{\text{Payables Outstanding}}{\frac{\text{Cost of material purchased over the measurement period}}{\text{\# days over the measurement period}}}$$

cAM.2.5: Spare Parts Inventory

The amount of spare parts inventory (stock) expressed in value (€, $, nok…).

It includes raw materials, work in process inventories and finished spare parts saleable to the customer or available for "Turn-key" Assist.

$$\text{Spare Parts Inventory} = \sum \text{cost of spare part} * \text{ Spare Parts held in warehouse}$$

cAM.2.6: Sales Outstanding (Accounts Receivable)

The amount which is owed to the company by customers for products and services provided on credit. It represents sales made but not paid-for by the customers (trade debtors).

Sales Outstanding, also known as Accounts Receivable (A/R), is presented in the balance sheet and it is expressed in value (€, $, nok...).

$$\text{Sales Oustanding} = \sum \text{Sales Outstanding from the single customer}$$

cAM.2.7: Payables Outstanding (Accounts Payable)

The amount which the company owes to suppliers (trade creditors) for products and services purchased on credit. The accounts normally include the purchased materials, labour and/or conversion resources.

Payables Outstanding, also known as Accounts Payable (A/P), is presented in the balance sheet and it is expressed in value (€, $, nok...).

$$\text{Payables Outstanding} = \sum \text{Payables Outstanding to the single supplier}$$

LEVEL 3

cAM.3.1: Spare Parts Inventory Turns in the Warehouse

It is an equation that measures the number of times inventory is sold or used over a period such as a year.

$$\frac{1}{\text{cAM. 2.2}} = \frac{1}{\text{Spare Parts Inventory Days of Supply}}$$

cAM.3.2: Spare Parts Inventory Turns on the Van

It is an equation that measures the number of times inventory is sold or used over a period such as a year.

$$\frac{\dfrac{\text{Cost of spare parts used in Turn\_Key Assist over the measurement period}}{\text{\# days over the measurement period}}}{\sum \text{Spare Parts Inventory on a single Van}}$$

- cAM.1.1: Return on Assist Assets
  - cAM.2.1: Assist Assets Value
- cAM.1.2: Assist Cash-to-Cash Cycle Time
  - cAM.2.2: Spare parts inventory days of supply
    - cAM.3.1: Spare parts Inventory turns in the warehouse
    - cAM.3.2: Spare parts Inventory turns on the van
  - cAM.2.3: Days of sales outstanding
  - cAM.2.4: Days of payables outstanding
- cAM.1.3: Return on Assist Working Capital
  - cAM.2.5: Spare Parts Inventory
  - cAM.2.6: Sales Outstanding (Accounts Receivable)
  - cAM.2.7: Payables Outstanding (Accounts Payable)

GROWTH

LEVEL 1

cGR.1.1: Assist operating margin growth

It measures potentiality of Assist to increase its consistency and sustainability over time

$$\frac{\text{Assist Operating margin at time t} - \text{Assist Operating margin at time t} - 1}{\text{Assist Operating margin at time t} - 1} \times 100$$

cGR.1.2: Customer loyalty

It measures customer loyalty behaviours, including relationship continuance, increased scale of relationship, and recommendation (word of mouth advertising)

cGR.1.3: Growth of maintenance contracts

It measures the increase of maintenance contracts over time

$$\frac{\left(\frac{\text{Number of maintenance contracts at time t}}{\text{working machine at time t}} - \frac{\text{Number of maintenance contracts at time t} - 1}{\text{working machine at time t} - 1}\right)}{\frac{\text{Number of maintenance contracts at time t} - 1}{\text{working machine at time t} - 1}} \times 100$$

cGR.1.4: Call variance (=collaborative or turn-key calls)

It measures the variance of calls received over time.

$$\frac{\left(\frac{\text{Total calls at time t}}{\text{working machine at time t}} - \frac{\text{Total calls at time t} - 1}{\text{working machine at time t} - 1}\right)}{\frac{\text{Total calls at time t} - 1}{\text{working machine at time t} - 1}} \times 100$$

LEVEL 2

cGR.2.1: Assist Operating margin

(Assist Operating Income/Assist Operating Revenue)*100 = cGR.3.2/cGR.3.1 *100

cGR.2.2: Customer retention

Ability to keep customers without losing them to competitors

# of current customers (who were also customers a year ago) / # of all customers from a year ago

cGR.2.3: Customer longevity

Longevity means both persistency (how long a customer holds a product) and length of time a customer has done business with the company.

# of years of continuous purchase from the customer

<u>LEVEL 3</u>

cGR.3.1: Assist Operating Revenue

Operating revenues generated from assistance activities and spare parts selling out of the warranty period

$$\begin{aligned}\sum \text{price of spare part} * \ \text{spare part out of warranty} \\ + \text{Spare parts for maintenance interventions under warranty} \\ + \left(\sum_{i=1}^{n} \text{cost of turn} - \text{key assit out of warranty}_{\mathrm{i}}\right) * \%\ \text{of markup} \\ + \sum \text{price of maintenance interventions} * \text{number of contracts}\end{aligned}$$

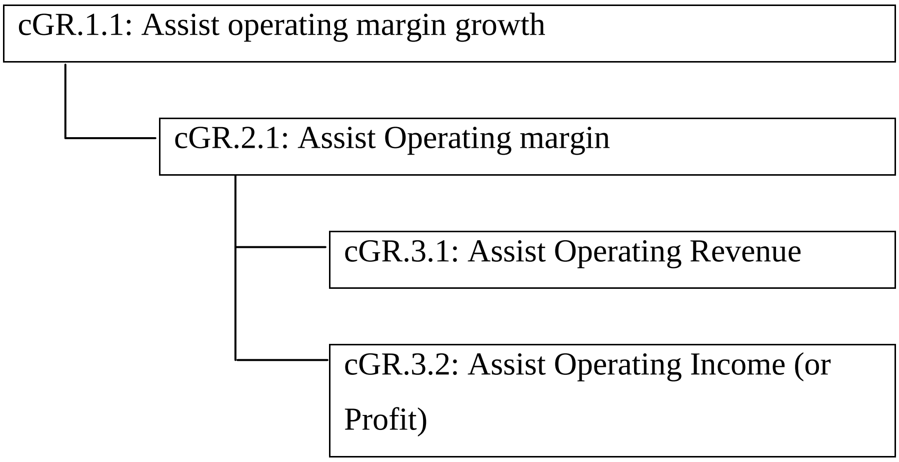
where i=1...n is the number of turn-key interventions made out of the warranty period

Note: spare parts or services sold under warranty don't have to be included

cGR.3.2: Assist Operating Income (or Profit)

Assist Operating Revenue - Total Assist Cost = cGR.3.1 - cCO.1.1

Note: This is the Gross profit - it doesn’t include administrative costs, amortization, taxes



cGR.1.2: Customer loyalty

- cGR.2.2: Customer retention
- cGR.2.3: Customer longevity

cGR.1.3: Growth of maintenance contracts

cGR.1.4: Call variance (=collaborative or turn-key calls)

Process-diagnostics structure

Passive Assist

A1.01	RL	cRL.3.7: N° of repeat compliant calls from the same customer cRL.3.3:Time the server is down	RS	cRS.2.1: Call center waiting time
A1.02				cRS.2.2: Average authorization request time
A1.03		cRL.3.5: Wrong routings rate		cRS.2.3: Average routing time cRS.2.5: Average time for diagnosis
A1.04				cRS.2.6: Average time to propose a solution
A1.05		cRL.3.4: Assist resolution rate		
A1.06		cRL.3.8: Assist payment documentation accuracy cRL.3.9: Intervention report accuracy		cRS.2.11: Average time to close requests

A1.01	AG		CO		AM	
A1.02		cAG.2.6: N°of contract-conditions modified				
A1.03						
A1.04						
A1.05						
A1.06						

Collaborative Assist

A2.01	RL	cRL.3.7: N° of repeat compliant calls from the same customer cRL.3.3: Time the server is down	RS	cRS.2.1: Call center waiting time
A2.02				cRS.2.2: Average authorization request time
A2.03		cRL.3.5: Wrong routings rate		cRS.2.3: Average routing time
A2.04				cRS.2.5: Average time for diagnosis
A2.05				cRS.2.6: Average time to propose a solution
A2.06				cRS.2.7: Waiting time for delivery spare parts
A2.07		cRL.3.4: Assist resolution rate cRL.3.1: MTBeforeF cRL.3.2: MTBetweenF cRL.2.2: First Call Fixed Rate		
A2.08		cRL.3.8: Asissit payment documentation accuracy cRL.3.9: Intervention report accuracy		cRS.2.11: Average time to close requests cRS.2.15: Average number of collaborative interventions during out of peak season cRS.3.2 Average number of collaborative assist calls for technician during out of peak season

A2.01	AG		CO		AM	
A2.02		cAG.2.6: N° of contract-conditions modified				
A2.03						
A2.04						
A2.05						
A2.06						
A2.07		cAG.2.5: Time required to perform a new and customized request				
A2.08		cAG.2.3: Average number of collaborative interventions during peak season cAG.3.1: Number of average collaborative interventions for technician during peak season		cCO.3.2: Assist outsourcing cost		cAM.2.2: Spare Parts Inventory Days of Supply (IDS) cAM.3.1: Spare part Inventory turns in the warehouse

Turn-Key Assist

A3.01		cRL.3.7: N°of repeated compliant calls from the same customer cRL.3.3: Time the server is down		cRS.2.1: Call center waiting time
A3.02				cRS.2.2: Average authorization request time
A3.03		cRL.3.5: Wrong routings rate		cRS.2.3: Average routing time
A3.04				cRS.2.4: Average time for scheduling technical assistance
A3.05				cRS.2.5: Average time for diagnosis
A3.06				cRS.2.6: Average time to propose a solution
A3.07	RL	cRL3.10: % interventions with wrong or missing spare parts cRL.3.11: Spare parts delivery quantity accuracy cRL.3.12: Spare parts delivery damage free cRL.3.13: Spare parts delivery location accuracy	RS	cRS.2.7: Waiting time for delivery spare parts
A3.08		cRL.3.6: Perfect technician intervention rate cRL.3.4: Assist resolution rate cRL.3.1: MTBeforeF cRL.3.2: MTBetweenF cRL.2.2: First Call Fixed Rate		cRS.2.8: MTTR (Mean Time To Repair) a machine cRS.2.9: MTTR (Mean Time To Repair) each machine per technician
A3.09				cRS.2.10: Average time for material disposal
A3.10		cRL.3.8: Assist payment documentation accuracy cRL.3.9: Intervention report accuracy		cRS.2.11: Average time to close requests cRS.2.14: Average number of turn-key interventions during out of peak season cRS.3.1: number of average turn-key interventions for technician during out of peak season

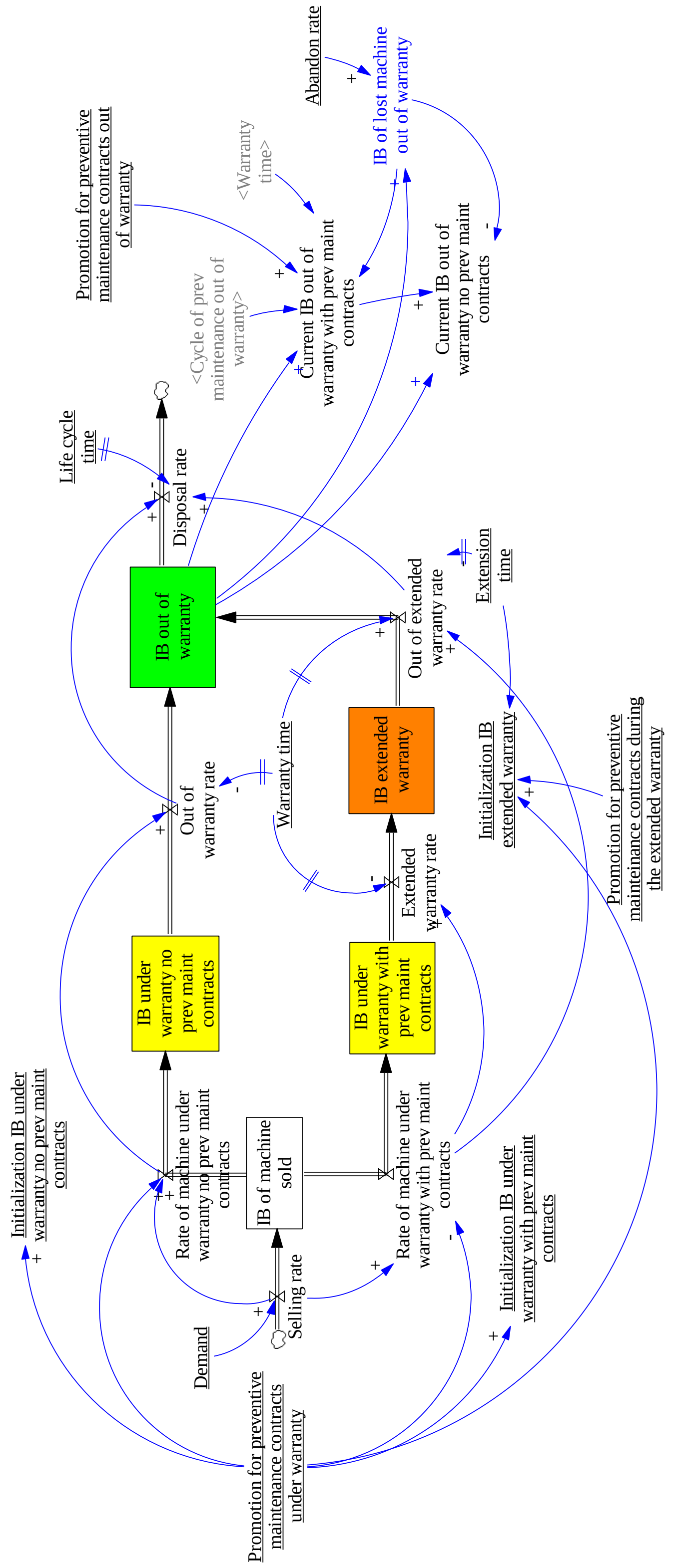
A3.01				cCO.3.1: Average call center cost		
A3.02		cAG.2.6: N°of contract-conditions modified				
A3.03						
A3.04		cAG.3.3: % of last minute interventions added in the scheduling				
A3.05						
A3.06						
A3.07	AG	cAG.2.1: Time to manage urgent and unplanned spare parts requests	CO	cCO.3.3: Average cost to obtain spare pars cCO.3.8: Cost of spare parts sold bought from the supplier cCO.3.9: Cost of spare parts sold internally made cCO.3.10: Cost of spare parts sold during warranty bought from the supplier cCO.3.11: Cost of spare parts sold during warranty internally made	AM	cAM.2.2: Spare Parts Inventory Days of Supply (IDS) cAM.3.1: Spare part Inventory turns in the warehouse cAM.3.2: Spare part Inventory turns on the van
A3.08		cAG.2.5: Time required to perform a new and customized request		cCO.3.4: Average repair intervention cost		
A3.09				cCO.3.5: Average cost for disposal of material		
A3.10		cAG.2.4: Average number of turn-key interventions during peak season cAG.3.2: Number of average turn-key interventions for technician during peak season		cCO.3.2: Assist outsourcing cost		

Annex III – The System Dynamics model

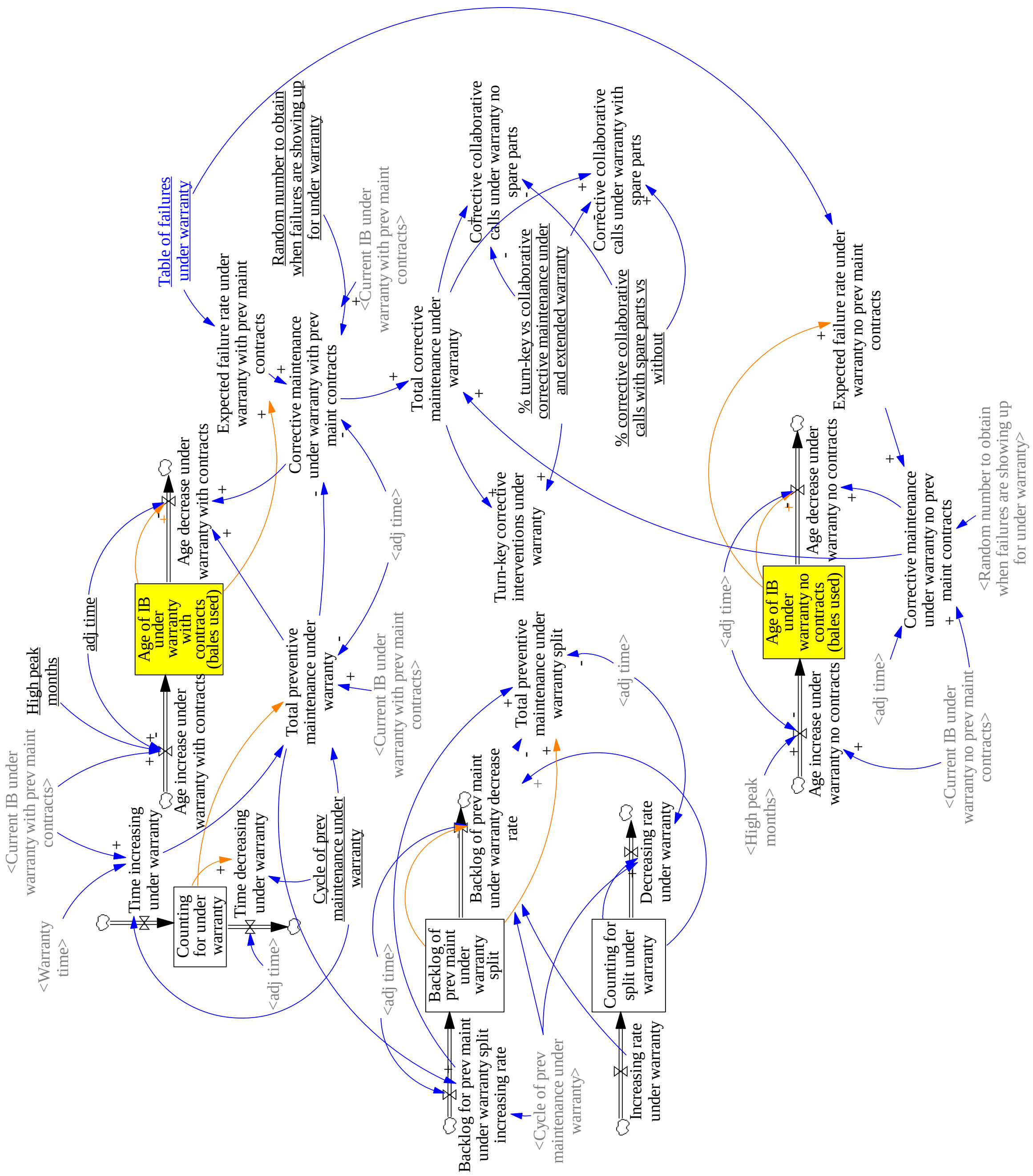
In this annex it is reported the System Dynamics model built to reproduce Orkel's AS business. In particular, it has been developed to assess how the introduction of preventive maintenance contracts can influence the overall Orkel's service performance. The SFDs built to reproduce Orkel's AS business are reported hereafter according to the following views:

1. Portfolio of sold machines which are under warranty, during the extended warranty and out of the warranty periods.
2. Number of requested maintenance interventions for:
   a) Preventive and corrective maintenance interventions under warranty;
   b) Preventive and corrective maintenance interventions during the extended warranty;
   c) Preventive and corrective maintenance interventions out of warranty.
3. Forecasting and spare parts inventory management for:
   a) Corrective maintenance interventions under and during the extended warranty;
   b) Corrective maintenance interventions out of warranty;
   c) Preventive maintenance interventions under and during the extended warranty;
   d) Preventive maintenance interventions out of warranty;
   e) Satellites' requests.
4. Number of requested technicians, hiring and laying off rates for:
   a) Corrective maintenance interventions - turn – key type;
   b) Corrective maintenance interventions – collaborative calls type;
   c) Preventive maintenance interventions.
5. Costs and revenues for:
   a) the installed based of machines under and during the extended warranty;
   b) the installed based of machines out of warranty;
   c) all the installed based of machines (these are common costs and revenues);
   d) calculating the total After-Sales service profit.
6. Working capital requirements and asset value.

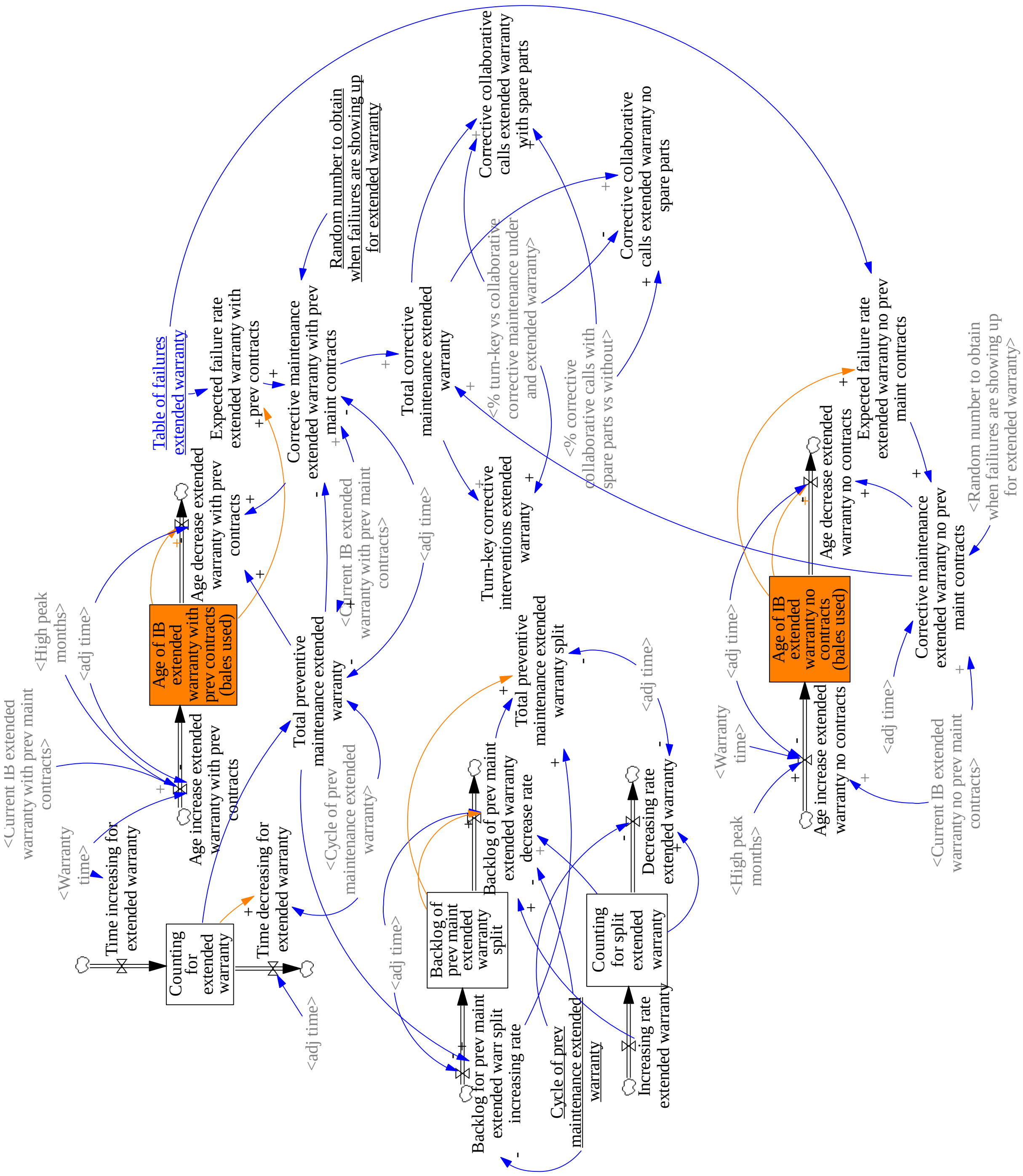
1. Portfolio of sold machines which are under warranty, during the extended warranty and out of warranty



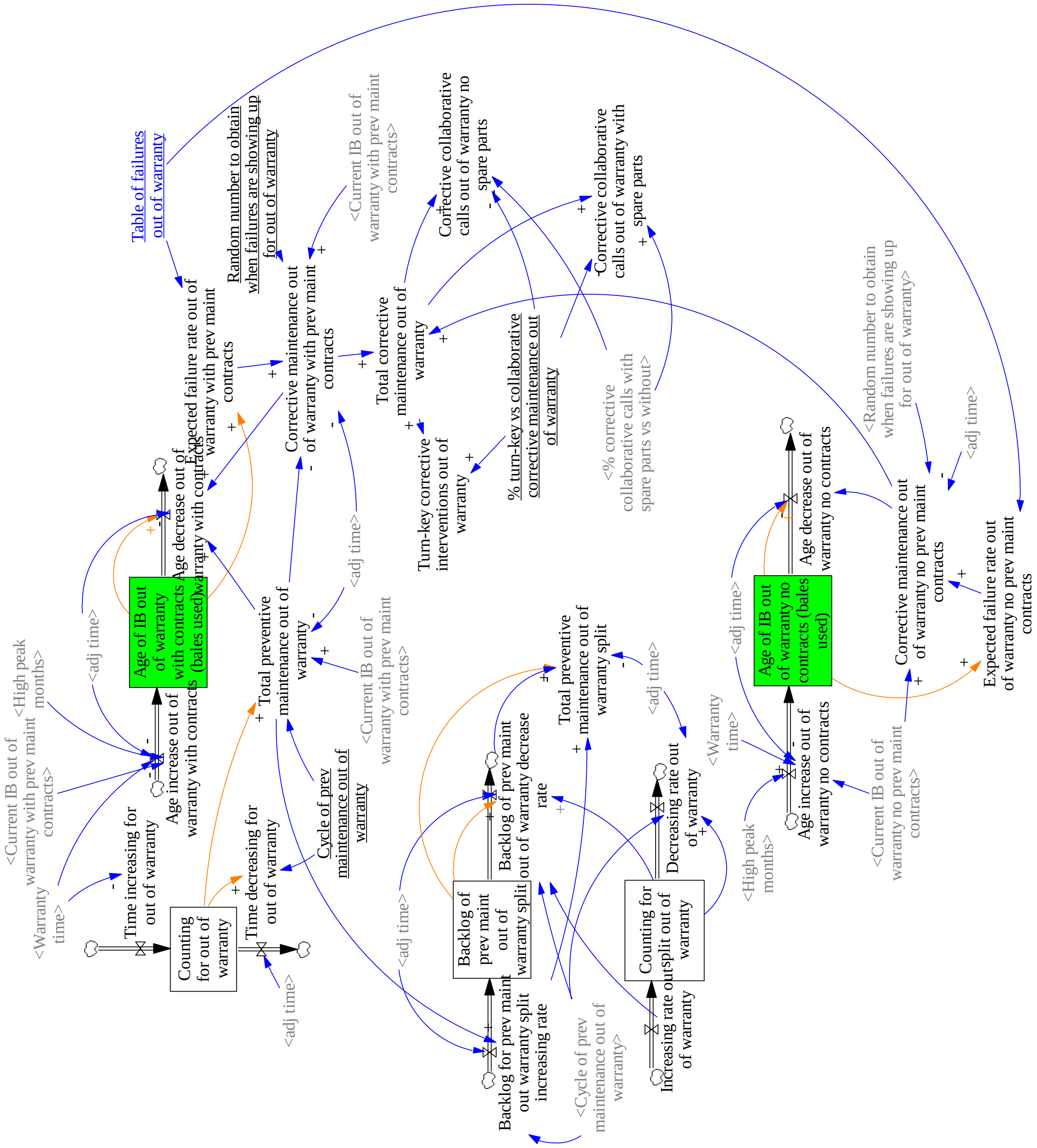
2a. Preventive and corrective maintenance interventions under warranty



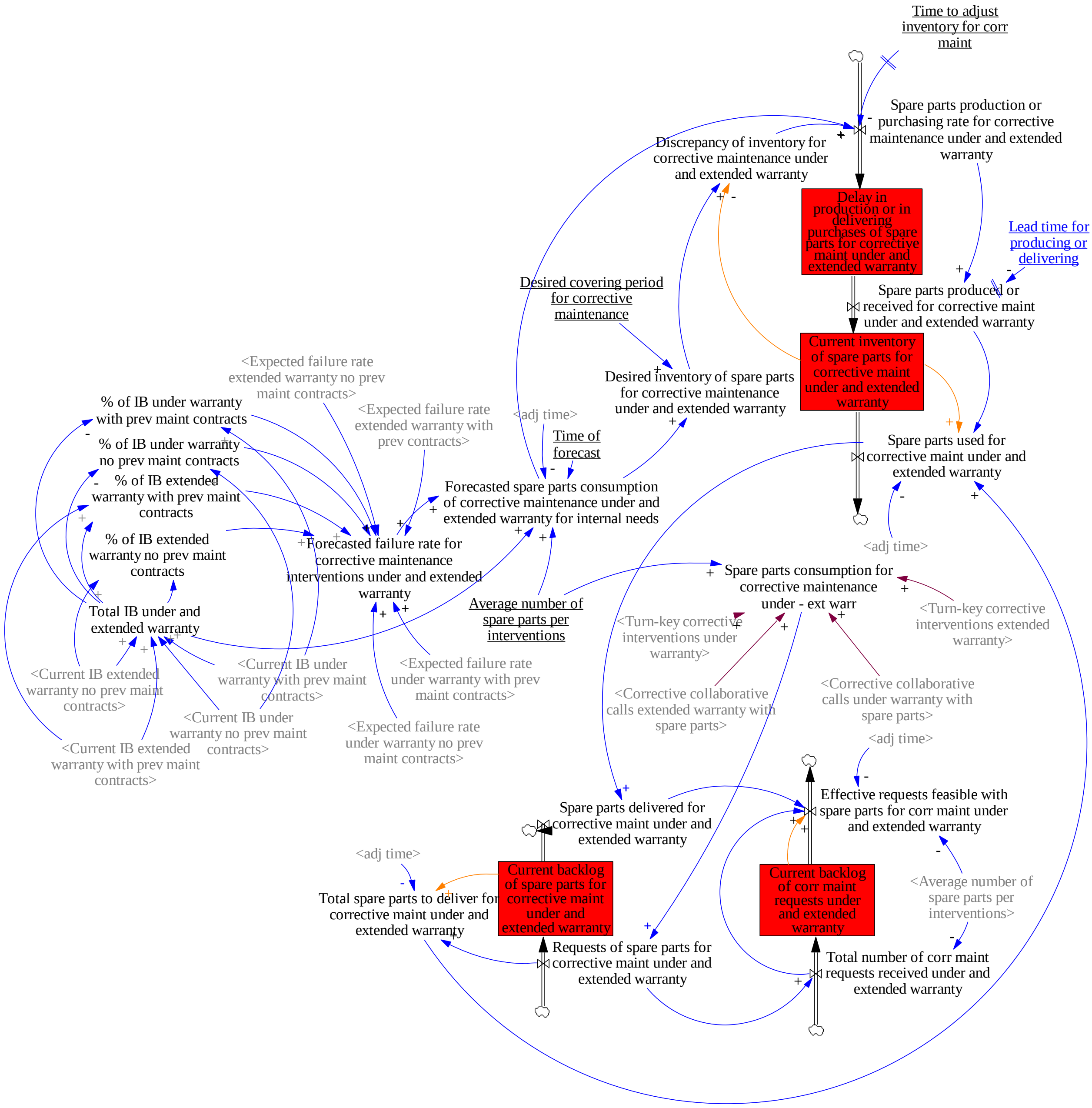
2b. Preventive and corrective maintenance interventions during the extended warranty



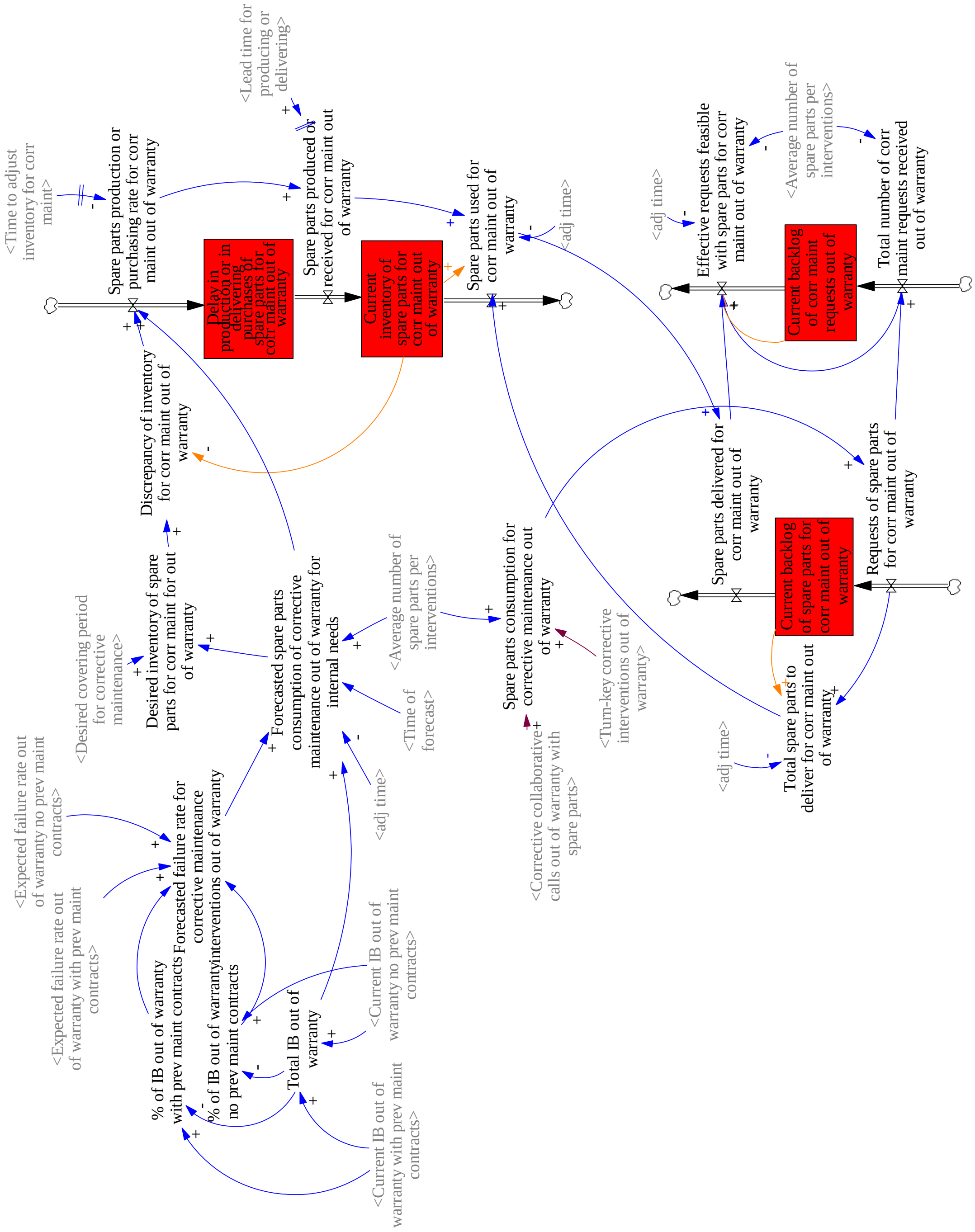
2c. Preventive and corrective maintenance interventions out of warranty



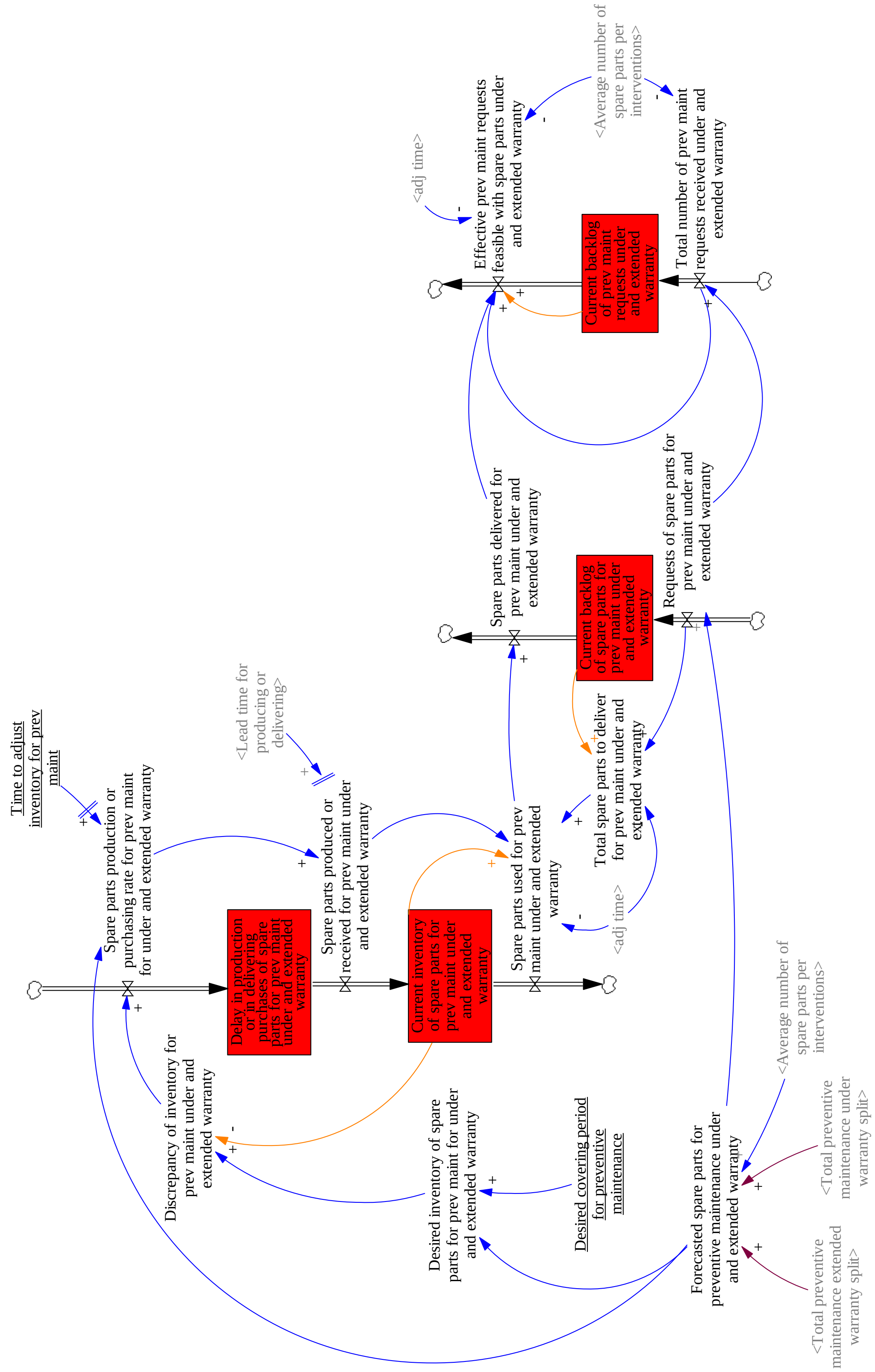
3a. Forecasting and spare parts inventory management for corrective maintenance interventions under and during the extended warranty



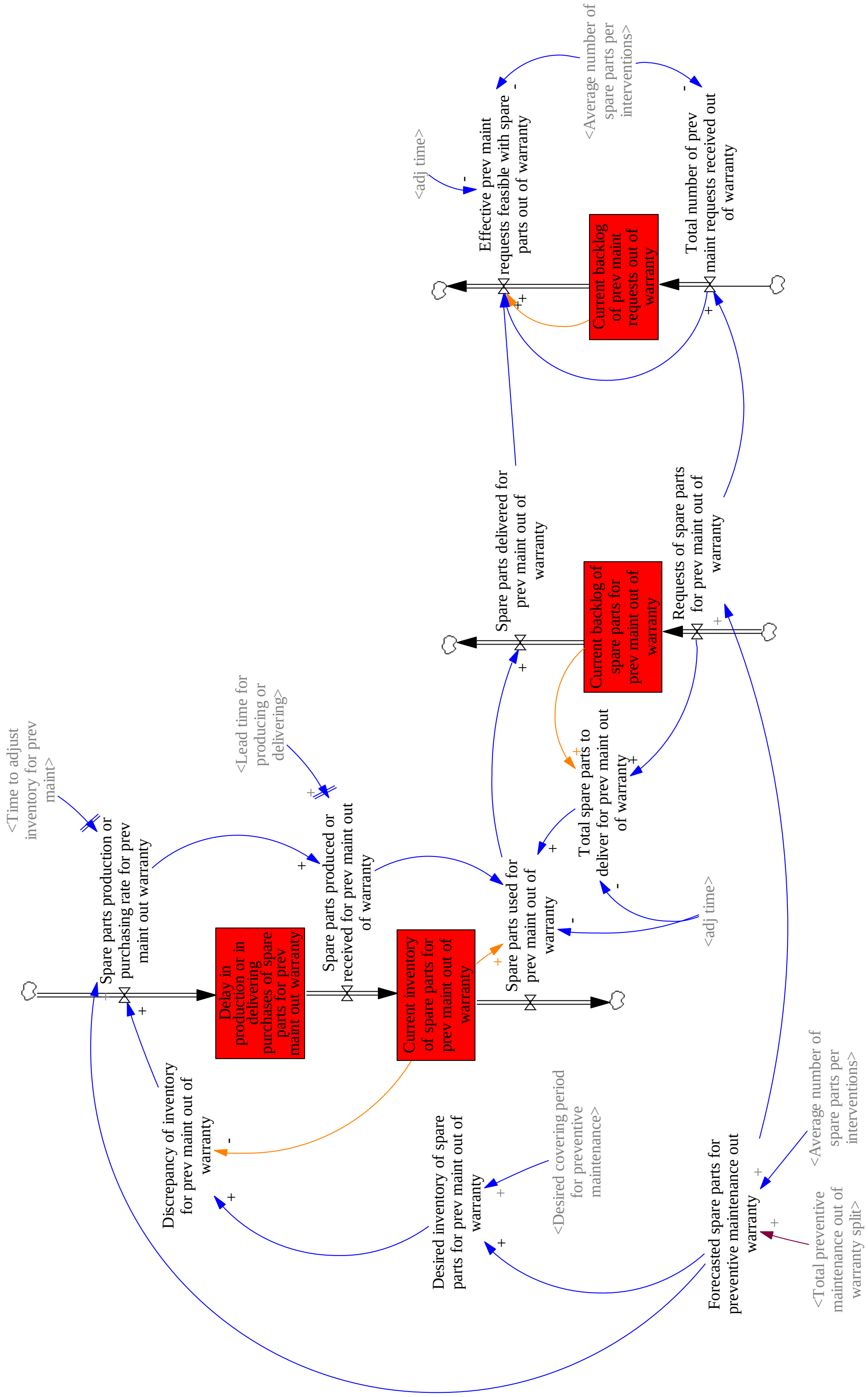
3b. Forecasting and spare parts inventory management for corrective maintenance interventions out of warranty



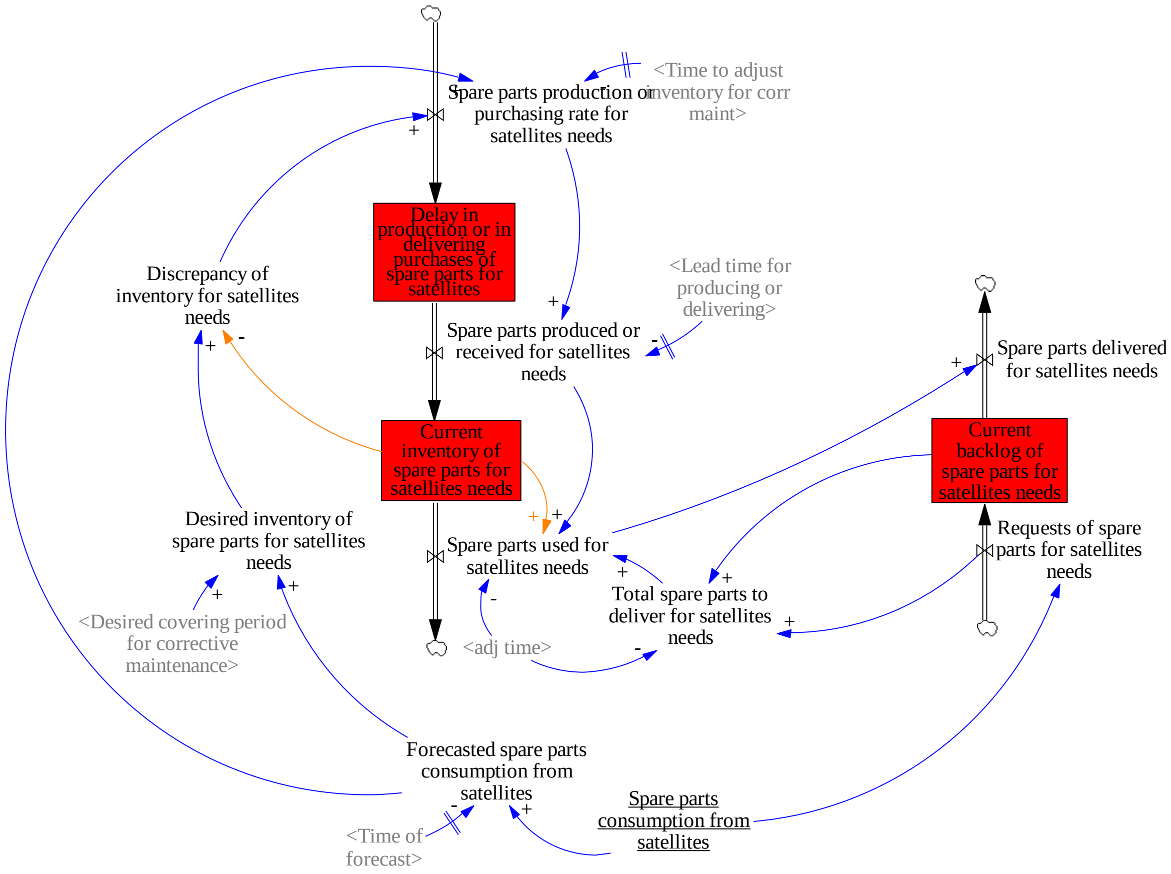
3c. Forecasting and spare parts inventory management for preventive maintenance interventions under and during the extended warranty



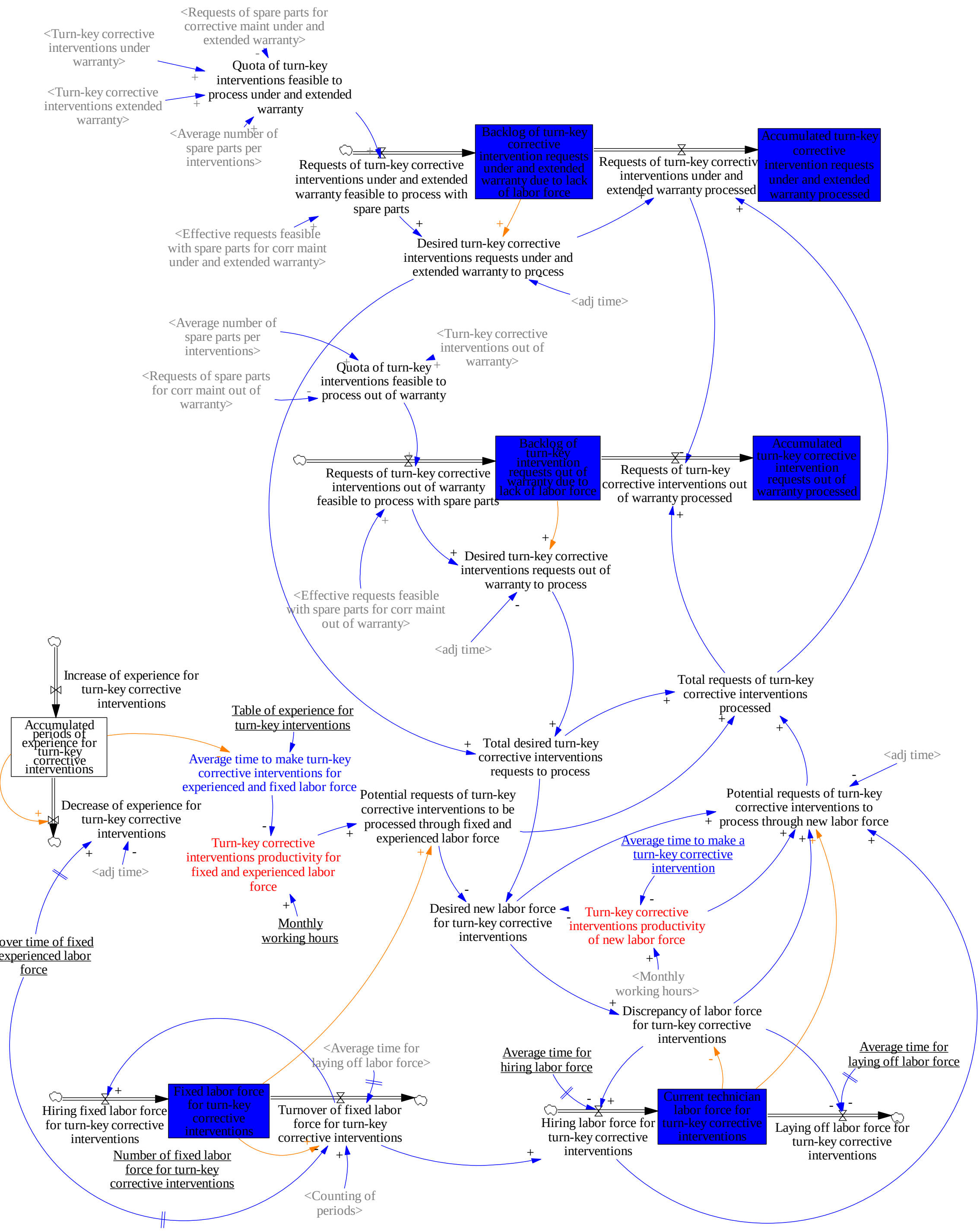
3d. Forecasting and spare parts inventory management for preventive maintenance interventions out of warranty



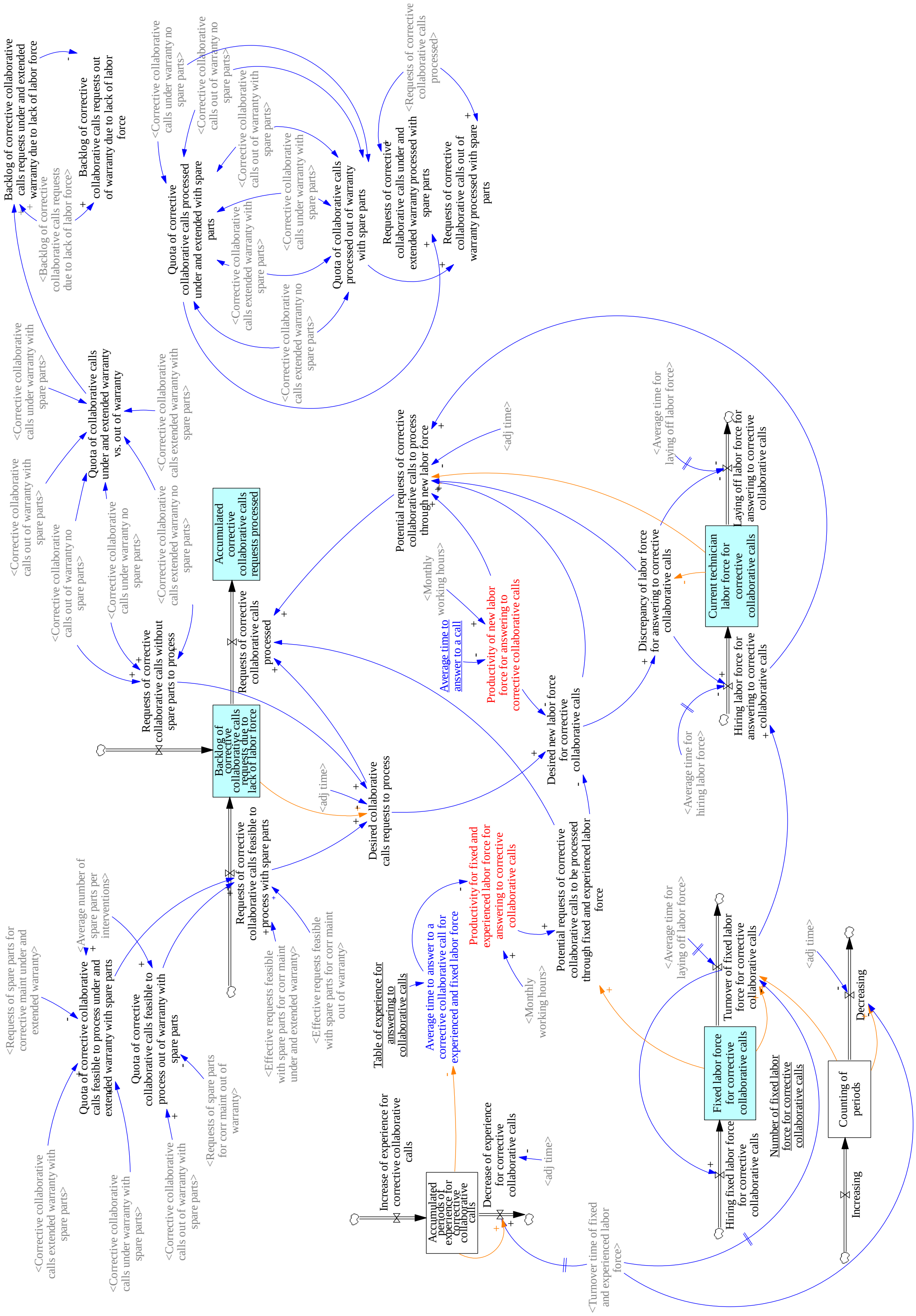
3e. Forecasting and spare parts inventory management for satellites' requests



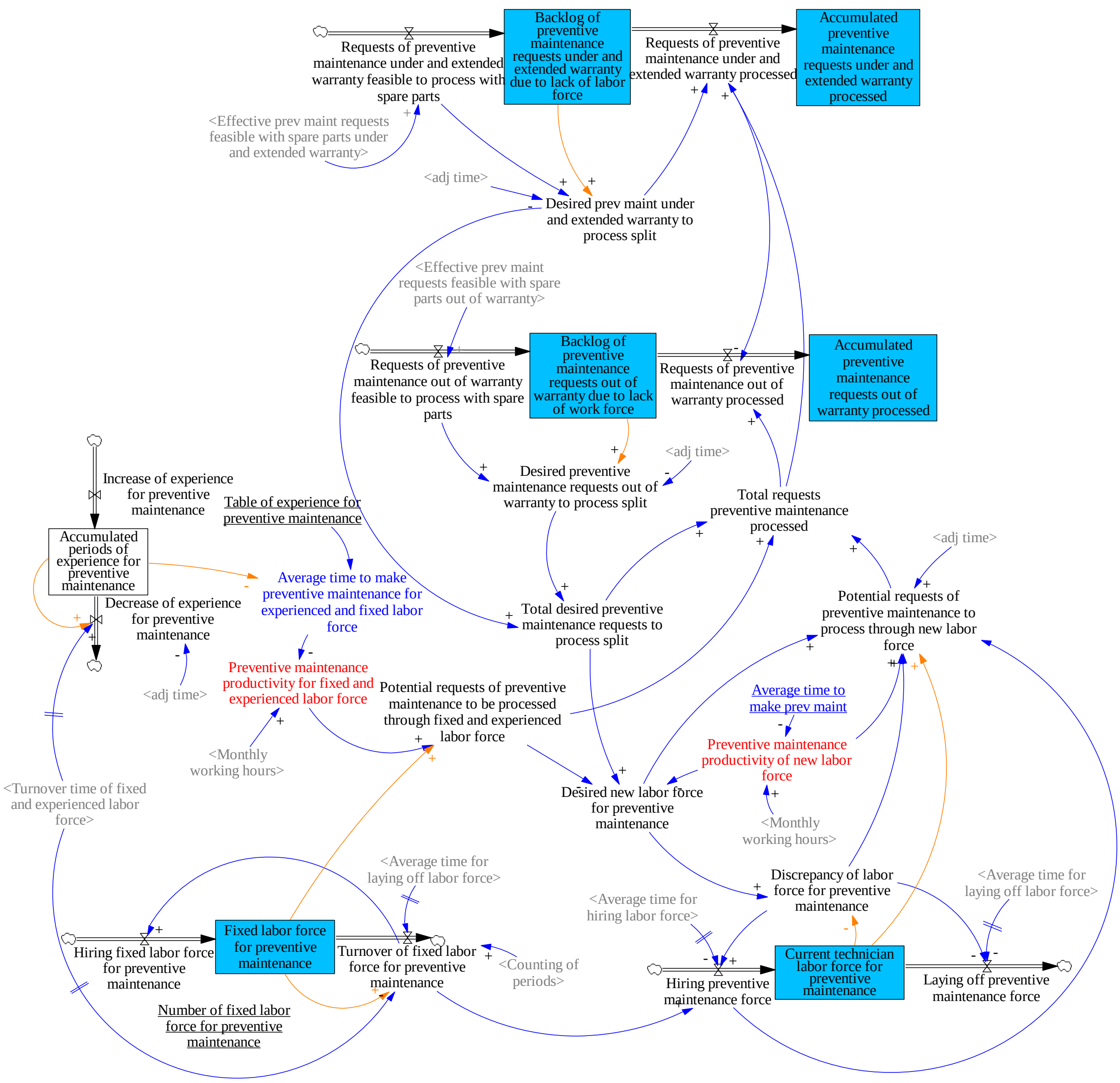
4a. Number of requested technicians, hiring and laying off rates for corrective maintenance interventions (Turn – Key type)



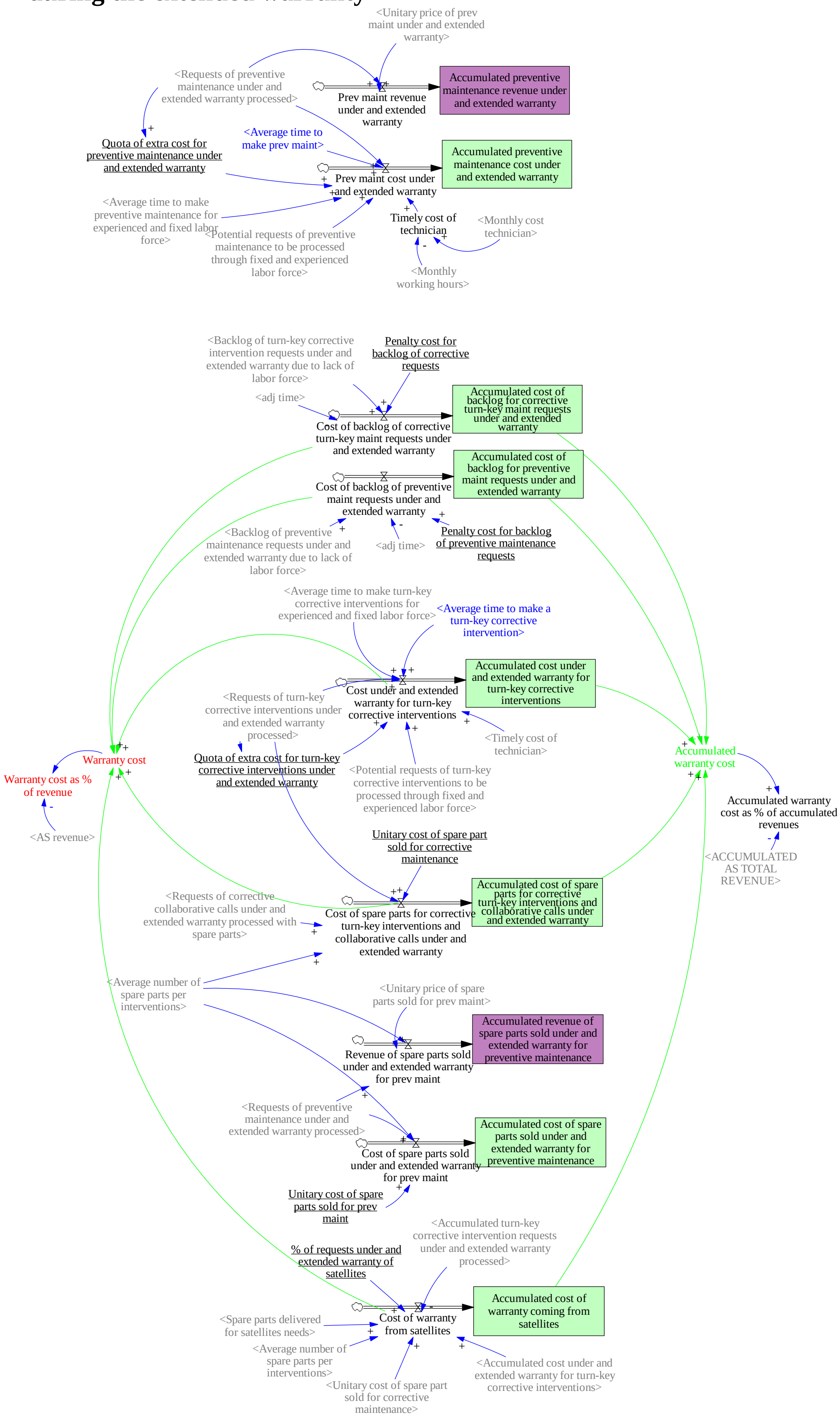
4b. Number of requested technicians, hiring and laying off rates for corrective maintenance interventions (Collaborative calls type)



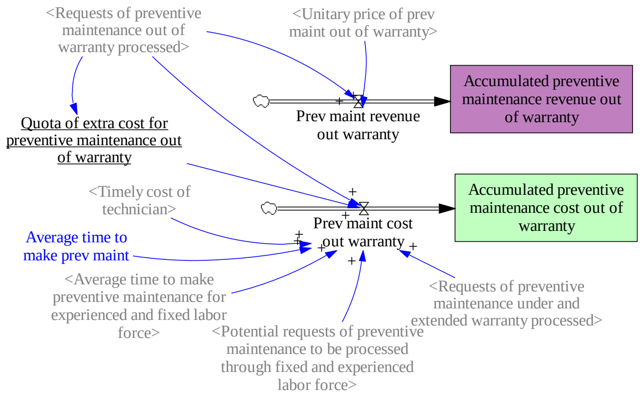
4c. Number of requested technicians, hiring and laying off rates for preventive maintenance interventions

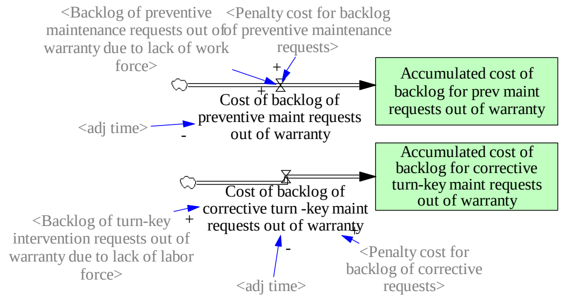


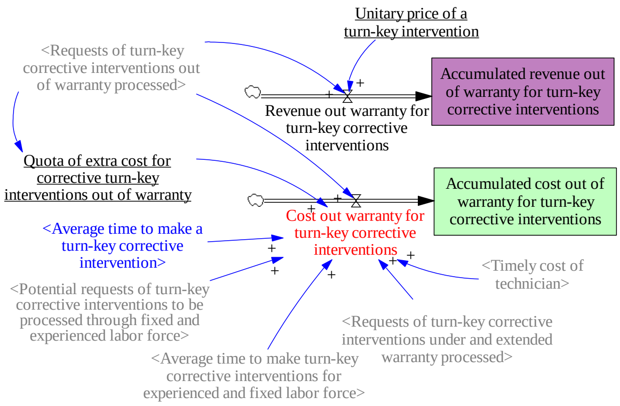
5a. Costs and revenues made on the installed based of machine under and during the extended warranty

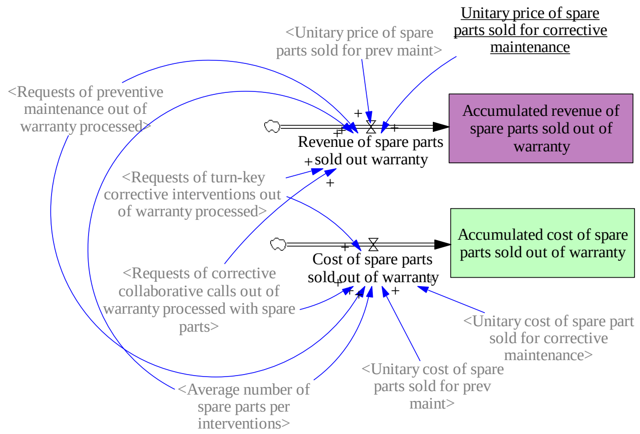


5b. Costs and revenues made on the installed based of machine out of warranty

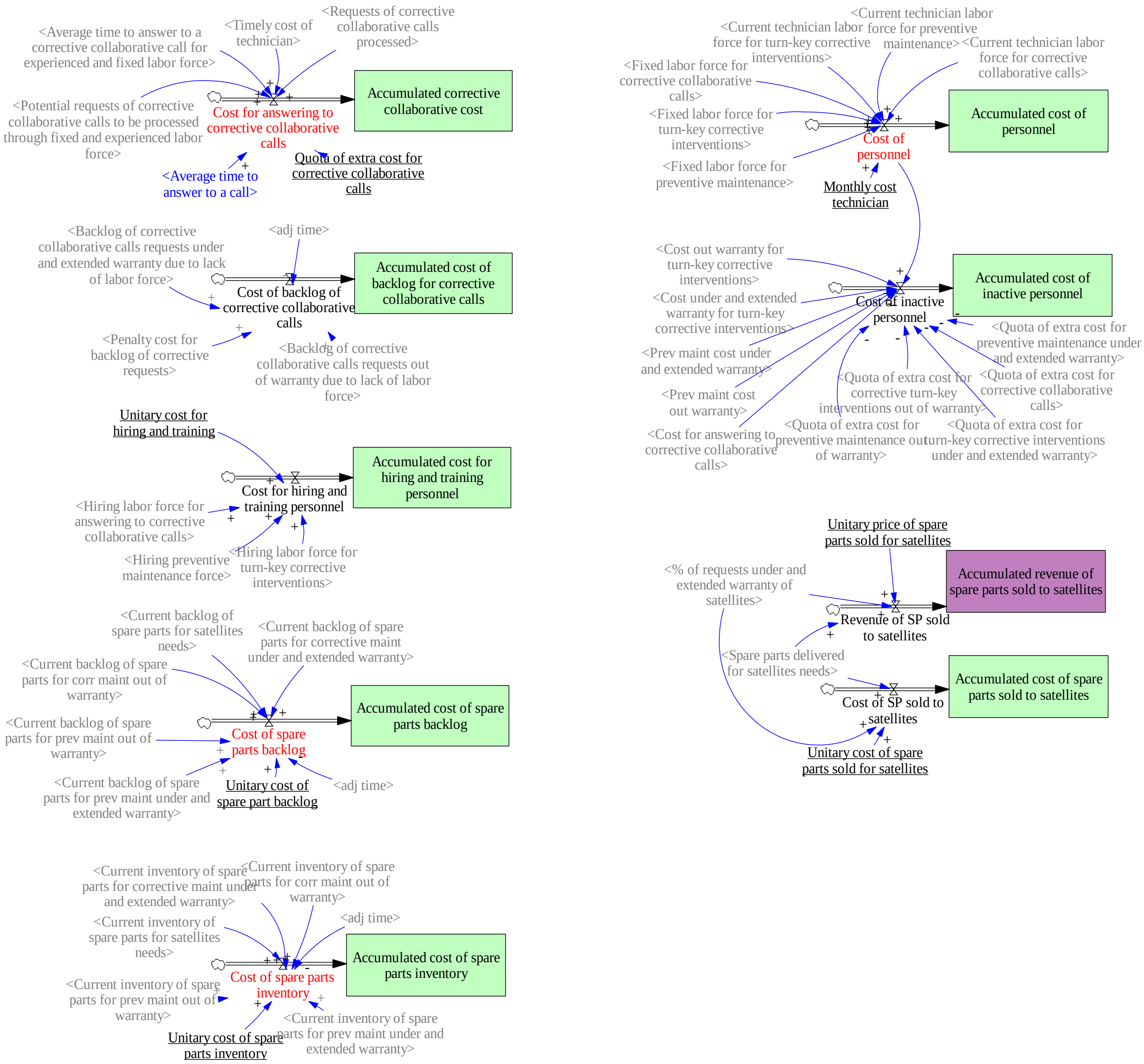




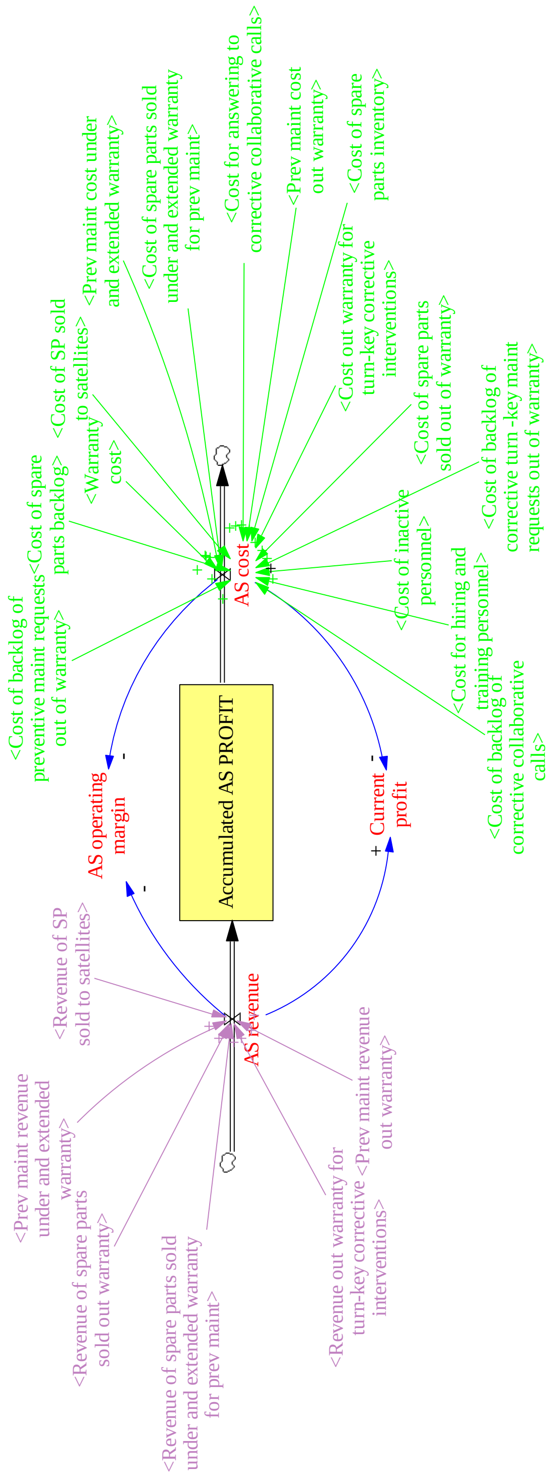




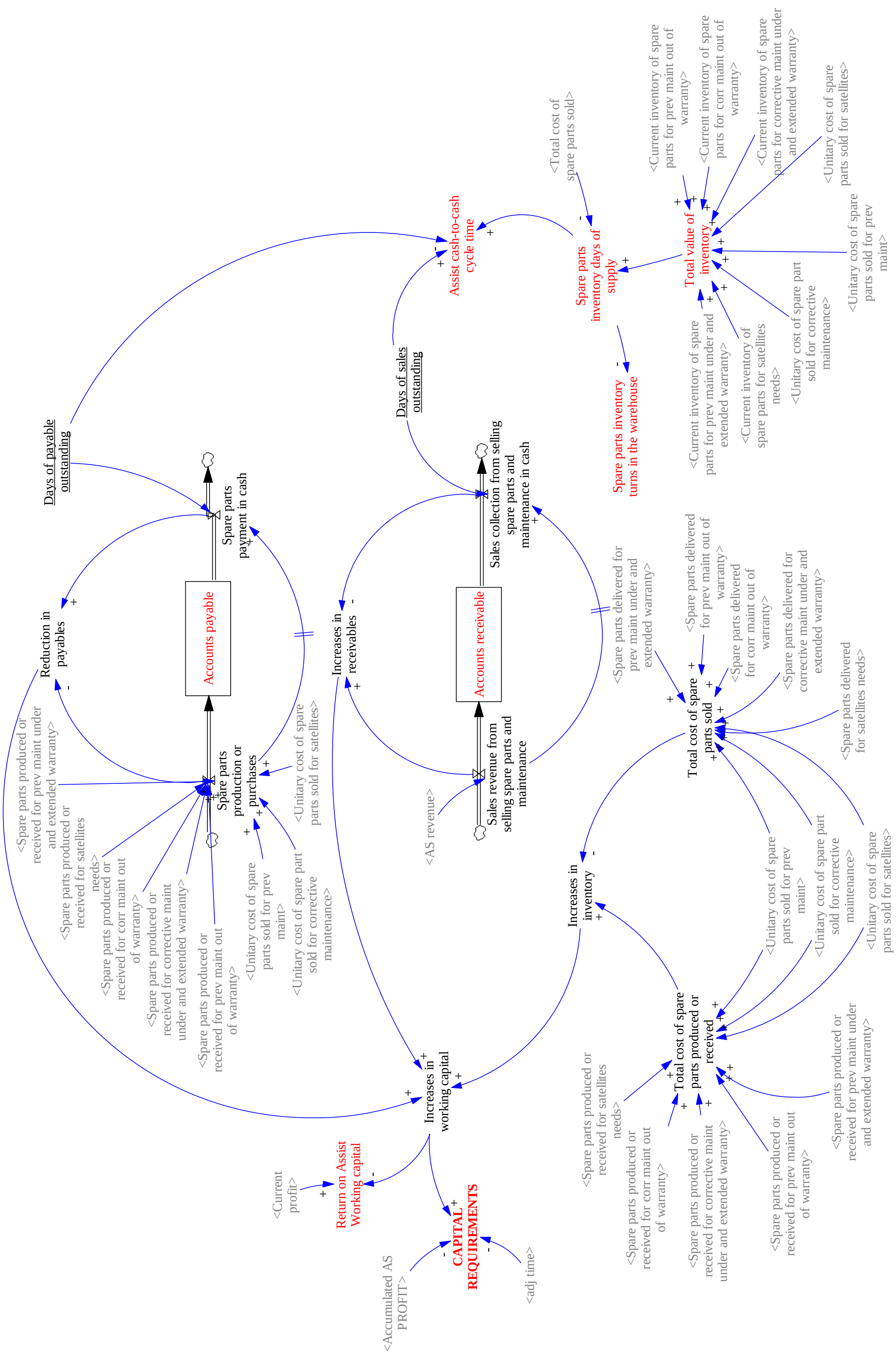
5c. Other costs and revenues made on all the installed based of machine



5d. Total After-Sales service profits



6. Working capital requirements and asset value



Annex IV – Published papers

The results of this PhD thesis have been presented in several international PhD workshops and scientific conferences. More in detail:

2008	APMS Conference, 14 - 17 September 2008, Espoo, Finland
2009	Doctoral Winter Workshop "Product and Asset Lifecycle Management" (PALM - DWW), 28 - 30 January 2009, Aprica, Italy
	ELA Doctorate Workshop, 24 - 27 June 2009, Saint Nazaire, France
	APMS, Conference and Doctoral workshop, 19 - 23 September 2009, Bordeaux, France
	Service Operations Management Forum: Second International Research Workshop, 5 - 6 October 2009, Barcelona, Spain
	MITIP, 11th International Conference, 15 - 16 October 2009, Bergamo, Italy
2010	Doctoral Spring Workshop, "Product and Asset Lifecycle Management" (PALM - DSW), 17 – 19 May 2010, Islantilla, Spain
	Grand challenge in Service, Conference and Doctoral workshop, 21 – 23 September 2010, Cambridge, UK
	Symposium - Emerging issues in performance measurement, 27 – 28 September 2010, Loch Lomond, Scotland
	APMS Conference, 11 - 13 October 2010, Cernobbio, Como, Italy

Progress in this research has been promoted also by some international exchanges and visiting research periods. In particular:

August – December 2008	MIT-Zaragoza International Logistics Program - Master of Engineering in Logistics & Supply Chain Management, Zaragoza, Spain
January 2010	SINTEF, Department of Operations Management, Trondheim, Norway
February – July 2010	University of Seville, Department of Industrial Management, School of Engineering, Seville, Spain

This reserch has received the following awards:

- Burbidge Award 2008 for the best presentation, received by IFIP WG 5.7 at APMS Conference, Espoo, Finland, 14 - 17 September 2008;
- Academic Excellence Award 2010, received by Supply Chain Council at Supply Chain World Europe conference, Munich, Germany, 25 – 26 October 2010.

The papers published during the PhD program and related to this PhD thesis are the following:

- Legnani E., Cavalieri S., 2008, Measuring the performance of after-sales service processes. A hierarchical approach, In: Proceedings of APMS 2008, International Conference on Advances in Production Management Systems, pp.359-368, Espoo, Finland, 14-17 September.
- Legnani E., Cavalieri S., Ierace S., 2009, A framework for the configuration for After-Sales service processes, Production Planning and Control, Vol. 20, No. 2, pp. 113 - 124.
- Legnani E., Cavalieri S., 2009, Exploring the causal relationships of key performance indicators in after sales service systems, In: Proceedings of APMS 2009, International Conference on Advances in Production Management Systems, Bordeaux, France, 19-23 September.
- Corti D., Gaiardelli P., Legnani E., Saccani N., 2009, Managing and controlling processes in product-based service networks, In: Proceedings of 11th International Conference MITIP, Bergamo, Italy, 15-16 October.
- Legnani E., Cavalieri S., Crespo A.M., González V.D., 2010, System Dynamics modeling for Product-Service Systems. A case study in the agri-machine industry, In: Proceedings of APMS 2010, International Conference on Advances in Production Management Systems, Cernobbio, Como, Italy, 9-13 October.
- Legnani E., Cavalieri S., Gaiardelli P., A performance measurement system for After-Sales Service processes, Submitted to Special Issue of Management Accounting Research – Emerging issues in performance measurement.

These papers are attached hereafter.

Other papers published but not related to the PhD thesis are the following:

- Legnani E., Cavalieri S., 2008, Implementation of a SCOR-based performance measurement system in the chemical sector, full paper submitted to International Conference on Flexible Supply Chains in a Global Economy, Molde, Norway, 16-18 July.
- Cavalieri S., Gaiardelli P., Legnani E., Pezzotta G., 2008, A Reference Model to manage company logistic complexity: an application in the automotive industry, Fifteenth International Working Seminar on Production Economics, Innsbruck, Austria, 3-7 March, Pre-prints, Vol. 2, pp. 205-216.
- Pezzotta G., Legnani E., Cavalieri S., Gaiardelli P., 2007, Assessing logistics practices of SMEs in the automotive sector: a survey in three European regions, In: Proc. of 14th International Annual EurOMA Conference, Ankara, Turkey, 17-20 June.
- Cavalieri S., Legnani E., Pinto R., 2007, Supply chain simulation-based optimisation: the ”Direct” approach, In: Proc. of 9th International Conference MITIP, Florence, Italy, 6-7 September.
- Legnani E., Cavalieri S., Dotti S., Pinto R., Evaluating the potential of RFID technology in the textile industry- opportunities, requirements and challenges, In: Unique Radio Innovation for the 21st Century: Building Scalable and Global RFID Networks, Springer - Verlag Berlin Heidelberg 2010.

Measuring the performance of After-Sales Service processes. A hierarchical approach

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Abstract
The importance of industrial services business has been growing during the last years becoming an essential competitive lever to survive and prosper on those mature markets affected by a sluggish demand, fierce competition and shrinking profit margins. As business has begun offering solutions instead of products, After-Sales service is becoming a thriving source of revenues and profits. However, despite its potential, it is still considered in most companies as a necessary evil. On the contrary, they need to change their tack since After-Sales is not just a mere set of operational activities: it plays a strategic role affecting the definition of the product-service mix offered and the physical and organisational configuration of the overall service chain. This situation does not just call on to define appropriate processes but also to create new metrics for their performance evaluation. Aim of the paper is to propose an integrated set of measures which spans the different peculiarities of the After-Sales area. It is organised in a hierarchical structure embracing different levels of analysis and it proposes a proper equilibrium between strategic and operational objectives, financial and non-financial indicators, tangible and intangible aspects, efficiency and effectiveness dimensions. An industrial application related to the heating and air-conditioning industry is finally reported.

Keywords
Service management, After-Sales service, Processes, Performance Measurement System, Hierarchical structure

1 INTRODUCTION

Since 1990s companies operating in the western mature markets have progressively realised the importance of complementing industrial goods with the provision of value added services. Service provision is becoming a real source of differentiation and advantage which enables manufacturing firms to affirm their leadership in a market characterised by high pressure and competition (Mathe & Shapiro 1990).
Supplying spare parts and conducting repairs, installing upgrades, reconditioning equipment, carrying out inspections and day-to-day maintenance, offering technical

support, consulting and training, as well as proposing financing solutions are just few examples which could be a bountiful source of revenues and profit generation for companies during the life cycle of a product after its sale (Cohen *et al.* 2006). Despite the obvious appeal, most organisations either do not know how or do not care to provide after sales (AS) services effectively. They spoil its potential, thus unexploited opportunities still exist (Wise & Baumgartner 1999; Gallagher *et al.* 2005). To manage AS support successfully, most companies require skills and knowledge they do not possess; for this reason, a strong interaction between the internal functions of a company and the actors involved in the service chain is essential: the co-creation of value with customers is the key and the interactive and experiential nature of this relationship form the basis for characterizing service (Edvardsson *et al.* 2005). Moreover, the customer direct involvement is an invaluable source to gather market information which is an essential input to product and service development (Armistead & Clark 1992, Cohen & Whang 1997; Thoben *et al.* 2004), to sales and promotion activities (Wise & Baumgartner 1999; Gallagher *et al.* 2005), as well as to marketing and Customer Relationship Management (Anderson & Kerr 2001; Ramaswamy *et al.* 2002; Campbell 2003).

This sweeping new perspective of the strategic vision of the service area, and AS in particular, calls for a thorough revision of the logistical and organisational configuration of the whole service chain. It comes out not only the need to design appropriate processes and to have a general and shared definition of their structure but also to implement rigorous metrics to boost the chain productivity. Measuring and monitoring performance is a fundamental prerequisite for identifying efficiencies and best practices and for spreading them throughout the organisation (Harmon *et al.* 2006).

The present paper aims at providing an integrated and multi-levelled set of measures for the AS area which classifies metrics in a hierarchical structure considering both strategic and operational perspectives. The paper is organized as follows: §2 defines the theoretical background with focus on the main contributions found in literature about Performance Measurement Systems (PMS) in the AS area; §3 reports the hierarchal set of indicators identified to measure the AS processes while §4 concerns the case study to which the defined PMS has been applied. Finally §5 draws some conclusions and presents future possible outcomes of the research.

2 THEORETICAL BACKGROUND

Performance measurement has become a popular topic for both practitioners and academicians, identifiable as a specific subset in the operations management literature. However, no significant emphasis has been put on the definition of a structured business PMS able to evaluate AS processes as a whole.

This may depend on the fact that this stream of literature is relatively new, but mainly because service processes are more difficult to measure than manufacturing ones due to their unpredictable nature. Improving service performance could be tricky: customers, activities, deals vary too widely as well as people, the basic unit of productivity in service, who bring different experiences, skills and motivation to the job (Harmon *et al.* 2006).

An extensive review of the existing body of knowledge about AS performance measurement is proposed by Gaiardelli *et al.* (2007), who classify the major theoretical contributions along with the following perspectives:

- product life-cycle (Shields &Young 1991; Cooper 1995; Cooper & Slagmulder 1999);
- AS strategy (Levitt 1983; Armistead & Clark 1991; Frambach *et al.* 1997; Lele 1997);
- spare parts logistics (Papadopoulus 1996; Hopp *et al.* 1999; Huiskonen 2001; Kennedy *et al.* 2002, Zhang *et al.* 2001);
- supply chain and process-oriented approach (Cohen & Lee 1990; Cavalieri *et al.* 2006; Cooper & Slagmulder 1999; Patelli *et al.* 2004).

From this analysis it has been noticed that literature dealing with AS service presents a highly fragmented picture: a systemic approach linking corporate strategic objectives with AS strategies and goals, and a consistent set of performance measures and indicators, is still lacking.

According to several authors (Dixon *et al.* 1990, Eccles 1991, Stewart 1991, Lynch & Cross 1991, Fitzgerald *et al.* 1991, Kaplan & Norton 1992, Fitzgerald & Moon 1996, Bititci *et al.* 2000), an effective PMS for operations management has: i) to be articulated according to different level of analysis, considering both strategic and operational decision making levels, such as strategic business areas, processes and organisational units; ii) to balance financial and non financial indicators; iii) to jointly consider long term and short term results, tangible and intangible aspects, efficiency and effectiveness. As a consequence, also a PMS specifically thought to capture all the critical aspects of the AS area needs to be organised in such an integrated structure.

In this sense, some interesting contributions are now coming out: the same Gaiardelli *et al.* (2007) propose a framework which integrates the features of some existing models (Lynch & Cross 1991; Kaplan & Norton 1992; Supply Chain Council 2008) to carry out an all-embracing PMS for AS. It is articulated into four levels (strategic business area, process, activity and development/innovation) and it addresses several performance areas at each level, giving emphasis to both efficiency and effectiveness measures as well as to internal and customer-oriented ones. Another interesting input that is worthwhile mentioning regards the results achieved by the EU-funded project InCoCo-S (Osadsky *et al.* 2007), where a reference model for the collaboration between service providers and manufacturers have led to the definition of processes, metrics and related best practices to perform.

3 THE PROPOSED PERFORMANCE MEASUREMENT SYSTEM

Goal of this section is to introduce a PMS organised in a hierarchical structure oriented to the measuring and evaluation of AS processes performance.

The proposed results come from an ongoing research project conducted by an international working group made up of practitioners and academicians, members of the Supply Chain Council, where the same authors are involved. Aim of the team is the definition of a new model, the Customer Chain Operations Reference (CCOR) model, whose objective is the mapping and measuring of sales and service activities within the supply chain management context. The CCOR model, which is still in a development phase, describes all those processes involved in the interaction between a company and its customers through the use of Plan, Relate, Sell, Contract and Assist processes. It aims at providing a set of metrics to systematically measure performance and observed trends and at enabling possible benchmarking and improvement actions through the definition of some best practices. Considered the authors' research interests, a more thorough study of the Assist process has been performed. An integrated view of the AS area has been suggested in a previous work (Legnani *et al.* 2007) where, according to a framework which links different typologies of customer supports with product characteristics for service operations, a configuration model for the Assist process has been proposed. Within this model, different categories of AS processes have been identified (i.e. Indirect support, Remote support, On-site support and Off-site support) and for each of them a detailed list of activities to be performed has been defined with the further goal to evaluate them through proper indicators.

As a consequence, according to the working group purpose, the proposed multi-levelled set of metrics for the evaluation of AS processes is built considering the same semantic structure and formalism of the SCOR (Supply Chain Operations Reference) model, the most acknowledged reference model in the supply chain management area developed by the Supply Chain Council (2008). This model links business processes, metrics, best practices and technology features into a unified structure to support communication between supply chain partners and improve the management and effectiveness of the related activities. It is structured into several sections and is organised into three levels of detail along five primary management processes (Plan, Source, Make, Deliver, Return), each having a broad set of indicators specifically thought to systematically measure their performance and observed trends. Moreover, these metrics are arranged in a hierarchical structure according to the following construction:

- *performance attributes* (reliability, responsiveness, flexibility, assets and costs), which are groupings for metrics used to explain company strategies and to analyse and evaluate them against others with competing approaches;
- *level 1 metrics*, which are strategic indicators (Key Performance Indicators) used to monitor the overall performance of the supply chain;
- *level 2* and *level 3 metrics*, respectively tactical and operational indicators, which serve as diagnostic measures to identify critical processes and variations in performance against the plan.

Taking advantage of this structure, six attributes, which span both internal-facing and customer-facing perspectives, have been identified within the current proposal of the CCOR model: reliability, responsiveness, agility, assets, costs and growth. A first draft of these performance attributes and their relative definitions are reported in Table 1.

PERFORMANCE ATTRIBUTES	**DEFINITION**
Reliability (RL)	The performance of the customer chain to generate sales that can be fulfilled and supported, the right products/services offered, the right contractual agreements in place, at the right time, providing the right answers to customer inquiries.
Responsiveness (RS)	The speed at which sales are generated and customer inquiries are resolved.
Agility (AG)	The agility of a customer chain in responding to marketplace changes to gain or maintain competitive advantage.
Costs (CO)	The costs associated with operating the customer chain in order to generate sales and to resolve customer inquiries.
Asset Management (AM)	The effectiveness of an organisation in managing assets to support generation of sales and resolve customer inquiries. This includes the management of fixed and working capital assets.
Growth (GR)	Ability of a customer chain to generate net income on a consistent and sustainable basis.

Table 1 - A first proposal of performance attributes and related definitions within CCOR

In particular, focusing on the Assist process, specific Level 1 metrics have been identified and associated to the appropriate performance attributes (Table 2).

	PERFORMANCE ATTRIBUTES					
LEVEL 1 METRICS	**RL**	**RS**	**AG**	**CO**	**AM**	**GR**
Perfect Assist Completion	X					
Assist Cycle Time		X				
Assist Agility			X			
Assist-Warranty Costs				X		
Return on Assist Assets					X	
Assist Operating Margin Growth						X
Customer Loyalty						X

Table 2 - Performance attributes and associated Level 1 metrics for AS

For each of the reported AS Level 1 metrics, a hierarchical structure has been built reporting the Level 2 and Level 3 indicators which are strongly related to the evaluation of the final outcome, represented by the associated performance attribute category. As an example, an insight of the *Perfect Assist Completion*, the Level 1 metric correlated to the *Reliability* (RL) attribute, is reported in Figure 1.

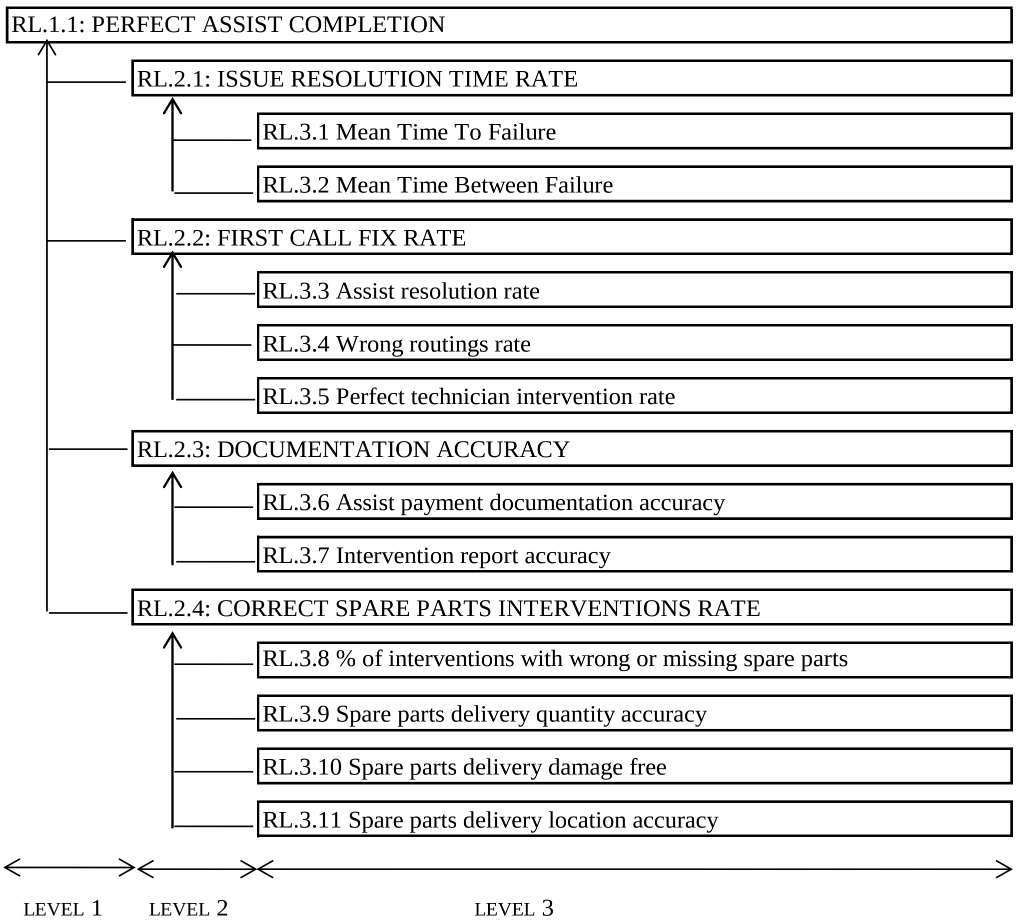

Figure 1 - Hierarchical structure for *Perfect Assist Completion*

For each metric, whatever level is, a definition and a calculation method are also proposed. For instance, Table 3 reports the definition and calculation for the Level 1 metric *Perfect Assist Completion*.

RL.1.1: Perfect Assist Completion
A Perfect Assist is a customer assist which meets all of the following standards: - Issue/Request responded to within agreed upon time - Issue/Request resolved within agreed upon time - Problem is completely resolved - Problem is resolved during the first customer contact - Customer satisfied with resolution - Resolution is documented - Product issue information communicated back to rest of the business (Design Chain, Supply Chain)
Calculation
(# of perfect assists / # of assists) * 100

Table 1 - Definition and calculation for *Perfect Assist Completion*

4 PRACTICAL APPLICATION

The hierarchical PMS proposed in the previous section has been applied to a case study in order to provide the company with an organised and structured system to evaluate its AS performance results. The analysis was carried out within a nine months project by making direct interviews, direct observations and picking over secondary sources like company documentation, corporate website and specialised press. Informants included the AS managing director, the spare parts warehouse and material planning managers, the customer care manager, technicians and call centre operators.

This case study refers to a company operating in the North of Italy which makes heating and air-conditioning systems fuelled by methane or Liquefied Petroleum Gas (LPG). It operates in a niche market where its customers are willing to pay more to have a high quality, safety and innovative product which guarantees considerable economic savings over time and ecological care. It provides specific solutions and support in several fields, such as food, textile, chemical, electronic and construction industries as well as for hotels, shopping centres and sports centres. It sells products which push for a fast repair when inactive, thus they need technical support but also detailed documentation, installation, training, spare parts supply, product upgrading and customised commercial contracts. Service delivery is guaranteed through a network of 450 authorised technical assistance centres spread all over Italy.

The AS Business Unit is divided in two parts:

- *Technical assistance,* which is responsible for collecting and routing customer requests - whatever they are, of technical, contract or warranty nature - to the appropriate competence team, resolving standard technical issues and supplying spare parts.
- *Technical customer support,* which manages relations with the external authorised technical assistance centres and solves particularly hard issues never experienced before by collaborating with the product-design team.

In particular, the AS Business Unit handles eight macro-processes classified as follows:

- new spare parts design and styling;
- spare parts management;
- customer feedbacks management;

- returned defective products management;
- start-up and installation management;
- authorised technical assistance centres management and selection;
- interventions management;
- maintenance and contract extension management.

Mapping in detail each macro-process and its interconnections with the other Business Units and external actors revealed some critical aspects: for example, the relation which claims for more accurate management and attention is the one with the authorised technical assistance centres whose role and position throughout the country strongly influences the company image. Furthermore, the company call centre, which has a direct contact with customers and routes assistance requests to the competence teams, has been noticed having a crucial function and being a bottleneck at times. For this reason, it has been decided to invest more on call centre personnel competence and training and to introduce an automatic and faster system to distribute calls.
Other critical processes, peculiar to the *interventions management* macro-process, are the technician scheduling, the solution identification, the product repair and the proper definition of customer agreements within a request closure.
Since the main issues picked out are related to the *interventions management* macro-process, it has been decided to concentrate efforts in its measuring at first. Interviews disclosed that company monitored just three traditional metrics: Mean Time To Failure (MTTF) and Mean Time Between Failure (MTBF), in order to assess the reliability of components and parts, and Mean Time To Repair (MTTR) for evaluating the degree of responsiveness of the technical support. The application of the PMS proposed in section 3 allowed to find out and calculate more indicators, providing the company with a useful tool to assess both financial and non-financial, strategic and operational perspectives.
A simple dashboard (Table 4), which allows to evaluate periodically the most critical processes, has been suggested according to the hierarchical structure of the defined PMS. It reports the identified key processes for the *interventions management* macro-process, the attribute categories to assess and the related Level 1, 2 and 3 indicators to calculate.
Further work will carry out the same analysis for the other seven macro-processes managed by the AS Business Unit.

KEY PROCESSES	ATTRIBUTES	LEVEL 1 METRICS	LEVEL 2 METRICS	LEVEL 3 METRICS
Route request	RS	Assist Cycle Time (RS.1.1)	Call centre waiting time (RS.2.1) Average routing time (RS.2.3)	
	RL	Perfect Assist Completion (RL.1.1)	First call fix rate (RL.2.2)	Wrong routings rate (RL.3.4)
	CO	Total Customer Chain Costs (CO.1.1)	Cost of Assist (CO.2.1)	Average call centre cost (CO.3.1)
Schedulin g	AG	Customer Chain Agility (AG.1.1)	Adaptability to the increase of unplanned requests (AG.2.2)	% of last minute interventions added in the scheduling (AG.3.3)
	RS	Assist Cycle	Average time for scheduling	

		Time (RS.1.1)	technical assistance (RS.2.4)	
Identify solution	RS	Assist Cycle Time (RS.1.1)	Average time for diagnosis (RS.2.5) Average time to propose solution (RS.2.6)	
Repair product	RL	Perfect Assist Completion (RL.1.1)	Issue resolution time rate (RL.2.1)	MTTF (Mean Time To Failure) (RL.3.1) MTBF (Mean Time Between Failure) (RL.3.2)
	RS	Assist Cycle Time (RS.1.1)	Waiting time for delivery spare parts (RS.2.7) MTTR (Mean Time To Repair) (RS.2.8) Average time for material disposal (RS.2.9)	
	AG	Customer Chain Agility (AG.1.1)	Reaction time to unplanned events (AG.2.1)	Time to manage urgent and unplanned spare parts requests (AG.3.1)
	CO	Total Customer Chain Costs (CO.1.1)	Cost of Assist (CO.2.1)	Average cost to obtain spare parts (CO.3.3) Average repair intervention cost (CO.3.4) Average costs for disposal of material (CO.3.5)
			Cost of spare parts and/or services sold (CO.2.3)	
Obtain customer agreements and close request	RS	Assist Cycle Time (RS.1.1)	Average time to close requests (RS.2.10)	
	AG	Customer Chain Agility (AG.1.1)	Adaptability to customised requests (AG.2.3)	Time required to perform a new and customised request (AG.3.5) Number of contract-conditions modified (AG.3.6)
	CO	Total Customer Chain Costs (CO.1.1)	Warranty Cost (CO.2.2)	Warranty Cost as % of Revenue (CO.3.6)
	GR	Assist Operating Margin Growth (GR.1.1)	Assist operating margin (GR.2.1)	Direct Assist Profit per Customer Classification (GR.3.3)

Table 2 - *Interventions management* macro-process: key processes, related attributes and metrics

5 CONCLUSIONS AND FURTHER DEVELOPMENTS

Since in several manufacturing industries AS is recognised as a key of competitive success, companies are getting aware of the importance of monitoring and controlling their AS processes. End-customer service measures need to be implemented and applied consistently by all the parties involved in the service chain in order to enhance its overall effectiveness.

This work aims at contributing to a better understanding of the peculiarities of a PMS in the AS area and at answering to the need of having an integrated and multi-attribute set of measures. Taking advantage of the SCOR model formalism, a hierarchical metric structure which drills down indicators according to different levels of analysis has been

proposed and applied to measure the AS processes of an industrial firm. The suggested list of metrics does not mean to be extensive and the accuracy of their calculations either. Further empirical analyses and applications in other companies are required to better finalise the research and generalise the model.
Furthermore, it is known that managing service is notoriously difficult due to its unpredictable nature: customer needs are always changing, activities differ widely and organisational and human aspects have a key role. For this reason, analysing AS just with the use of quantitative metrics could be limiting: there are several subjective and intangible aspects which influence companies final outcomes and thus need to be considered as well. For evaluating "soft" elements surveys can be carried out through filled in questionnaires specifically arranged and submitted to samples of customers; a useful methodology to assess the results is to associate a weighted score to the answers and then perform the analysis through statistical techniques. For instance, customer satisfaction can be affected by the technician attitudes, such as technical qualification and flexibility, by the courtesy, politeness and willingness of the call centre operators or by internal quality drivers related to the employees satisfaction as personal fulfilment with the job, training, pay, advancement fairness, treatment with respect and teamwork.

6 REFERENCES

Anderson, K.A. & Kerr, C.J. 2001. *Customer Relationship Management*, McGraw-Hill.

Armistead, C. & Clark, G. 1992. *Customer Service and Support, Implementing Effective Strategies*, FT Books, London, Pitman Publishing.

Bititci, U.S., Turner, T. & Begemann, C. 2000. Dynamics of performance measurement systems, *International Journal of Operations and Production Management*, Vol. 20, No. 6, pp.692–704.

Campbell, A.J. 2003. Creating customer knowledge competence: managing customer relationship management programs strategically, Industrial Marketing Management, Vol. 32, No. 5, pp. 375-383.

Cavalieri, S., Brun, A., Ierace, S. 2006. After-Sales Processes in the SCOR model: a proposal and an empirical application, *14th Working Seminar on Production Economics*, Vol.3, pp. 25-36.

Cohen, M.A., Agrawal, N. & Agrawal, V. 2006. Winning in the Aftermarket, *Harvard Business Review*.

Cohen, M.A. & Lee, H.L. 1990. Out of touch with customer needs? Spare parts and after sales service, *Sloan Management Review*, Winter, pp.55–66.

Cohen, M.A. & Whang, S. 1997. Competing in product and service: a product life-cycle model, *Management Science*, Vol. 43, No. 4, pp. 535-545.

Cooper, R. 1995. *When Lean Enterprises Collide*, Boston: Harvard Business School Press.

Cooper, R. & Slagmulder, R. 1999. *Supply Chain Development for the Lean Enterprise: Interorganizational Cost Management*, Portland: Productivity Press.

Dixon, J.R., Nanni, Jr., A.J. & Vollmann, T.E. 1990. The new performance challenge: measuring operations for world-class manufacturing, *Business One Irwing*, Homewood, Ill.

Eccles, R.G. 1991. The performance measurement manifesto, *Harvard Business Review*, January–February.

Edvardsson, B., Gustafsson, A. & Roos, I. 2005. Service portraits in service research: a critical review, *International Journal of Service Industry Management*, Vol. 1, No. 1, pp. 107-121.

Fitzgerald, L., Johnston, R., Brignall, S., Silvestro, R. & Voss, C. 1991. Performance measurement in service businesses, *CIMA*, London.

Fitzgerald, L. & Moon, P. 1996. Performance measurement in service industries: making it work, *CIMA*, London.

Frambach, R.T., Wels-Lips, I. & Gundlach, A. 1997. Proactive product service strategies, *Industrial Marketing Management*, Vol. 26, pp.341–352.

Gaiardelli, P., Saccani, N. & Songini, L. 2007. Performance measurement systems in the after-sales service: an integrated framework, *International Journal Business Performance Management*, Vol. 9, No.2, pp. 145-171.

Gallagher, T., Mitchke, M.D. & Rogers, M.C. 2005. Profiting from spare parts, *The McKinsey Quarterly*.

Harmon, E., Hensel, S.C. & Lukes, T.E. 2006. Measuring performance in services, *The McKinsey Quartely: The Online Journal of McKinsey & Co.*, No. 1.

Hopp, W.J., Zhang, R.Q. & Spearman, M.L. 1999. An easily implementable hierarchical heuristic for a two-echelon spare parts distribution system, *IEEE Transactions*, Vol. 31, pp.977–988.

Huiskonen, J. 2001. Maintenance spare parts logistics: special characteristics and strategic choices, *International Journal of Production Economics*, Vol. 71, pp.125–133.

Kaplan, R.S. & Norton, D.P. 1992. The Balanced Scorecard. Measures that Drive Performance, *Harvard Business Review*, January-February.

Kennedy, W.J., Pattersonb, J.W. & Fredendall, L.D. 2002. An overview of recent literature on spare parts inventories, *International Journal of Production Economics*, Vol. 76, pp.201–215.

Legnani, E., Ierace, S. & Cavalieri, S. 2007. Towards a reference model for After-Sales service processes, in *IFIP International Federation for Information Processing*, vol. 246, Advances in Production Management Systems, eds. Olhager, J., Persson, F., (Boston Springer), pp. 289-296.

Lele, M. 1997. After-sales service – necessary evil or strategic opportunity?, *Managing Service Quality*, Vol. 7, No. 3, pp.141–145.

Levitt, T. 1983. After the sale is over…, *Harvard Business Review*, Vol. 61, No. 5, pp. 87-93.

Lynch, R.L. & Cross, K.F. 1991. Measure Up – The Essential Guide to measuring Business Performance, *Mandarin*, London.

Mathe H. & Shapiro R.D. 1990, Managing the Service Mix: After Sale Service for Competitive Advantage, *The International Journal of Logistics Management*, Vol.1, No.1, pp.44-50.

Osadsky, P., Garg, A., Nitu, B., Schneider, O. & Schleyer, S. 2007. Improving service operation performance by a cross-industry reference model, in *IFIP International Federation for Information Processing*, Vol. 246, Advances in Production Management Systems, eds. Olhager, J., Persson, F., Boston Springer, pp. 397-404.

Papadopoulos, H.T. 1996. A field service support system using a queueing network model and the priority MVA algorithm', *Omega*, Vol. 24, pp.195–200.

Patelli, L., Pistoni, A. & Songini, L. 2004. The appraisal of after-sales service contribution to value creation. A conceptual framework, *27th Annual Congress of the European Accounting Association*, Prague, April.

Ramaswamy, Katzenbach, Lederer, Hill, Prahalad, Ramaswamy & Seybold 2002. Harvard Business Review on Customer Relationship Management, *HBS Press.*

Shields, M.D. & Young, S.M. 1991. Managing product life cycle costs: an organisational model, *Cost Management*, Fall, pp.39–52.

Stewart, G.B. 1991. The Quest for Value: *The EVA^{TM} Management Guide*, HarperCollins Publishers, Inc.

Supply Chain Council (SCC) 2008. *Supply Chain Operations Reference model (SCOR)*, version 9.0, *Customer Chain Operations Reference model (CCOR)*, www.supply-chain.org.

Thoben, K.-D., Jagdev, H. & Eschenbaecher, J. 2001. Extended products: evolving traditional product concepts, *Proceedings of the 7th International Conference on Concurrent Enterprising: Engineering the Knowledge Economy through Co-operation*, Bremen (Germany), 27-29th June, pp. 429-439.

Wise, R. & Baumgartner, P. 1999. Go downstream - the new profit imperative in manufacturing, *Harvard Business Review*, Vol. 77, pp. 133-141.

Zhang, R.Q., Hopp, W.J. & Supatgiat, C. 2001. Spreadsheet implementable inventory control for a distribution center, *Journal of Heuristics*, Vol. 7, pp.185–203.

A framework for the configuration of After-Sales Service Processes

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Abstract
In the competitive world of industrial goods, where products are getting commoditised and profit margins are cut down, the search for new business opportunities encompasses also the provision of a portfolio of service activities. The observed trend is that companies need to package their core products with additional services in order to make them more attractive to final customers. In this context, After-Sales (AS) service has become increasingly important as a source of differentiation and market share for manufacturers and resellers, as well as a strategic driver for customer retention. This leads to a detailed revision of the logistical and organisational configuration of the whole service chain entailing the design of appropriate processes and a general and shared definition of their structure. Aim of the paper is to propose a framework which provides a common representation of the AS processes and activities according to a configuration model that links different typologies of assistance with product characteristics for service operations. Three case studies have been considered in order to ascertain the validity of the framework in the industrial context.

Keywords
Service operations, After-Sales service, Framework, Performance metrics

1 Introduction

The widening of geographic horizons, the downfall of technological barriers and the more pressing and specific requests of the final customers are some of the most compelling factors which are currently pushing manufacturing companies to strive for new forms of market strategies. Being excellent in the technical, economical and qualitative performance of products are features nowadays considered in most industries as mere order qualifiers for surviving in a market. Business actions need rather to be addressed to the establishment of a long-lasting and stable relationship with the customers throughout the whole product life-cycle by providing a value-added portfolio of connected services. A bundle of tangible and intangible components extends the physical functionalities of the core product whose value for companies does not end with the transactional undertaking of the product sale (Rispoli and Tamma, 1992, Thoben *et al*., 2001).

The term service refers to the description of the customers' requirements and how they need to be satisfied according to the design of the service package (Edvardsson and Olsson, 1996). Service is viewed as an organisational corporate philosophy consisting of a comprehensive and related set of activities prior, during and after the transaction.

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To improve company performance, service and sales need to work together and develop joint programs to maintain valuable and durable relationships with customers, which are involved as well in the process as co-producers (Peeling, 2004).

Within the service area, After Sales (AS) service has been acquiring a strategic role for a company business. It is a source of differentiation and revenue generation: profit margins are often higher than those obtained with the product sales, and it may generate at least three times the turnover of the original purchase during a given product lifecycle (Alexander *et al.*, 2002). Moreover, it is also a powerful marketing force for promoting the brand of a company.

It is evident how end-users of many types of products, ranging from industrial goods to domestic appliances, require assistance and support at some time in order to gain maximum value from their purchase. In detail, customer support entails all activities to ensure that a product is available for trouble-free use to consumers over its useful life span (Goffin and New, 2001). Traditionally, support merely constituted maintenance, service and repair activities. However, as the customer needs have been increasing over the past decade, it has also progressively encompassed other services as product installation, commissioning, training, documentation, spare parts supply and logistics, product upgrading and medications, software patches, warranty schemes, phone support, etc. (Tore and Uday, 2003).

Although the service area, and AS in particular, are becoming more and more important for the survival of an industrial company, there is no single, comprehensive and consistently used unifying structure which defines what services are (Sampson and Froehle, 2006). The design or the thorough reengineering of service business processes is thus required and their common understanding, their inherent activities, related performance metrics and best practices should be considered and properly assessed.

The present paper attempts to fill this necessity proposing a framework whose aim is to provide a comprehensive mapping of the AS service processes, activities and performance measures according to a configuration model which correlates some product characteristics with different types of customer support. The paper is organised as follows: section 2 reports a literature review about the existing models used to map the service area; section 3 deals with the description of the framework suggested for the configuration of the AS processes; section 4 illustrates three case studies used to describe the applicability of the proposed framework and discusses some of the most interesting outcomes. Finally, section 5 reports concluding remarks and further developments.

2 Literature review

Literature related to service has mushroomed in the last years encompassing several fields of investigation, from spare parts logistics to service marketing (Cavalieri *et al.*, 2006). For the purpose of the paper, the classification reported in Table 1 puts its emphasis on two main research streams: *service strategies* and *service processes*.

The fact that numerous works are related to service strategies does not appear a surprising result, as the strategic importance that the provision of services has been acquiring for industrial companies is well acknowledged. In addition, it turns out a consolidated understanding on the importance of processes as basic units to perform services. As remarked by Acur and Bititci (2003), value is created and strategies are realised at business processes level.

On the contrary, many companies are still using a "hit-and-miss" approach to handle their services (De Brentani, 1989), neglecting how strategic objectives should be implemented through appropriate business processes, whose generalisation and standardisation in a unique form is also lacking.

TAKE IN TABLE 1

With regard to scientific contributions to service strategies, an in-depth analysis drills them down into *strategic models* and *configuration models*.

Among the strategic models, it is remarkable to cite the works of: (i) Mathe and Shapiro (1990), proposing the Service Mix approach which considers service as a correct balance between customer needs and resource capacity provided by a company; (ii) Heskett *et al*. (1994), introducing the theme of service profit as the combination of several factors like corporate policies, employee satisfaction, value creation, customer loyalty and profitability; (iii) Edvardsson and Olsson (1996), dealing with service development from a quality management perspective and providing useful guidelines for companies according to three different dimensions of service concept, service system and service process; (iv) Mathieu (2001), suggesting a matrix which classifies services according to their specificity (i.e. customer service, product service and service as a product) and their organisational intensity (tactical, strategic and cultural).

Configuration models, instead, have been proposed with respect to market and product characteristics on the one hand and the processes on the other. Johansson and Olhager (2003), in addition to their matrix for industrial services, propose a classification as a synthesis of the main contributions coming out from Chase (1981), Schmenner (1986), Silvestro *et al*. (1992), Tinnilä and Vepsäläinen (1995), Kellog and Nie (1995) and Buzacott (2000). With specific reference to AS, Cohen *et al*. (2000) propose a model considering the centralised or distributed service strategy vs. high or low service criticality, while Lele (1997) suggests a classification of AS strategies according to fix and variable costs.

Other significant contributions concern the role of service processes. This category can be further declined into *product-based* and *service-based models*. The proposition of product-based models in the service field derives from the assumption that modelling service processes requires the mere application and adaptation of consolidated best practices deriving from the manufacturing area (Ellram, 2004). The most known product-based models adopted to describe service chains have been developed by: (i) Hayes and Wheelwright (1979), linking different production processes to the product life cycle stages; (ii) Lee and Billington (1995), analysing the flow of goods among suppliers, manufacturers and customers within an uncertain environment; (iii) Croxton *et al.* (2001), whose model conceptualises a supply chain that includes the business processes, the management components and the structure of the chain; (iv) the Supply Chain Council (2008), proposing the Supply Chain Operations Reference (SCOR) model to map the supply chain processes and their related metrics and best practices.

However, the application of these models explicitly created to map manufacturing dynamics does not appear to be a suitable approach. Particular features and issues related to the service area as well as the inherent differences among the wide variety of services to offer, lead to define specific service-based models which consider and entail their peculiar processes and activities. According to the Unified Service Theory (Sampson 2001) "with service processes, the customer provides significant inputs into the production process; with manufacturing processes, groups of customers may contribute ideas to the design of the product, but individual customers' only participation is to select and consume the output".

Referring to Table 1, service-based models are characterised by a long-term strategic or tactical/execution perspective. Among the strategic perspective category, some interesting proposals have been suggested by: (i) Shostack (1984), who defines a 10 stages model for mapping service processes; (ii) Reidenbach and Moak (1986), with a 6 stages model which includes phases as idea generation, concept development and testing, economic analysis, product testing, market testing and commercialisation; (iii) Johnson *et al*. (2000), who propose a 4 stages model organised around the design, analysis, development and full launch phases. Among the tactical and operational perspective category, attempts found out are the After Sales Chain Operations Reference (ASCOR) model proposed by Cavalieri *et al*. (2006), though with a limited applicability just on a typology of assistance support, and the Customer Chain Operations Reference (CCOR) model defined by the Supply Chain Council (2008), which is still in an early development phase.

Aim of the paper is to merge the two main visions – *strategies and processes* - through the proposal of a framework which helps an industrial decision maker in finding out:

- the right correspondence between the main economical and functional features of a manufactured product and the related assistance supports;
- those processes and performance metrics which need to be carried out accordingly.

3 Aligning product characteristics and assistance processes: a framework for industrial service

3.1 Product characteristics for service operations

Focusing on the service strategies associated to a product, Lele (1997) states that any product can be assigned to one out of four AS service segments. Considering low and high fixed costs (which occur regardless of the duration of equipment downtime) vs. low and high variable costs (which change according to the duration of equipment downtime), these strategies are classified as: disposable, repairable, rapid response and never fail. However, what turns out from this classification is the lack of a precise understanding of the point of view considered to define the categorisation, whether the customer or the service provider's one.

For this reason, in this paper another classification is proposed considering the customer's perspective in order to categorise product characteristics. Two dimensions have been considered: variable costs on the one hand and the ratio replace costs/repair costs on the other. More in detail:

- *variable costs (VC)* refer to those opportunity costs sustained by the customer when a product/service does not work properly or does not suit his/her needs and requires assistance to be fixed; the higher they are, the more remarkable the losses are for the customer;
- α represents the ratio replace costs/repair costs; it is a balance that indicates what is more convenient between a substitution and a repair of a product when a problem occurs. For example, if $\alpha=1$ it means that the product can be either swapped or fixed,

if $\alpha<1$ the product is advisable to be fully replaced and, finally, if $\alpha>1$ the product is economically repairable.

According to these two dimensions, products can be classified as follows (Figure 1):

- *commodity* refers to products with low replace costs and low variable costs; it includes goods that are normally not fixed once broken down or, if necessary, just repaired by the customer; it includes small household appliances and inexpensive office equipment; contracts for product selling are not stipulated with the customer, generally just commercial invoices are exchanged;
- *conventional* belongs to the cost-sensitive product category, that is represented by goods with a high α ratio, which thus need to be repaired, and little influenced by variable costs fluctuations; it is the case of some domestic appliances like home PCs provided also with adequate documentation, warranty schemes and regulated by simple transactional contracts;
- *essential* refers to products very sensitive to variable costs which imply a fast repair when inactive; this category includes more sophisticated appliances like office PCs or industrial equipment; these products need technical support but also detailed documentation, installation, training, spare parts supply and logistics, product upgrading and customised commercial contracts;
- *vital* includes products with a very high α ratio and very high variable costs (both tending to infinite); it refers to products of crucial importance, as the case of medical equipment, which can never malfunction; this is the most complex category where assistance support plays a fundamental and irreplaceable role.

TAKE IN FIGURE 1

In conclusion, α represents the boundary between commodities (α<1 and tending to zero) and repairable products (when α>1) which can be further split into vital (when both α and *VC* tend to infinite) and cost-sensitive products. Cost-sensitive products present a wide α range, thus they can be classified according to the sustained variable costs: when the amount is low-medium they are considered as conventional, when it is high as essential products.

3.2 Assistance categories and processes

Traditionally, customer support has been considered a post-sale capability, primarily focussed on problem resolution or on providing technical assistance. In this sense, regarding assistance processes to perform, Cavalieri and Corradi (2002) identify different typologies of support according to the service level offered, the level of involvement of the customer and the sustained costs. They can be categorized as: indirect support, remote support, off-site support, on-site support, proactive and customised supports. However, these definitions merely focus on a technical perspective covered by the assistance processes. Hence, they need to be integrated as they appear quite limited. In fact, an AS support strategy associated with a product/service may include assigning support resources and responding to customer inquiries, repair services or upgrades, warranty claims or contractual issues, and providing quality feedback for business transactions and products/services life performance.

Considering this wider concept of support, assistance processes may be classified as follows:

- *passive assist,* where contract-related information and documentation are prepared and updated and pre-packaged solutions to products/services inquiries or issues are offered, as diagnosed solely by the customer or customer-agent;
- *collaborative assist,* where contract-related information and documents for performance expectations are defined and checked and pre-packaged or custom solutions to products/services requests or issues are provided; inquiries are diagnosed jointly by the customer or customer-agent and the assistance-provider;
- *turn-key assist,* where contract-related information and documents for performance expectations are monitored and checked and mainly custom solutions are implemented; diagnosing activities are performed primarily or solely by the assistance-provider.

According to these definitions, companies require a service-based model to refer to while revising their AS processes in order to map in detail how they can be performed and then evaluated through the use of suitable indicators. The service-based model proposed in this section has been conceived by a working group operating within the Supply Chain Council, where the same authors are involved. The team is made up by practitioners with significant experience in service development and academicians; the goal is the definition of a new model, the Customer Chain Operations Reference (CCOR) model, whose objective is the mapping and measuring of sales and service activities within the supply chain management context. The CCOR model, which is still in a development phase, describes all those processes involved in the interaction between a company and its customers through the use of Plan, Relate, Sell, Contract and Assist processes. Moreover, it aims at providing a set of metrics to systematically measure performance and observed trends and at enabling improvement actions through the definition of some best practices. CCOR is arranged following the same semantic structure and formalism of the SCOR model, the most widespread reference model developed by the Supply Chain Council (2008). SCOR provides a detailed description of the production-logistic processes (Plan, Source, Make, Deliver and Return) and it identifies a broad set of performance indicators and some relevant best practices to adopt. Processes are structured into three different levels of detail, starting from the most aggregate (Level 1), which depicts the process type, moving through process categories (Level 2), till process elements and activities (Level 3). Moreover, a set of performance metrics is also assigned to each process, whatever level is, in order to measure and continually monitor its trend and thus identify corrective actions.

According to the topic of this paper, the service-based model proposed hereafter relates to the scope of the CCOR Assist process. As an example of the structure, Table 2 reports how assistance processes are configured with a specific insight on the Turn-Key Assist process. In particular, the “repair product or obtain customer agreement” Level 3 process has been selected: its definition and its related performance metrics are shown.

TAKE IN TABLE 2

3.3 Matching product features with the most appropriate assistance processes

As highlighted from the literature review, there are several contributions which focus on service management considering product characteristics and the related processes to perform. However, the majority of these works is about approaches which consider service from a strategic point of view failing to define a common structure of processes, activities and performance metrics that should be handled and measured at a tactical and operational level.

Aim of this section is to propose a framework which entails both aspects: a strategic alignment of product features with the appropriate assistance support and, at the same time, a list of activities and metrics that companies should carry out once assessed their strategic position.

In this sense, the first step is to clarify the relation between product characteristics and the most suitable typologies of assistance support: the configuration model reported in Figure 2 is a useful tool which highlights this match and it helps companies in detecting their placement along the matrix.

TAKE IN FIGURE 2

As Figure 2 shows, along the diagonal of the configuration model there is a proper fit between products and assistance supports. More specifically, it turns out that:

- *commodity products* mainly require a *passive support* even if in most cases their low value generally do not lead to any assistance request;
- *conventional products* mainly include *passive* and *collaborative supports* and sometimes also a *turn-key* one; though products belonging to this group have a quite high α ratio, a repair is normally required but not necessarily immediate because the associated variable costs are not very considerable;
- *essential products* refer to goods with a high α ratio which need to be fixed promptly since they have high variable costs. *Turn-key* and *collaborative assistance* are mainly performed, including in some cases also the *passive* mode;
- *vital products* embrace mainly a *turn-key support*, since they have a very high α ratio and variable costs; *collaborative assistance* is also performed at times.

Once a company has assessed the position of its products along this grid, a further step consists in defining the actions to accomplish according to the service-based model previously reported in section 3.2.

In conclusion, the proposed framework results from the combination of two different models: i) a *configuration model* which aligns product characteristics with the most consistent assistance supports (reported in Figure 2) and ii) a *service-based process model* which formalises the operational processes and activities and the relative performance metrics (reported in Table 2).

4 Case studies

In order to ascertain the validity of the proposed framework in the industrial context, three companies have been examined as case studies. Product characteristics, support strategies and assistance processes of each company have been identified to bear out and verify their fitting with the framework. Purpose of this section is also to show how a company can adopt a consistent design of its assistance processes according to its product characteristics.

Company 1 sells an essential product: it provides machines and services for folding carton, corrugated board and flexible materials markets. It has three different manufacturing and commercial branches, is present in more than 50 countries in the world and has a wide range of machines, plants and spare parts. When the customer claims that a failure has occurred to one machine, Company 1 has to provide a rapid and timely intervention. Normally replacement costs are higher than repair ones (high α), thus the company has to act hastily and be able to fix the problem at a first intervention, since an idle machine causes delays and high losses for the industrial customer (high VC). Analysing the nature of its assistance activities, it comes out that the more frequent assistance requests are of technical support, even if contract-related information is also required. In some situations, when the failure is not too hard to fix, the problem is diagnosed and solved jointly by the customer and the company, otherwise it is the company itself which works out the issue. This leads to categorise its support as a *collaborative* and mainly *turn-key assist.* More specifically, among the mapped processes, the most critical ones regard the resource scheduling, the material or information feedback gathering, the product repairing and the definition of customer agreement in case of a contract re-design.

Company 2 is an American multinational society involved in the high-tech industry and operating both in the hardware and in the software market. It offers facilities and IT service, personal computer, access equipment and solutions for imaging and printing. The case study under analysis is related to the support requested by a client company operating in the express service field which needs an assistance support for 24 hours a day and for 7 days a week. In this case, it has been observed that the company product can be defined as vital: generally products are checked and continually monitored in order to avoid any occurrence of malfunctioning or failure. As soon as a request is received, it is fundamental to identify a rapid solution and correctly deliver it to the customer. Replace costs are remarkable ($\alpha \rightarrow +\infty$) and variable costs are not measurable as losses coming from a breakdown are too high to sustain ($VC \rightarrow +\infty$). In this case support is always supplied by the service provider and it is for both technical assistance and updating or re-defining customer contracts. For this reason, assistance strategies have been identified as a *turn-key* support. Key processes for handling service provision to this category of clients are the identification and proposal of a solution, which has to be as fast as possible, and the repair or customer agreement fulfilment. Technician scheduling as well as obtaining the right material at the right time and at the right place are critical activities hard to manage for the company.

Company 3 is a multinational enterprise with several subsidiaries around the world and headquarter in Japan which operates in the consumer and professional electronics industry. As a case study, it is an interesting example which shows how a big company needs often to deal with different support typologies according to the heterogeneous characteristics of its wide product portfolio. The company has a solid market position and a widely known brand which continue to be strengthened thanks to the development of new products and innovative technologies. In this context, assistance support plays a fundamental role. Hence, it is well-structured and organised and makes use of an extensive network, which can count on more than 160 assistance points just in the Italian subsidiary. Company 3 exploits different support strategies according to the typology of products sold:

- commodities products, such as MP3 players or USB data storage devices, have normally quite low replacement costs, thus a swap policy appears the best solution in most cases ($\alpha \rightarrow 0$);
- conventional products represent a quite broad range of goods, as they spread from simple domestic appliances to home PCs, video cameras or high technology televisions. In this case also the assistance support varies widely: for simple products *passive support* is the most performed, mainly making use of web. In fact, on the company's web site, customers can find FAQs sections, drivers and manuals to

download, interactive catalogues to consult for spare parts, important announcements about defective products to be returned or fixed and information about warranties. For other appliances, depending on their value, their dimensions and occurred issues, support can be classified as either *collaborative* or *turn-key*. In this situation skilled technical counselling is generally requested;

- essential products refer to business customers with whom personalised contracts are defined and specific solutions are implemented; product reparations as well as customer assistance are executed through *collaborative* and *turn-key* supports;
- vital products are components of medical equipments; their functional integrity as well as their reliability have to be always guaranteed. These products are also provided with traceability devices which help the company in promptly recognising a problem whenever it turns out. In this case, *turn-key* support is normally carried out.

The Chief Service Officer of Company 3 claims that critical processes to manage for *passive* and *collaborative* supports regard the definition of adequate business model requirements - especially for passive assist - the request routing, the identification, the proposal and the release of correct solutions. Concerning the *turn-key* support, resource scheduling, solution identification, material or information feedback gathering, product repair and proper definition of customer agreement result, among all, the most crucial and complex activities to handle.

Table 3 summarizes the results carried out from the analyzed case studies. It shows how assistance support is strongly influenced by the product characteristics. Each section of the diagram is filled with a different shade of grey colour according to the emphasis that each company gives to a specific process. Dark grey implies key processes which make critical the success of the company for the specific category of products under analysis.

The outcome deriving from the case study is in line with the content framework defined in the previous section. It confirms that there are some processes which have a critical impact on the company final outcome and thus they need to be carefully managed. For instance, it turns out that for *turn-key assist* the most crucial processes are related to resource scheduling, solution identification, product repair and the obtainment of material or customer agreements in case of contract re-negotiation. Among the *collaborative* processes, the most significant to handle regard the identification and the proposal of answers in agreement with the customer's requests as well as the releasing of suitable and adequate solutions. Quite critical results also the routing of the request to the right operator or technician. Finally, regarding the *passive* support, request routing and solution proposal are quite important and, together with the definition of business model requirements, they require significant efforts for their management.

TAKE IN TABLE 3

5 Conclusions and managerial implications

This paper emphasises the need to have adequate and useful product-process models for service operations which consider both the tangible and intangible aspects and the strategic and operational dimensions related to the service area. The literature review proves that there are several contributions which classify service considering either some specific aspects (e.g. the quality perspective) or the underlying processes mostly adapted from the manufacturing area. Moreover, the majority of works is about approaches which consider service from a strategic point of view neglecting to define a common and a shareable structure of processes, activities and performance metrics that should be performed and measured at a tactical and operational level.

This paper tries to fill the gap focusing the analysis on the industrial AS service. It proposes a framework whose aim is to provide a comprehensive mapping of the AS service processes and activities according to a configuration model which links different customer supports with product characteristics for service operations. Summarising, the proposed work could allow enterprises to: i) relate more coherently their AS strategy to their tactical and operational assistance processes according to the service operations characteristics of the managed products and ii) identify the key processes to handle in order to achieve a sustainable competitive advantage.

Further developments of this research could lead to the definition of a more exhaustive standard service-based model. The work could be addressed to additionally develop the assistance processes and their related specific performance metrics: in particular, a deeper analysis should tackle the definition and the role of proactive and customised supports, the new assistance forms which have been recently established next to the conventional ones. Moreover, the model could be enlarged in order to map all the service activities linked to the interaction between the customer and the service provider, encompassing also the pre-sale and the sale phases and their performance measurements arranged in a hierarchical structure.

Finally, it would be interesting to give an all-embracing overview of the whole processes, activities and performance indicators of a company ranging over manufacturing and service operations perspectives in a unique reference model. In this sense, it is worthwhile mentioning the current research efforts within the Supply Chain Council, aiming to develop a framework encompassing the customer centred perspective (CCOR model), the product-service designer perspective (DCOR, Design Chain Operation Reference model) and the product-service supply chain management perspective (SCOR model).

6 Acknowledgments

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7 References

Acur, N. and Bititci, U., 2003. Managing strategy through business processes, *Production Planning & Control*, 14 (4), 309-326.

Alexander, W.L., Dayal, S., Dempsey, J.J. and Vander Ark, J.D., 2002. The secret life of factory service centers, *The McKinsey Quarterly*, (3), 106-115.

Bundschuh, R.G. and Dezvane, T.M., 2003. How to make after sales services pay off , The McKinsey Quarterly, (4), 116–127.

Buzacott, J.A., 2000. Service system structure, International Journal of Production Economics, 68 (1), 15–27.

Cavalieri, S., Brun, A. and Ierace, S., 2006. After-Sales Processes in the SCOR model: a proposal and an empirical application, in Proceedings of the 14th Working Seminar on Production Economics, Innsbruck, February 20-24, 2006, (3), 25-36.

Cavalieri, S. and Corradi, E., 2002. L'evoluzione del servizio di assistenza del post-vendita: modelli di supporto, aspetti logistici ed opportunità IT (in Italian), in Proceedings of the XXVIII Convengo Nazionale ANIMP, Spoleto, October 25-26, 2002.

Chase, R.B., 1981. The customer contact approach to services: theoretical bases and practical extensions, Operations Research, 29 (4), 698–706.

Cohen, M.A., Cull, C., Lee, H.L. and Willen, D., 2000. Saturn's supply chain innovation: high value in after-sales service, Sloan Management Review, 41 (4), 93–101.

Croxton, K.L., Garcia-Dastugue, S.J., Lambert, D.M. and Rogers, D.L., 2001. The Supply Chain Management Process, The International Journal of Logistic Management, 17-32.

De Brentani, U., 1989. Success and failure in new industrial services, Journal of Product Innovation Management, 6 (4), 239-258.

Edvardssdon, B. and Olsson, J., 1996. Key concepts for new service development, The Service Industries Journal, 16 (2), 140-164.

Ellram, L.M., Tate, W.L. and Billington, C., 2004. Understanding and managing the service supply chain, The Journal of Supply Chain Management, 17-32.

Froehle, C.M. and Roth, A.V., 2007. A resource-process framework of new service development, Production and Operations Management, 16 (2), 169-188.

Goffin, K. and New, C., 2001. Customer support and new product development, International Journal of Operations and Production Management, 21 (3), 275-301.

Hayes, R.H. and Wheelwright, S.C., 1979. Link manufacturing processes and product life cycles, Harvard Business Review, 57 (1), 133-140.

Heskett, J.L., Jones, T.O., Loveman, G.W., Sasser, W.E. and Schlesinger, L.A., 1994. Putting the service-profit chain to work, Harvard Business Review, March-April, 164-174.

Johansson, P. and Olhager, J., 2003. Industrial service profiling: matching service offerings and processes, International Journal of Production Economics, 89, 309-320.

Johnson, S.P., Menor, L.J., Roth, A.V. and Chase, R.B., 2000. A critical evaluation of the new service development process. In: J. Fitzsimmons, M. Fitzsimmons, ed. New Service Development. Thousand Oaks, CA: Sage, 1-32.

Kellogg, D.L. and Nie, W., 1995. A framework for strategic service management, Journal of Operations Management, 13 (4), 323–337.

Lee, H. and Billington, C., 1995. The evolution of Supply Chain Management Models and Practice at Hewlett-Packard, Interface, 25 (5), 42-63.

Lele, M., 1997. After-Sales service-necessary evil or strategic opportunity?, Managing Service Quality, 7 (3), 141-145.

Mathe, H. and Shapiro, R.D., 1990. Managing the Service Mix: After Sale Service for Competitive Advantage, The International Journal of Logistics Management, 1 (1), 44-50.

Mathieu, V., 2001. Service strategies within the manufacturing sector: benefits, costs and partnership, International Journal of Service Industry Management, 12 (5), 451-475.

Peeling, B., 2004. Partnering service with sales, Foodservice equipment & supplies, July (6).

Reidenbach, R.E. and Moak, D.L., 1986. Exploring retail bank performance and new product development: a profile of industry practices, Journal of Product Innovation Management, 3 (3), 187-194.

Rispoli, M. and Tamma, M., 1992. Beni e Servizi, cioè prodotti (in Italian), Sinergie, 28.

Sampson, S.E., 2001. Understanding service businesses: Applying principles of the unified services theory, 2nd ed. New York: John Wiley & Sons.

Sampson, S.E. and Froehle, C.M., 2006. Foundations and implications of a proposed unified services theory, Production and Operations Management, 15 (2), 329-343.

Schmenner, R.W., 1986. How can service business survive and prosper?, Sloan Management Review, 27 (3), 21–32.

Shostack, G.L., 1984. Designing services that deliver, Harvard Business Review, 62 (1), 133-139.

Silvestro, R., Fitzgerald, L. and Johnston, R., 1992. Towards a classification of service processes, International Journal of Service Industry Management, 3 (3), 62–75.

Supply Chain Council, 2008. Supply Chain Operations Reference model - version 9.0, Customer Chain Operations Reference model, Design Chain Operations Reference model, Available from: www.supply-chain.org [Accessed 11 June 2008].

Thoben, K.D., Jagdev, H. and Eschenbaecher, J., 2001. Extended Product: Evolving Traditional Product concepts, in Proceedings of the 7th International Conference on Concurrent Enterprising: Engineering the Knowledge Economy through Co-operation, Bremen.

Tinnilä, M. and Vepsäläinen, A.P.J., 1995. A model for strategic repositioning of services, International Journal of Service Industry Management, 6 (4), 57–80.

Tore, M. and Uday, K., 2003. Design and development of product support and maintenance concepts for industrial system, Journal of Quality Management Engineering, 9 (4), 376-392.

Tables

<table>
<tr><td rowspan="2">STRATEGIES</td><td>STRATEGIC MODELS</td><td colspan="2">Mathe and Shapiro (1990), Heskett et al. (1994), Edvardsson and Olsson (1996), Mathieu (2001),</td></tr>
<tr><td>CONFIGURA-TION MODELS</td><td colspan="2">Chase (1981), Schemenner (1986), Silvestro et al. (1992), Tinnilä and Vepsäläinen (1995), Kellog and Nie (1995), Lele (1997), Buzacott (2000), Cohen et al. (2000), Johansson and Olhager (2003)</td></tr>
<tr><td rowspan="3">PROCESSES</td><td>PRODUCT-BASED MODELS</td><td colspan="2">Hayes and Wheelwright (1979), Lee and Billington (1995), Croxton et al. (2001), SCOR model (Supply Chain Council, 2008)</td></tr>
<tr><td rowspan="2">SERVICE-BASED MODELS</td><td>STRATEGIC PERSPECTIVE</td><td>Shostack (1984), Reidenbach and Moak (1986), Johnson et al. (2000)</td></tr>
<tr><td>TACTICAL-OPERATIONAL PERSPECTIVE</td><td>ASCOR model (Cavalieri et al., 2006), CCOR model (Supply Chain Council, 2008)</td></tr>
</table>

Table 1. Literature contributions for service operations.

LEVEL 1	ASSISTANCE PROCESS		
LEVEL 2	**Passive-Assist**	**Collaborative-Assist**	**'Turn-Key'-Assist**
LEVEL 3 ACTIVITIES	Define business model requirements	Receive inquiry/request	Receive inquiry/request
	Receive inquiry/request	Authorize request	Authorize request
	Authorize request	Route request	Route request
	Route request to identify solution	Identify solution	Scheduling
	Propose solution	Propose solution	Identify solution
	Release solution to customer	Distribute solution	Propose solution
	Close request	Release solution to the customer	Obtain materials or feedback
		Close request	Repair product or obtain customer agreement
			Dispose materials
			Close request

PROCESS NAME	**'Turn-Key' Assist process :"Repair product or obtain customer agreement"**
PROCESS DEFINITION	The process of preparing, decomposing the product, replacing the part and re-assembling the product. The product is fully operational upon completion. In case the request is a re-negotiation of the assist contract, it is necessary to refine the counter offer within constraints and obtain agreements with the customer
RELATED METRICS	• Annualized Service Event Rate: n° of service calls per system per year • Customer Commit Resolution Time met: % of time a customer problem/question is resolved within the agreed upon time • First Time Fix Rate: % of time the problem was fixed during the first contact with the customer • Repair Product Total Cost: Process costs. It includes direct and indirect cost

Table 2. An insight of the suggested service-based model for AS processes.

	Company 1 Essential product	Company 2 Vital product	Company 3 Wide portfolio of products
No Assist			
Passive Assist	Define business model req.	Define business model req.	Define business model req.
	Receive inquiry/request	Receive inquiry/request	Receive inquiry/request
	Authorize request	Authorize request	Authorize request
	Route request to identify solution	Route request to identify solution	Route request to identify solution
	Propose solution	Propose solution	Propose solution
	Release solution to Customer	Release solution to customer	Release solution to customer
	Close request	Close request	Close request

Collaborative Assist	Receive inquiry/request	Receive inquiry/request	Receive inquiry/request
	Authorize request	Authorize request	Authorize request
	Route request	Route request	Route request
	Identify solution	Identify solution	Identify solution
	Propose solution	Propose solution	Propose solution
	Distribute solution	Distribute solution	Distribute solution
	Release solution to customer	Release solution to customer	Release solution to customer
	Close request	Close request	Close request
turn-key Assist	Receive inquiry/request	Receive inquiry/request	Receive inquiry/request
	Authorize request	Authorize request	Authorize request
	Route request	Route request	Route request
	Scheduling	Scheduling	Scheduling
	Identify solution	Identify solution	Identify solution
	Propose solution	Propose solution	Propose solution
	Obtain material or feedback	Obtain material or feedback	Obtain material or feedback
	Repair product or obtain customer agreement	Repair product or obtain customer agreement	Repair product or obtain customer agreement
	Dispose material	Dispose material	Dispose material
	Close request	Close request	Close request

Table 3. Overview of the main processes analysed in the three case studies.

Figures

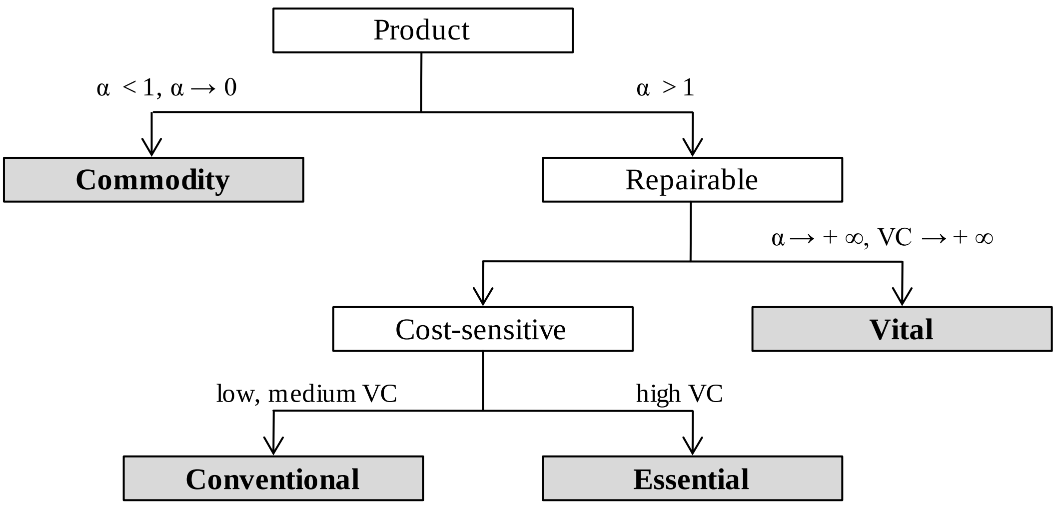

Figure 1. Classification of a product according to its service requirements.

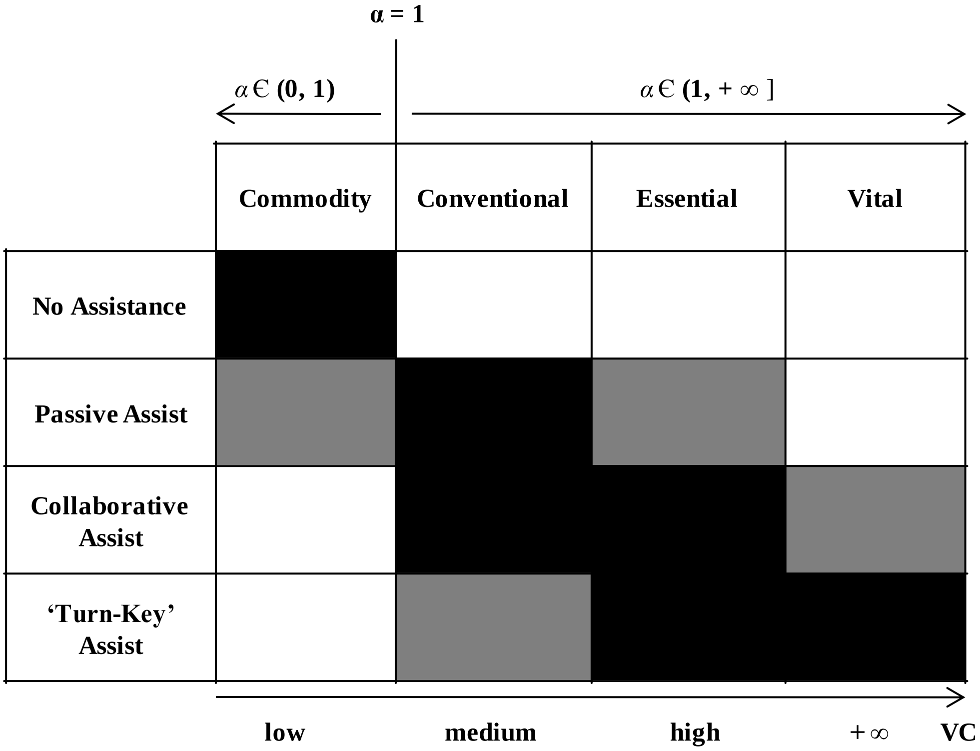

Figure 2. The proposed configuration model.

Exploring the Causal Relationships of KPIs in After Sales Service Systems

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Abstract. A plethora of research and industrial contributions emphasizes the economic and strategic role of services in adding further value to a product throughout its lifelong journey with the customer. However, there is still a limited comprehension of the dynamics underlying After-Sales (AS) processes along the whole service network - which usually encompasses a manufacturer, spare parts wholesalers/retailers and technical assistance centres - till the final user. AS can be no more considered as a mere corporate function, but rather as a series of interconnected activities involving more independent organizations, each one having different objectives and perspectives to be properly aligned. Starting from previous contributions of the same authors on this research topic, aim of the paper is to examine AS as a complex system of interlinked processes, to elaborate a proposal of the main Key Performance Indicators (KPIs) which can take into account the various perspectives of the different actors involved, and, as a main result, to explore the most relevant causal relationships among these KPIs.

Keywords: After-Sales Service System, Product-Services, Performance Measurement System, Systems Thinking, System Dynamics

Introduction

Given the high market pressure, the increased competition in several industries and the reduced margins on undifferentiated products, the search for new business opportunity is emphasizing the strategic and economic role of service activities as powerful add-ons to the mere delivery of a manufactured product. The provision of services can be both an effective commercial tool during the transactional phase of product sale and a means of enduring a durable relation with the customer. In the long term, this strategy can ensure to a manufacturer and its service network stable and long-lasting cash flows and empower the degree of retention and loyalty of the client. However, despite the potential advantages, this transition from a pure manufacturer to a product-service provider is not immediate and, if not properly managed, it could have some negative side-effects [10], [18].

Provision of services require the adoption of specific forms of organizational principles, structures and processes, which could constitute a major managerial challenge for a manufacturer [9]. In addition, what is usually neglected in the industrial practice is the involvement of the whole downstream service network which acts as the real front-end with the final user. As a service manager of an important multinational company operating in the consumer electronics industry stated, "*we do not have any direct interaction with our customers, since when they need to buy our products they go to large multi-branded retailing chains; when they have specific claims, they call at our contact centres, which we have outsourced to an external partner; when they need* *repair or refurbishment activities they go to our technical assistance centres, which in most cases are still run in a "mom-and-pap" way*". Hence, AS service cannot be considered as a mere ancillary function within a manufacturing company but it needs to be re-interpreted as a more complex system which encompasses a series of primary and supporting processes and involves independent organisations with very often conflicting objectives and behaviours. Thus it is essential to: i) be able to develop a Performance Measurement System (PMS) which incentives all the different actors and aligns their perspectives through a common set of measurable KPIs and ii) explore and understand the beneath interrelationships among these KPIs.

Regarding the scientific literature, contributions deal essentially with descriptive models which identify and depict the main elements that constitute the service system. However, they do not capture the underneath interrelations and its intrinsic dynamic nature. Moreover, the main works propose linear models which cover just local aspects related to the service management [11], [7] without providing a whole picture of the AS system and without embracing different perspectives and effects.

An appealing challenge is to define a model which highlights the causal relationships existing among some key indicators and explore the effect that they exert on the management of the main processes and on the enhancement of the overall company performance. The analysis proposed in this paper aims at emphasizing the causal-loop relationships existing within the main KPIs of the AS system, taking into account: i) the *customer perspective*, in terms of customer perceived value and repurchasing attitudes; ii) the *service network* operational results; iii) the *company perspective*, in terms of profitability and investment strategies.

The paper is organized as follows: §2 explains the meaning of modelling a global system considering overall structures, patterns and feedback loops, and it gives some insights about the adopted methodologies, namely *Systems Thinking* and *System Dynamics*; §3 reports the causal relationships among the KPIs for each of the three identified perspectives and the main literature contributions used to build, strengthen and reinforce the elements and the relations pinpointed. §4 shows the developed model which embraces together all the three perspectives while §5 draws some conclusions and further developments of the work.

Systems Thinking and System Dynamics

The term *System* is used for many purposes ranging over economic, political and ecological issues. A system consists of distinguishable elements which are linked to each other in a certain structure. The nature of the relations can be flows of material, information as well as cause and effect loops [6]. Systems are generally open as they interact with elements of the environment and are related each other through a hierarchical architecture. Moreover, every system is active and changes its status over time: in fact, without the recognition of time, systems would be static and not realistic. According to [16], many advocate the development of *Systems Thinking* as the ability to see the world as a complex system where everything is connected to everything else. It is argued that if people had a holistic worldview, they would act in consonance with the long-term best interests of the system as a whole, identify high leverage points and avoid policy resistance. An action of one element causes effects on other elements altering the state of the system and, therefore, leading to further actions to restore the balance. These interactions or feedbacks are usually the main reasons for the complex behaviour of a system.

Modelling complex structures such as AS service systems requires a powerful tool or method which helps to understand complexity, to design better operating polices and to guide change in systems: *System Dynamics* is a method used to represent, analyse and explain the dynamics of complex systems along the time. The main goal of System Dynamics is to understand, through the use of qualitative and quantitative models, how the system behaviour is produced and to exploit this understanding to predict the consequences over time of policy changes to the system [12]. In the field of Supply Chain Management there are several applications of System Dynamics – [1], [16] report the main uses – while contributions that explore the main causal relations of KPIs are still quite few.

Referring to the specific case of this paper, Systems Thinking is adopted as the approach to foster the understanding of the logic underlying performance generation and to identify the factors that may trigger off effective changes in the AS service system. System Dynamics will be exploited in further contributions to make simulation and what-if analyses on the developed Systems Thinking logic model.

AS service perspectives and related causal relationships

As outlined in §1, an AS service system can be depicted as powered by three actors: the customer, the manufacturing company and the service network. The strong interaction among them is the key for managing the AS activities and achieving high performance results.

The *customer* is the main trigger for the AS business: his/her satisfaction and, hopefully, loyalty have a significant influence on the company profitability. Moreover, his/her continuous involvement is the fundamental basis for developing new services and co-creating value.

The *company* has the goal of being competitive, growing and achieving loyalty from its customers through the Product-Services offered. The company does not act alone but it operates within a *service network*, where different actors (e.g. spare parts wholesalers, retailers and technical assistance centres) play to guarantee a reliable, responsive and flexible service to the customers.

These powerful and intense interactions generate results that the company aims at measuring through some KPIs. A PMS for analysing the main AS KPIs has been proposed by the same authors in a previous paper presented at APMS Conference 2008 [8]. After an in-depth literature review and a validation with an industrial case study, the proposed PMS provides an integrated and multi-levelled set of measures for the AS area. It classifies metrics considering both strategic and operational perspectives. Indicators have been arranged in a hierarchical structure according to the following construction:

- *performance attributes* (reliability - RL, responsiveness - RS, agility - AG, assets - AM, costs – CO and growth - GR), which are groupings for metrics used to explain company strategies and to analyse and evaluate them against others with competing approaches;
- *level 1 metrics*, which are strategic indicators (Key Performance Indicators - KPIs) used to monitor the overall performance of the company and its service network;
- *level 2* and *level 3 metrics*, respectively tactical and operational indicators, which serve as diagnostic measures to identify critical processes and variations in performance against the plan.

For the sake of clarity, the main *level 1 metrics (KPIs)* have been reported and associated to the proper performance attributes in Table 1.

Table 1. Performance attributes and associated Level 1 metrics (KPIs) for AS

	PERFORMANCE ATTRIBUTES					
LEVEL 1 METRICS (KPIs)	**RL**	**RS**	**AG**	**CO**	**AM**	**GR**
Perfect Assist Completion	X					
Assist Cycle Time		X				
Assist Agility			X			
Assist-Warranty-Spare Parts Costs				X		
Return on Assist Assets					X	
Assist Operating Income						X
Customer Loyalty						X

Goal of this section is to explore and highlight the causal relationships existing among the main AS KPIs according to the three different players' perspectives. To support the model building, a literature analysis has been reckoned to be essential: the main contributions have helped to make and reinforce the identified relations. In literature there are few contributions that deal with service and, more specifically, with AS service as an overall system. Some contributions can be found in [3], [6] and [5]. However, it turns out that most of the analyses reported regard just a portion of the entire system with a local perspective on few specific aspects.

The customer perspective

The *customer perspective* is the underlying rationale that derives the customer repurchasing attitude based on his/her needs and wants. *Customer loyalty* is the metric explored in this loop. The service management literature discusses the links between customer satisfaction, customer loyalty and profitability. This theory argues that:

- customer satisfaction is the result of a customer perception of the value received in a transaction or relationship relative to the value expected from transactions or relationships with competing vendors [19]. In accordance with [13], [7], customer value is a balance between perceived benefits and perceived costs and sacrifices.
- loyalty behaviours, including relationship continuance and recommendation, such as positive word of mouth or advertising, result from customer belief that the amount of value received from one supplier is greater than that available from other suppliers. Loyalty, measured in the form of customer retention, creates increased profits to the company through enhanced revenues, reduced costs to acquire customers, lower customer-price sensitivity, and decreased costs to serve customers familiar with a firm service delivery system.

Other proponents who believe that customer satisfaction influences customer loyalty, which in turn affects the profitability of a company are [5], [11] and [14].

Figure 1 shows the main elements which make the customer perceived value and the relations to customer satisfaction (measured through *Recruitment rate*) and loyalty. Moreover, from the graph it turns out that the demand of product-services is generated by the repeated business of loyal customers together with the assist requests coming from new customers.

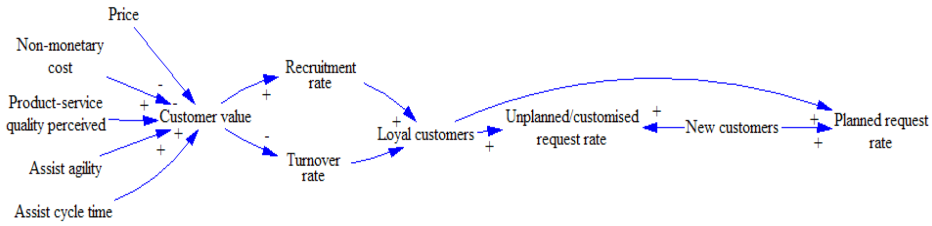

Figure 1. The customer perspective

The service network perspective

The *service network perspective* is related to operational results that the service network can achieve through its ability in satisfying both planned and unplanned/customised pending requests. This area depicts the relations existing among:

reliability (RL), measured by the combinations of *perfect assist completion* of planned and unplanned/customised requests;

responsiveness (RS), measured through the *assist cycle time*;

agility (AG), measured through *assist agility*.

The performance and operational outcomes strongly depend on the interrelations among all the actors of the service network and on the effectiveness of their coordination. Some interesting contributions that helped to build the loop can be found in [6], [4] and [16]. The main relations are shown in Figure 2.

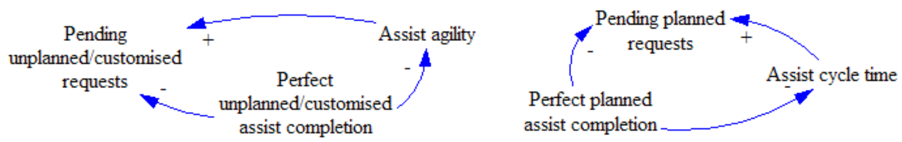

Figure 2. The service network perspective

The company perspective

The *company perspective* is more related to the financial performance results which justify the costs and investments carried out on the AS unit. It aims at identifying the relations among:

costs (CO), measured through the *assist-warranty-spare parts costs*;

growth (GR), measured in terms of *assist operating income*;

asset management (AM) investment strategies, measured in terms of *return on assist assets*.

This diagram starts with the generation of AS revenue, that is the key to profitability and company growth [7]. According to [15], it is important that a company understands the way a service system can be improved over time through investments in order to achieve high efficiency, effectiveness and sustainability. Literature contributions that have been analysed to build this loop are [2] and [17]. The main relations are shown in Figure 3.

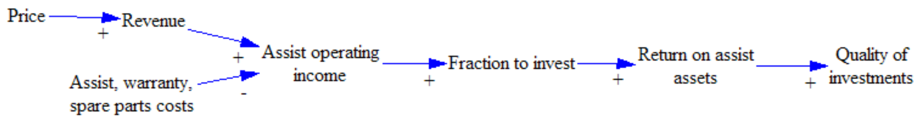

Figure 3. The company perspective

The developed model

From the analysis reported in §3, it comes out that the main scientific works describe locally or partially the AS service system elements and relations. According to the three main identified actors, the customer perspective can count on numerous contributions since this is a topic widely covered and argued by the marketing literature. Few works dealing with the operations management field, instead, have been found covering the company and the service network perspectives: this may be due to the fact that AS is still a relatively new topic not yet completely exploited. Examples of complete service or AS service system modelling are also quite scant. The model displayed in Figure 4 aims at describing the whole AS system and at capturing the interactions among the

KPIs reported in Table 1. It has been conceived according to a Systems Thinking logic and is based on the following hypothesis:

it represents the behaviour of the AS service system as an independent business unit which strongly interacts with a downstream service network;

it refers to services supporting the product (Product-Services), where the service focus is on basic services such as documentation, installation, help desk, repairs, upgrades, reconstruction and recycling.

The model highlights the interlinked relations which make up the AS system and how the three perspectives are related each other. Referring to the dotted lines in Figure 4, starting form the customer perspective, the perceived *Customer value* is derived from some *non-monetary costs*, the *perceived quality of product-services*, the service network operational results - in terms of responsiveness (*Assist cycle time*), flexibility (*Assist agility*) and indirectly reliability (*Perfect planned and unplanned/customised assist completion*) – and the *price* set up by the company. Moreover, the customer purchasing requests of loyal customers (measured in terms of *Planned and Unplanned/customised request rate*) have an impact both on the service network, which needs to be organised to satisfy the demand (*Pending planned and unplanned/customised requests*), and the company costs (*Assist, warranty, spare parts costs*). Regarding the company perspective, as just mentioned, operational costs depend on the number of customer requests (*Planned and unplanned/customised requests*); revenues are influenced by the number of reliable assistance interventions performed by the service network (*Perfect planned and unplanned/customised assist completion*). The company, furthermore, if it is profitable, can make strategic investments to improve its tangible and intangible assets (Q*uality of investments*) and consequently the relations with its service network.

In conclusion, as also Figure 4 shows, AS system and its dynamics cannot be depicted through a linear representation: there are lots of interlinked relations and feedback loops that need to be considered and explored.

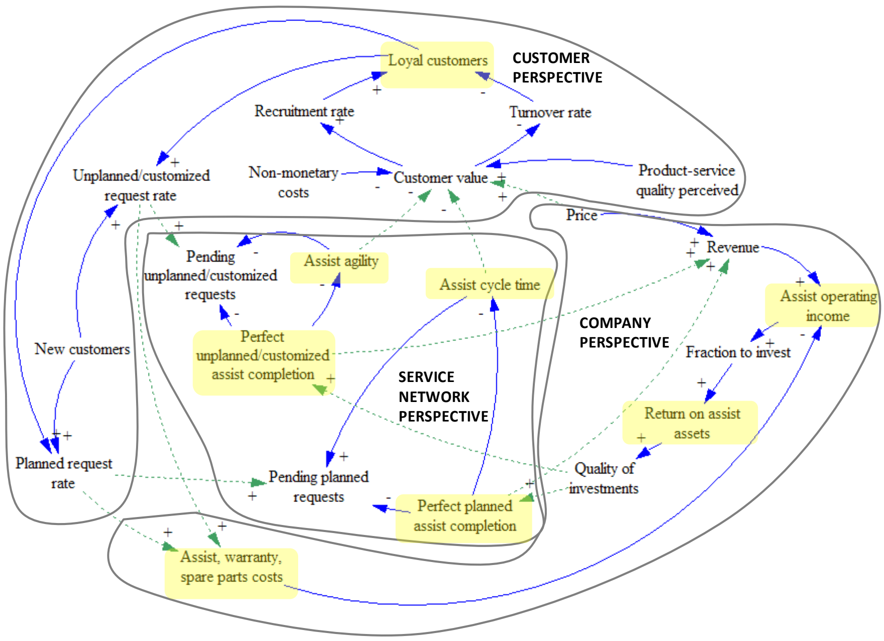

Figure 4. Relationships within the AS service system and its performance results

Conclusions and further developments

Although in the past and present years a considerable amount of literature has dealt with the topic of service modelling, most of these contributions are about descriptive models which depict scenarios in a static and linear form without any evaluation analysis of the underneath dynamics. In this paper, the causal-loop relationships existing among AS performance KPIs and their connections with the three main identified actors, have been explored and supported by a literature analysis. The proposed model has been carried out through a Systems Thinking approach in order to identify the key logic relations; it is based on some assumptions and actually it is strongly theoretically based. Further work will imply a more massive use of System Dynamics methodology and, in particular, it will regard the identification of causal diagrams showing stock and flow structures, the definition of mathematical and logic equations, simulation runnings and what-if analyses. To make a quantitative examination, data will be collected through a survey conducted within the ASAP Service Management Forum network (http://www.asapsmf.org/), an Italian forum finalized to the promotion of cultural and scientific activities in the AS area, with specific know-how in the automotive, domestic appliances, machinery and digital systems industries. Final goal will be to identify the main prior relations among the KPIs for some specific industries and, consequently, find out the beneath related AS processes to enhance.

References

1. Angerhofer, B. J., Angelides, M. C.: System dynamics modelling in supply chain management: research review. In: Proc. of the 2000 Winter Simulation Conference, pp. 342-351, (2000)
2. Camerinelli, E., Cantu, A.: Linking supply chain measures with financial performance: a framework.Technical Report, Supply Chain Council Research (2006)
3. Crespo, M.A., Blanchar, C.: A decision support system for evaluating operations investments in high-technology business. Decision Support Systems, 41, 472-487 (2006)
4. Gaiardelli, P., Saccani, N., Songini, L.: Performance measurement systems in the after-sales service: an integrated framework. International Journal Business Performance Management, 9, 2, 145-171 (2007)
5. Heskjett, J., Jones, T., Loveman, G., Sasser, W., Schlesinger, L.: Putting the service-profit chain at work. Harvard Business Review, March-April (1994)
6. InCoCo’s 2007, EU-funded project, www.incoco.net/
7. Kingman-Brundage, J., George, W.R., Bowen, D.E.: “Service logic”: achieving service system integration. International Journal of Service Industry Management, 6, 4, 20 (1995)
8. Legnani, E., Cavalieri, S.: Measuring the performance of after-sales service processes. A hierarchical approach. In: Proc. of APMS 2008, International Conference on Innovations in network, pp. 359-368, Espoo, Finland (2008)
9. Oliva, R., Kallenberg, R.: Managing the transition from products to services. International Journal of Service Industry Management, 14, 2, 160-172 (2003)
10. Potts, G.W.: Exploiting your product’s service life cycle. Harvard Business Review, 66, 5, 32-35 (1988)
11. Rust, R.T., Metters, R.: Mathematical models of service. European Journal of Operational Research, 91, 427-439 (1996)
12. Santos, S.P., Belton, V., Howick, S.: Adding value to performance measurement by using system dynamics and multicriteria analysis. International Journal of Operations & Production Management, 22, 11, 1246-1272 (2002)
13. Sawhney, M., Balasubramanian, S., Krishnan, V.V.: Creating growth with services. MIT Sloan Management Review (2004)

14. Schneider, B., Bowen, D.E.: Winning the service game. Harvard Business School Press, Boston, MA (1995)
15. Spohrer, J., Maglio, P.P., Bailey, J., Gruhl, D.: Steps toward a science of service systems. Computer, IEEE Computer Society Press, 40, 1, 71-77 (2007)
16. Sterman, J.: Business dynamics: system thinking and modelling for a complex world. McGraw-Hill (2000)
17. Supply Chain Council (SCC): Supply Chain Operations Reference model (SCOR), version 9.0, www.supply-chain.org (2008)
18. Wise, R., Baumgartner, P.: Go downstream - the new profit imperative in manufacturing. Harvard Business Review, 77, 133-141 (1999)
19. Zeithaml, V.A., Parasuraman, A., Berry, L.L.: Delivering quality service: balancing customer perceptions and expectations. Free Press, New York (1990)

MANAGING AND CONTROLLING PROCESSES IN PRODUCT-BASED SERVICE NETWORKS

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Abstract:

The increasing importance of the service provision within manufacturing companies calls for the introduction of a proper system of governance and control along the overall product-based service chain. The literature dealing with product support services is highly fragmented and contributions considering the whole supply chain or network are very scarce. This paper aims at filling this gap by proposing a conceptual performance measurement model for a product-based service network. Different set of performance indicators are developed depending on the type of assistance process (passive, collaborative and "turn-key"). The management perspective is extended from one company to a whole service network and a brief application case allows to clarify how the model can be applied to different actors. A higher number of case studies would be useful to further develop and complete the model.

Keywords: product-based service network, support processes, service chain relationships, performance management.

INTRODUCTION

The evolution of cultural and sociological models has progressively forced companies to change their proposition from the "sale of product" to the "sale of use" [3]. The transition from product manufacturers into providers of knowledge-intensive systemic solutions, has become the main way to maintain a competitive differentiation, in terms of financial, strategic and marketing benefits [17]-[18] which an industrial company cannot refrain from, and therefore representing a major managerial challenge [6]-[22].

Among the different forms of service provisions, Product-extension [10] or product-based services, such as assistance support, have acquired a strategic role within manufacturing companies. In fact, they are a source of: (i) revenue, (ii) customer satisfaction, (iii) potential competitive advantage, and (iv) success rate of new products [9]. Since many actors, with different roles, strategies and competences are involved in the service provision, it becomes crucial to create a common and shared system of governance and control along the overall product-based service chain, adopting an integrated perspective to performance and process management.

This paper moves from these considerations and proposes a conceptual performance measurement model for a product-based service network. In particular, the next section provides the literature background about the measuring of product-based service processes such as after-sales service, through appropriate Performance Measurement Systems (PMSs) and the impact of the insourcing-outsourcing decision and buyer-supplier relationship on PMSs development. Section three presents the original model. Finally, a discussion and directions for future research are proposed.

BACKGROUND

Measuring the performance of product-based service systems and processes

An extensive review of the existing body of knowledge about PMSs for product service systems and processes is proposed by [7], who classify the main theoretical contributions along with the following perspectives: *i)* product life-cycle; *ii)* after-sales strategy; *iii)* spare parts logistics and *iv)* supply chain and process-oriented approach.

The reported analysis points out that literature dealing with product support services presents a highly fragmented picture. Very scarce is the presence of contributions considering the whole supply chain or network. Recently, nonetheless, some contributions have been proposed in this sense. For instance, a framework which integrates the features of some existing models [11]-[16]-[27] to carry out an all embracing PMS for after-sales services is proposed by [8]. It is articulated into four levels (strategic business area, process, activity and development/innovation) and it addresses several performance areas at each level, giving emphasis to both efficiency and effectiveness measures as well as to internal and customer-oriented ones. Another interesting input regards the results achieved by the EU-funded project InCoCo-S [21], where a reference model for the collaboration between service providers and manufacturers have led to the definition of processes, metrics and related best practices to perform. Finally, [12] propose a three-level metric framework for after-sales processes, encompassing six performance attributes: Reliability, Responsiveness, Agility, Cost, Asset Management and Growth.

Buyer-supplier relationships in product-based service networks

The issue of vertical integration in product-based service chains or networks has been treated by research focusing on the provision of field services [1]-[2]-[9]-[14]-[15]-[19]-[23]. According to these authors, different drivers influence the choice of the after-sales support channel and the level of vertical integration [2]-[9]-[14]-[15]-[23]. [19] observes that often the different factors may be in trade-off, leading to choices that are "maladjusted" in some ways. Firms try to compensate maladjustments by increasing internal resources and competence, or by reinforcing governance mechanisms. In particular, when outsourcing decision are made, the importance of supply-chain relationships is critical in order to retain the value related with the customer contact and to craft differentiation-related advantages. [20] suggests that the more the service is unstandardized, strategic and specialized, the more it is important "to retain service processes internally or to align with external partners in close relationships", and, as well, to retain the "positive bonds" with end customers as a way to achieve competitive advantage in the long run.

On a more general perspective, buyer-supplier relationships have been treated widely in literature, although with few references to service provision in product service systems. [26] classify buyer-seller relationships according to the supply chain complexity and the exchanged product/service strategic relevance. Both aspects of complexity suggest interdependence between trading partners: relationships that are both strategically important and complex to manage, therefore, should be treated collaboratively.

Moreover, as suggested by [24], the relationship has an influence on the performance management system:

- the higher is the product/service strategic relevance, the higher the buyer need to monitor and control the relevant managerial processes. Incentive systems can be used by the buyer to induce suppliers at controlling specific processes, when the product/service is not relevant for them,
- the lower is the complexity in managing the relationship with the seller, the easier for the buyer to impose its performance measurement model. On the contrary, the higher the complexity, the higher is the buyer's need to collaborate with suppliers in defining a common PMS.

THE PROPOSED MODEL

As shown in the previous section, literature addressing the performance measurement for product-based services, adopting a network perspective and considering the relationship among actors is still very scarce. In such a context this paper aims at filling this research gap by proposing a preliminary framework for performance management in product-based service networks.

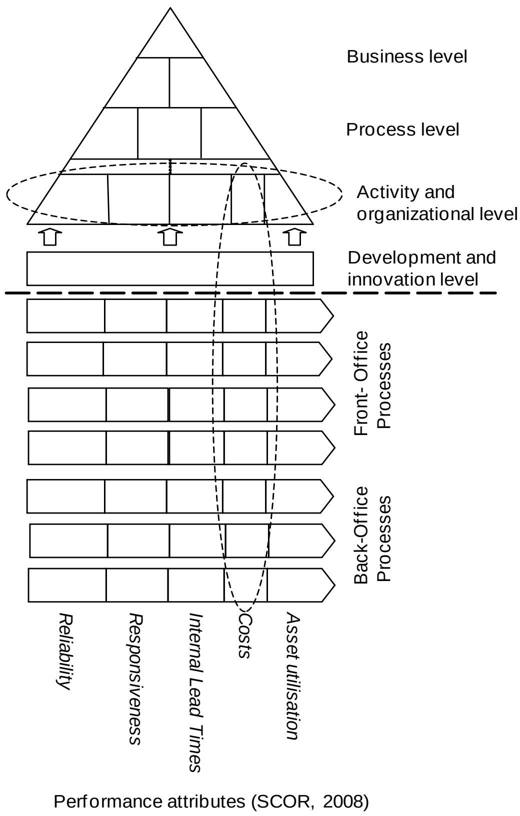

Figure 1: PMS proposed by [5]

The model structure is based on a previous work by [5] who developed a PMS suitable for a single company operating in a service network, shown in Figure 1. The PMS integrates a multi-level reference framework (see [7]) with the main back-office (BO) and front-office (FO) assistance processes, in accordance with the SCOR model formalism [4].

However, this PMS does not distinguish among different types of assistance: it has a limited applicability just on a specific typology. For this reason, it has been enlarged according to the work provided by [13] who classify the assistance processes in three categories, as follows:

- *passive assist*, where contract-related information and documentation are prepared and updated. Pre-packaged solutions to products/services inquiries or issues are offered, as diagnosed solely by the customer or customer-agent,
- *collaborative assist*, where contract-related information and documents for performance expectations are defined and checked and pre-packaged or custom solutions to products/services requests or issues are provided; inquiries are diagnosed jointly by the customer or customer-agent and the assistance provider,
- *'turn-key assist'*, where contract-related information and documents for performance expectations are monitored and checked and mainly custom solutions are

implemented; diagnosing activities are performed primarily or solely by the assistance-provider.

The updated version is reported in Figure 2, while a description of each assistance process is reported in Table 1.

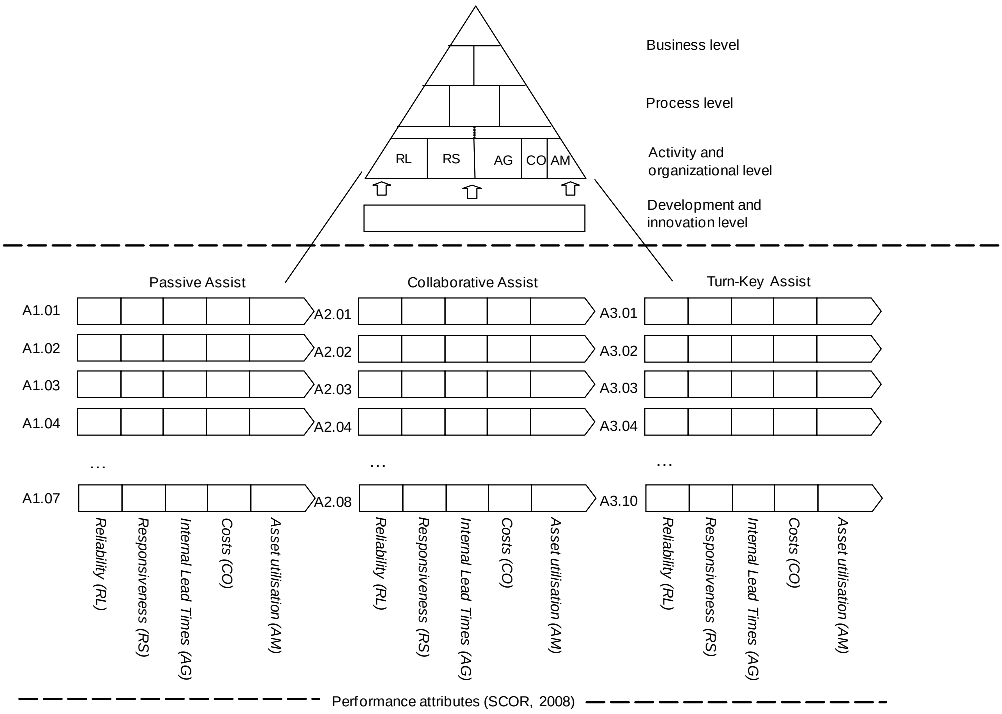

Figure 2: The proposed model

ASSISTANCE PROCESS		
A1 Passive-Assist	**A2 Collaborative-Assist**	**A3 'Turn-Key'-Assist**
A1.01 (BO): Define business model requirements	A2.01 (FO): Receive inquiry/request	A3.01 (FO): Receive inquiry/request
A1.02 (FO): Receive inquiry/request	A2.02 (BO): Authorize request	A3.02 (BO): Authorize request
A1.03 (BO): Authorize request	A2.03 (BO): Route request	A3.03 (BO): Route request
A1.04 (BO): Route request to identify solution	A2.04 (FO): Identify solution	A3.04 (BO): Scheduling
A1.05 (FO): Propose solution	A2.05 (FO): Propose solution	A3.05 (FO): Identify solution
A1.06 (FO): Release solution to customer	A2.06 (FO): Distribute solution	A3.06 (FO): Propose solution
A1.07 (FO): Close request	A2.07 (FO): Release solution to customer	A3.07 (BO): Obtain materials
	A2.08 (FO): Close request	A3.08 (Front-office) Repair product
		A3.09 (Front-office) Dispose materials
		A3.10 (Front-office) Close request

Table 1: Processes and activities of the proposed model

A set of performance metrics is assigned to each type of assistance activity [12]: due to space restrictions Table 2 reports only the indicators related to the Turn-Key assistance process.

TURN-KEY ASSIST	A3.01	*RELIABILITY (RL)*	N° of repeated compliant calls from the same customer	*RESPONSIVENESS (RS)*	Time the server is down; Call center waiting time; Customer calls abandon rate
	A3.02				Average authorization request time
	A3.03		Wrong routings rate		Average routing time
	A3.04				Average time for scheduling technical assistance
	A3.05				Average time for diagnosis
	A3.06				Average time to propose a solution
	A3.07		% interventions with wrong or missing spare parts; spare parts delivery quantity accuracy; spare parts delivery damage free; spare parts delivery location accuracy		Waiting time for delivery spare parts; Maximum spare parts delivery time
	A3.08		Perfect technician intervention rate Assist resolution rate Mean Time Before Failure Mean Time Between Failure First Time Fixed Rate		MTTR (Mean Time To Repair)
	A3.09				Average time for material disposal
	A3.10		Assist payment documentation accuracy; Intervention report accuracy		Average time to close requests

Table 2-a: Reliability (RL) and Responsiveness (RS) proposed metrics (Turn-Key assistance process)

TURN-KEY ASSIST	A3.01	*AGILITY (AG)*		*COST (CO)*	Average call center cost	*ASSET UTILISATION (AM)*	
	A3.02		N° of contract-conditions modified				
	A3.03						
	A3.04		%of last minute interventions added in the scheduling				
	A3.05						
	A3.06						

	A3.07		Time to manage urgent and unplanned spare parts requests		Average cost to obtain spare pars		
	A3.08		Time required to perform a new and customized request		Average repair intervention cost		
	A3.09				Average cost for disposal of material		Dispose of material for recycle rate Disposal material rate Rebuild or recycle rate
	A3.10		N° interventions per employee		Warranty cost as % of revenues Warranty cost per unit shipped Assist outsourcing cost		

Table 2-b: Agility (AG), Cost (CO) and Asset Utilisation (AM) proposed metrics (Turn-Key assistance process)

Moreover, the proposed model extends the management perspective from one company to a whole service network, consisting of one (global) focal firm (owning a brand and/or providing a main product/service), and a network of third party service providers. The focal firm, according to its strategy and its competences, may decide to internally perform some activities and outsource others to third parties, building different forms of relationship with them.

In such a context, the model shown in Figure 2 can be applied to each actor involved in the service provision as a sequence of systemic and hierarchical PMSs, integrated at the process level, as a peculiar measurement dimension for the overall service network. Moreover, as suggested by [24] companies' PMSs may be aligned in different ways according to both the strategic relevance of the product/service exchanged and the complexity in managing buyer-seller relationship [25]. In particular:

- in an *open market* negotiation context, characterized by a time limited collaboration that finishes as soon as the operational transaction between the parties ends, PMSs of different companies are independent and not linked at any level. In this case, according to Table 1 and 2, each actor of the service network can independently perform and, consequently, measure some activities for each of the three types of assistance support. The decision of which indicators to measure, among all the proposed ones, depends on the strategies of each company involved in the service network. Firms can monitor different dimensions, ranging from financial results to non-financial performance, from process and activity efficiency to effectiveness. Also the companies' perspective is different: some companies are more oriented to short-term results, others to a longer term perspective,
- *in a co-operation context* even though the action of the focal company is one of managing risk driving the network companies to implement independent and not correlated PMSs, third party service providers and focal company may cooperate at the definition, through contracts, of operative KPIs to be monitored, controlled and evaluated. The third party service providers is then urged to cooperate with the focal

company to define in the contract a common set of operative performances which have to be measured in order to maintain a high customer satisfaction. Anyway they can continue to perform and, consequently, measure their activities adopting specific indicators accordingly to their own strategy,

- in a *co-ordination* context the focal firms exploits its dominant role in the service network, imposes its strategy and organization structure to the other partners, requiring them to implement a PMS completely integrated and correlated. As a consequence the consistency and alignment among the metrics and actual performance of the firms at the activity levels is needed in order to achieve and preserve success in the long-term,
- in a *collaboration* context characterized by a high degree of complexity in company relationships coupled with a high relevance of product/service, the focal company is required to integrate its PMS with the ones adopted by the partners, at every level. Although the focal company might be interested in monitoring specific KPIs of the whole service network at process level, it has no power to impose its PMS to the third parties. Therefore the provision of incentives can be used by the company to promote supplier coordination.

As an example, an application case of a company operating in a B2B market is represented in figure 3 and briefly described hereafter. The service network depicted in Figure 3 is made of three companies, which, according to their own strategies, manage all back and front office service activities and implement a consistent and structured PMS:

- Company 1, the focal company, provides all the three types of assistance mentioned in the previous section (passive, collaborative and turn-key assist). Accordingly to its competences, it manages internally some assistance processes (A1.01, A1.03 and A1.07; A2.02, A2.07-A2.08; A3.02, A3.04, A3.10) while others are outsourced. Moreover Company 1 has a long term perspective, thus it tends to monitor all performance indicators,
- Company 2, which is one of the third party providers, manages on behalf of Company 1 processes A1.02, A1.04-A1.06; A2.01, A2.03-A2.06; A3.01, A3.03, A3.05-A3.06 and A3.08. The company, which adopts a short-term perspective, considers a budgeting horizon rather than a strategic planning one; thus its performance measuring is more focused on efficiency indicators. However the coordination form of relationship with Company 1, forces Company 2 to monitor also the effectiveness of the managed processes,
- Finally in Company 3, the third party service provider for A3.07 and A3.09 assistance processes, After Sales is still seen as a necessary evil rather than a business opportunity, thus the relative PMS is more focused on cost indicators. Since an open market relationship exists between Company 3 and 1, their PMSs are totally independent and not linked at any level.

CONCLUSIONS

The strategic importance of the service provision in the manufacturing industry makes it suitable the use of a PMS that could reflect the complexity level of the network. Literature references on this topic are still scarce. Aim of this paper is thus the development of a PMS for the product-service network by extending and integrating existing models (starting points are the works by [5]-[7]-[13].

Worth of mention are two features of the model: i) the introduction of the type of assistance process that is taken explicitly into consideration; ii) the consideration of the level of vertical integration of the service network giving the possibility to build a PMS extended to different actors and adapted to the type of buyer-seller relationships.

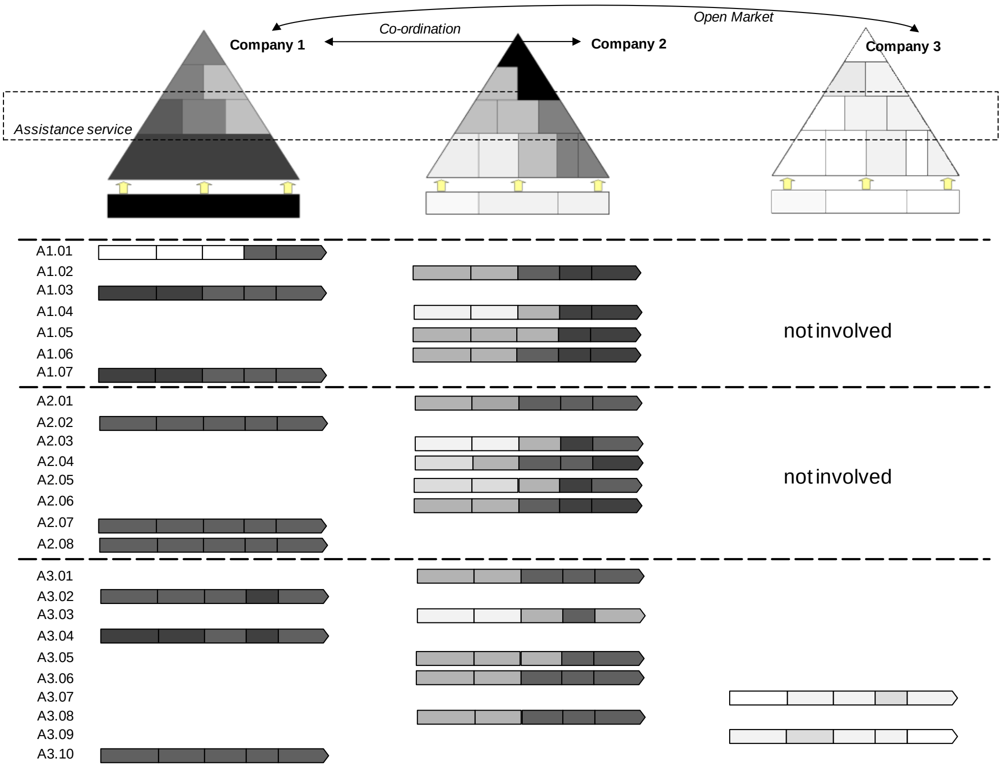

Figure 3: Example of PMS structure in a product-based service network

The contribution of the paper is, therefore, twofold. On the one hand, it helps to fill the highlighted literature gap about the PMS in product-based service networks. On the other hand, the proposed model structure in the present form can be already used a supporting tool for practitioners who want to improve the management of the service network by introducing a proper monitoring system.

However, the paper is mainly of a conceptual nature since the model structure is developed starting from the analysis and integration of existing models. Although a practical application has been included in the discussion to clarify the use of the model, there is the need to test the model in several case studies in order to assess its validity. The assumptions related to the model form depending on the nature of the buyer-seller relationships need to be further investigated too. This latter observation calls for more empirical as well as conceptual research on how network relationships and the strategic priorities of the different actors influence the way PMSs are structured and aligned (or not aligned) among parties, and about which mechanisms should be adopted to orient the performance measurement systems to improving the effectiveness and efficiency of the whole network.

REFERENCES

Amini M.M., Retszaff-Roberts D., Bienstock C.C. (2005), “Designing a reverse logistics operation for short cycle time repair services”, in *International Journal of Production Economics,* 96(3):369-380.

Armistead C., Clark G. (1991), “A framework for formulating after-sales support strategy”, in *International Journal of Operations and Production Management,* 11(3):111-124.

Baines T., Lightfoot H., Evans S., Neely A.D., Greenough R., Peppard J., Roy R., Shehab E., Braganza A., Tiwari A., Alcock J., Angus J., Bastl M., Cousens A., Irving P., Johnson M., Kingston J., Lockett H., Martinez V., Micheli P., Tranfield D., Walton I., Wilson H. (2007), “State-of-the-Art in Product Service Systems”, in *Proceedings of the Institution of Mechanical Engineers, Part B, Journal of Engineering Manufacture*: 1543-1552.

Cavalieri S., Brun A., Ierace S. (2006), “After Sales Processes in the SCOR model: a proposal and an empirical application”, in *Proceedings of the 14th Working Seminar on Production Economics,* 3:25-36.

Cavalieri S., Gaiardelli P., Ierace S. (2007), “Aligning strategic profiles with operational metrics in after sales service”, *in Special Issue of Performance Measurement and Management Systems: Public and Private, International Journal of Productivity and Performance Management*, 56(5/6):436-455.

Bundschuh R.G., Dezvane, T.M. (2003), “How to make after-sales services pay off” in *The McKinsey Quarterly,* 4.

Gaiardelli P., Saccani N., Songini L. (2007a), “Performance measurement systems in the after-sales service: an integrated framework”, in *International Journal of Business Performance Measurement,* 9(2):145-171.

Gaiardelli P., Saccani N., Songini L. (2007b), “Performance measurement of the After-Sales Service network. Evidences from the automotive industry”, in *Computers in Industry,* 58(7):698-708.

Goffin K. (1999), “Customer support - A cross-industry study of distribution channels and strategies”, in *International Journal of Physical Distribution and Logistics Management*, 29:374-397.

Heiskanen E., Jalas M. (2000), “Dematerialization through services e a review and evaluation of the debate”, *Helsinki: Finnish Ministry of the Environment*.

Kaplan R.S., Norton D.P. (1992), “The Balanced Scorecard. Measures that Drive Performance”, in *Harvard Business Review*, January-February:71-79.

Legnani E., Cavalieri S. (2008), “Measuring the performance of after-sales service processes. A hierarchical approach”, in *Proceedings of APMS 2008, International Conference on Innovations in network*, Espoo, Finland:359-368.

Legnani E., Cavalieri S., Ierace S. (2009), “A framework for the configuration of after-sales service processes”, in *Production Planning and Control, Special Issue on Manufacturing and Service Operations Network*, forthcoming.

Loomba A. (1996), “Linkages between product distribution and service support functions”, in *International Journal of Physical Distribution and Logistics Management,* 26(4):4–22.

Loomba A. (1998), “Product distribution and service support strategy linkages”, in *International Journal of Physical Distribution and Logistics Management*, 28(2):143-161.

Lynch R.L., Cross K.F. (1991), *Measure Up – The Essential Guide to measuring Business Performance*, Mandarin, London.

Mathieu V. (2001), “Service strategies within the manufacturing sector: benefits, costs and partnership”, in *International Journal of Service Industry Management*, 12(5):451-475.

Morelli N. (2002), “Designing Product/Service Systems: A Methodological Exploration”, in *Design Issues*, 18:3-18.

Nordin F. (2005), “Searching for the optimum product service distribution channel: Examining the actions of five industrial firms”, in *International Journal of Physical Distribution and Logistics Management*, 35(8):576–594.

Nordin F. (2008), “Linkages between service sourcing decisions and competitive advantage: A review, propositions, and illustrating cases”, in *International Journal of Production Economics*, 114:40-55.

Osadsky P., Garg A., Nitu B., Schneider O., Schleyer S. (2007) “Improving service operation performance by a cross-industry reference model”, in *Proceedings of the IFIP International Federation for Information, Advances in Production Management Systems*, eds. Olhager J., Persson F., Springer, Boston, 246:397-404.

Pezzotta G., Cavalieri S., Gaiardelli P. (2009), “Product-Service Engineering Process: Theoretical and Empirical Evidences”, in *Proceedings of International Conference on Product Lifecycle Management (PLM09)*, Bath (UK), July 6-8.

Saccani N., Johannson P., Perona, M. (2007a), “Configuring the After-Sales Service Supply Chain - A multiple case study”, in *International Journal of Production Economics*, 110(1/2):52-69.

Saccani N., Songini L., Gaiardelli P. (2007), “A Supply-Chain Oriented Performance Measurement System for the After Sales Process and Network”, in *Proceedings of 14th Annual International EurOMA Conference: Managing Operations in an Expanding Europe*, Ankara (TR), June 17-20.

Spekman R.E., Carraway R. (2006), “Making the transition to collaborative buyer-seller relationship”, in *Industrial Marketing Management*, 35 (1):10-19.

Spekman R.E., Kamauff Jr. J.W., Myhr N. (1998), “An empirical investigation into supply chain management”, in *International Journal of Physical Distribution & Logistics Management*, 28(8):630-650.

Supply Chain Council (2008), “Supply-Chain Operations Reference Model (SCOR)’, Ver. 8.0, Pittsburgh PA, USA, www.supply-chain.org.

System Dynamics modeling for Product-Service Systems A case study in the agri-machine industry

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Abstract. The increasing role of services in the strategic plans and the economics of industrial companies poses new relevant organizational and management challenges. Shifting from a transactional to a lifelong relational approach with the customer requires major consideration of those processes which are carried out through the service network. Empirical decisions for tackling such new market opportunities could turn out to be counterproductive if taken on the fly, affecting negatively the overall performance of a service network. This paper exploits the potential of continuous simulation as a support for handling decision making processes in a Product-Service System context. A System Dynamics model has been developed and, within this paper, has been specifically applied to quantitatively assess how the introduction of preventive maintenance contracts can influence the overall service performance of a manufacturer of farm machinery.

Keywords: Product-Service System, Service Performance, Maintenance, System Dynamics

Introduction

Companies operating in the western mature markets have progressively realized the importance of complementing industrial goods with the provision of value added services. This has been pushing companies into providing services jointly devised with the products and into searching for new methodologies and tools to design a product-service bundle. A term, namely Product-Service System (PSS*)*, has been recently coined in literature for identifying a solution which consists of tangible products and intangible services, designed, combined and delivered so that they are jointly capable of fulfilling specific customer’s needs [3]. Supplying spare parts, offering technical support, conducting repairs, installing upgrades, reconditioning equipment, carrying out inspections and day-to-day maintenance are some consolidated and traditional examples of services bundled with products. Their supply, which normally comes during the middle and end of life of a product, can be a more stable source of revenues, since services are more resistant to the economic cycles that drive investments and equipment purchases [9, 13], and also a bountiful way of generating profits for companies [4]. According to [1], profits from services are generally higher than those obtained with the product sales, and they may generate at least three times the turnover of the original purchase during a given product life cycle.

However, despite the obvious appeal, most industrial organizations do not detain the right competences and managerial levers to effectively provide these services. Even if they heavily invest in extending their service business and in increasing their service offerings, they experience the so-called “service-paradox”, that is, they incur in higher costs, and at the end they do not get the expected returns [7]. In order to gain the envisioned benefits, it is necessary to develop new capabilities, organizational structures, processes, metrics and incentive mechanisms not only at a company’s scale, but necessarily involving all the downstream service network. This could turn out to be a major managerial challenge for a company [8, 2].
Concerning this research domain, the authors have already provided in previous publications some contributions which have been addressed to: (i) design the main service processes that a company manages when provides its PSS and identify the relation between the product characteristics and the most suitable typologies of assistance support to carry out at the tactical and operational levels; (ii) boost and control the results of companies operating in a PSS context through the definition of a specific and multi-level Performance Measurement System (PMS); (iii) qualitatively explore the causal relations which lie within the defined PMS in order to understand the non-linear relations among all those processes that are involved when providing a PSS.
Based on the results achieved in these former contributions, this paper provides a further insight: it deals with the development of a System Dynamics model which has been created to quantitatively explore the abovementioned causal and non-linear relations and the impact that introducing a new policy may exert on the improvement of the service performance. More in detail, to show the potentiality of the developed model, a specific application is proposed for a company operating in the agri-machine industry: analyses will get into understanding the effect of making use of preventive maintenance contracts, during the warranty and post warranty periods.
The paper is organized as follows: §2 gives some insights about the methodology adopted to carry out the simulations and the developed model; §3 shortly describes the case study used to perform the analyses and explains the policy introduced and tested within the dynamic model, while §4 discusses the results achieved through the simulations. Finally, §5 draws some conclusions and insights on future developments.

System Dynamics modeling

Traditionally, formal modeling of systems has been carried out via mathematical models which attempt to find analytical solutions enabling the prediction of the system behavior from a set of parameters and initial conditions. For many systems, however, simple closed form analytic solutions are not applicable and thus computer simulation models are necessary. Simulation generates a sample of representative scenarios for a model in which a complete enumeration of all possible states would be prohibitive or impossible [5]. Modeling multifaceted, interactive and dynamic structures, like those involved in the PSSs provision, requires a powerful tool or method which helps to understand complexity, to design better operating product-service polices and to guide changes. System Dynamics (SD) modeling as well as Discrete Event Simulation (DES) can be both used to model corporate business decisions. For the purpose of this research, it has been decided to apply a SD approach as it is the most suitable method to enhance learning in compound systems [11]. Moreover, it is suited to problems associated with continuous processes where behavior changes in a non-linear fashion and where extensive feedback occurs. The main goal of SD is to understand, through the use of

quantitative models, how the system behavior is produced and to predict the consequences over time of policy changes on the system performance [10]. DES models, in contrast, more often represent particular processes, not entire systems, and they are better at providing a detailed analysis of systems involving linear processes and modeling discrete changes in system behavior [12].
Given the aforesaid potential of SD, a model has been developed to: i) understand and represent, through the study of the causal relations between the service metrics, the non-linear relations among all those processes that are involved when providing a PSS; ii) quantitatively evaluate how introducing new policies for handling PSSs significantly affects the company's performance; iii) attribute the appropriate organizational changes to the processes thanks to the answers (feedbacks) given by the simulation study with regard to the changes adduced to the service performance. From a technical point of view, the introduction of a policy requires a proper change of some exogenous parameters which trigger off the SD model and whose value is usually provided by the user of the model. The model has been applied to two specific types of services: maintenance and spare parts provision. Figure 1 shows, in a macro detail, the elements and the logic adopted to build the SD model.

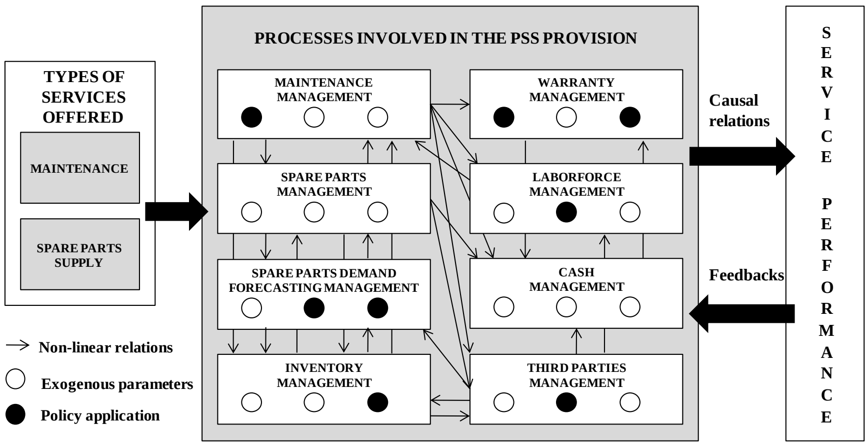

Figure 1. Logic beneath the SD model building

The developed SD model has a general structure and it can be used by any company which ventures in the provision of new services (at this stage of application, limited to maintenance and spare parts provision) and needs to test the impact that the application of a new policy can determine on its service performance. In order to show the potential of the model, this paper proposes a specific application for an agribusiness firm.

The case study

The case study refers to a company which manufactures and assembles farm machinery with a considerable presence both in Europe and in the rest of the world. Beside the production and sale of trailers, which however constitute a considerable share of its profits, its main market regards the production, selling and repairing of round balers. They are used to compress grass and maize feed for cows, industrial waste and garbage. Sales of round balers count around 50% of the turnover; around 240 balers are manufactured a year and almost 50% of them are exported.

A key issue for the company is to improve and optimize its service processes in order to increase the profits coming from this business and retain its customers to secure itself with future sales. Service activities consist in providing spare parts and maintenance to the customers. A round baler standing idle might cause losses for the customer: the harvest season has to be completely exploited and a quick repair has to be assured by the company or one of its authorized technical assistance center. For this reason, the company has recently approached a new strategy to keep down the number of maintenance interventions, especially during the harvest season: since these corrective repair services are completely unplanned and difficult to handle, it is moving towards the additional provision of a preventive support to be performed with more regularity.
According to [6], maintenance can be defined as a series of actions either to (i) prevent the deterioration process leading to the failure of a system or (ii) restore the system to its operational state through corrective actions after a failure. The former is called Preventive Maintenance (PM) and the latter Corrective Maintenance (CM). CM actions are unscheduled activities intended to restore a system from a failed state to a working state. This involves either repair or replacement of failed components. In contrast, PM actions are scheduled actions carried out to either reduce the likelihood of a failure or prolong the life of a component. Normally, the regularly scheduled downtime provided by the application of PM activities could imply higher direct costs to the manufacturer than operating the equipment until repair is absolutely necessary. However, it is important to compare not only direct costs but the long-term benefits and savings deriving from opportunity or indirect costs associated with PM (e.g. decrease of the system downtime, better spare parts inventory management, improved system reliability, etc.). Moreover, from the manufacturer's perspective, the role of PM assumes more relevance during the warranty period: in general, a customer pays for having a PM contract, thus the costs of repairing item failures through CM can be reduced for the manufacturer. However, for a myopic buyer, who does not consider the impact that investments in PM during the warranty and the post warranty periods have on the total life cycle maintenance cost of a product, there is no incentive to invest any effort into PM, especially during the warranty period when the buyer can claim any repairs on the product. For this reason, it is worthwhile for the manufacturer to promote a PM policy only if the expected extra costs are more than balanced by an overall positive return. Regarding the case study, due to the recent introduction of PM contracts, the management of the company needed to better assess the main pros and cons related to their adoption. The simulation, based on a SD model, tries to provide some valuable answers.

Modeling and results

In order to assess how the introduction of PM contracts impacts on the company's service performance, the analyses have been conducted assuming three different scenarios:

Scenario A – PM contracts are not applied, either under or out of warranty;

Scenario B – PM contracts are purchased by the customers just during the warranty period;

Scenario C – PM contracts are purchased throughout the whole life cycle of the product, both under and out of the warranty periods.

The analyses have been performed considering the manufacturer's perspective (in terms of revenues and costs) and considering a life cycle temporal horizon. The model has

been initialized considering the current company's installed base; the simulation time has been set on a monthly base and simulations have been run for 30 years, in order to analyze the entire life cycle of a round baler, which normally accounts for 10-15 years.
The model has been based on the following assumptions: (i) whenever a failure happens, it is due to a component malfunctioning and it occurs on all the installed base of machines on the market; (ii) just one type of component is considered (i.e. the rotor cutter); (iii) the part failure rate has been estimated constant and occurring after a certain number of bales produced; (iv) the customer purchases a PM contract paying a quota which includes the price of the PM intervention and of the part replaced, both during and out of the warranty periods; (v) PM actions are time-cyclical, being carried out at predetermined time intervals; (vi) both PM and CM interventions are performed assuming that the restored component works as good as new.
In order to run the SD model, different exogenous parameters have been introduced, and in particular: (i) the demand and the disposal rate of round balers sold, (ii) the warranty time (set to 1 year), (iii) the cycle time of a PM intervention, (iv) the part failure rate, (v) the prices and costs of respectively a PM intervention and a CM intervention, (vi) the unitary cost of personnel, (vii) the unitary cost of spare parts backlog and inventory. Their values have been provided by the company.
The following graphs report the main results achieved through the simulation. The crucial outcome is that the company gets benefits from the introduction of PM contracts. In particular, the higher the use of PM is, the higher the company's service performance is. Limiting the PM just to the warranty period is less convenient than extending it to the entire life cycle of the round balers. Even though following this strategy makes the company incur in higher operational costs (due to the necessity of performing both CM and PM interventions and, consequently, due to the presence of more personnel who accomplishes these interventions), this is more than balanced by the profit made along the product life cycle (Figure 2 and 3).

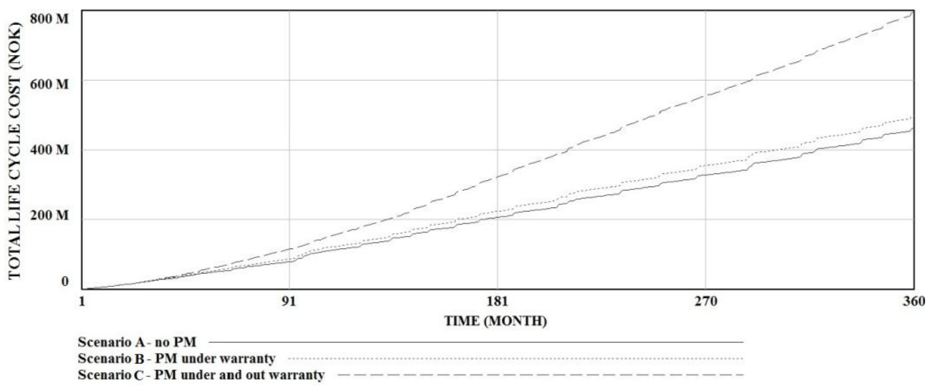

Figure 2. Total life cycle cost for the three simulated scenarios

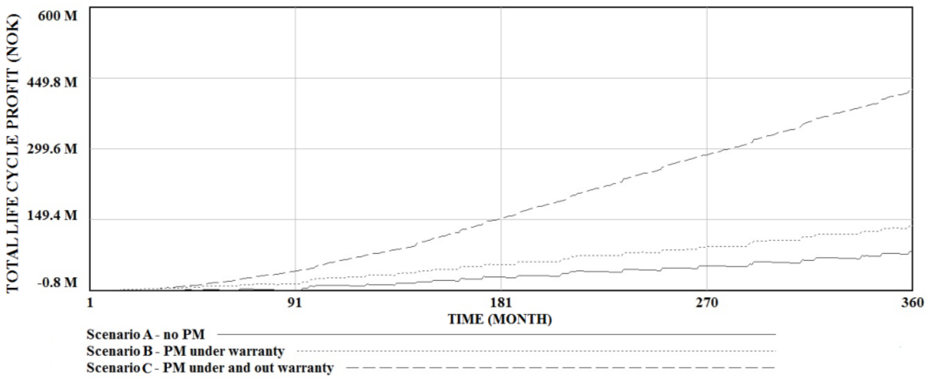

Figure 3. Total life cycle profit for the three simulated scenarios

Another interesting result regards the reduction of the spare parts backlog. This is due to the fact that PM interventions are regularly scheduled and this reduces the uncertainty in forecasting the desired level of spare parts necessary. Figure 4 shows the trend of the spare parts backlog costs accumulated during the product life cycle for each simulated scenario.

Finally, it is interesting the trend that the costs for the inactivity of the personnel accumulate during the product life cycle. As already mentioned, PM interventions are regularly planned compared to those of CM, thus the working time of the personnel can also be planned and better exploited. Figure 5 shows how the costs of the inactive personnel decreases when the incidence of the PM increases.

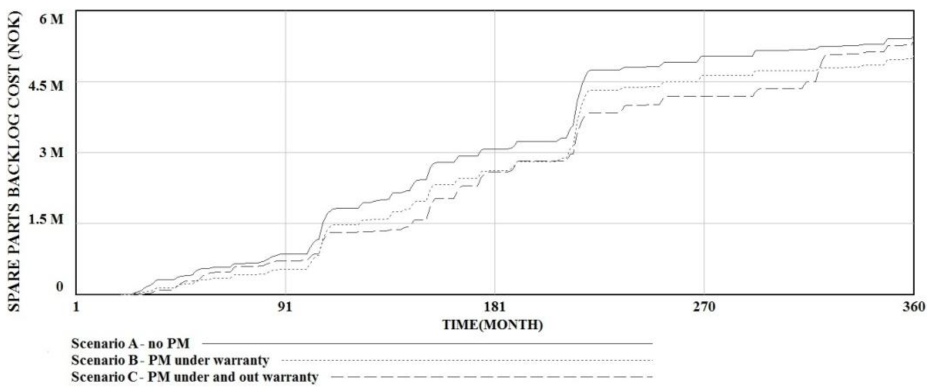

Figure 4. Spare parts backlog cost in the product life cycle for the three simulated scenarios

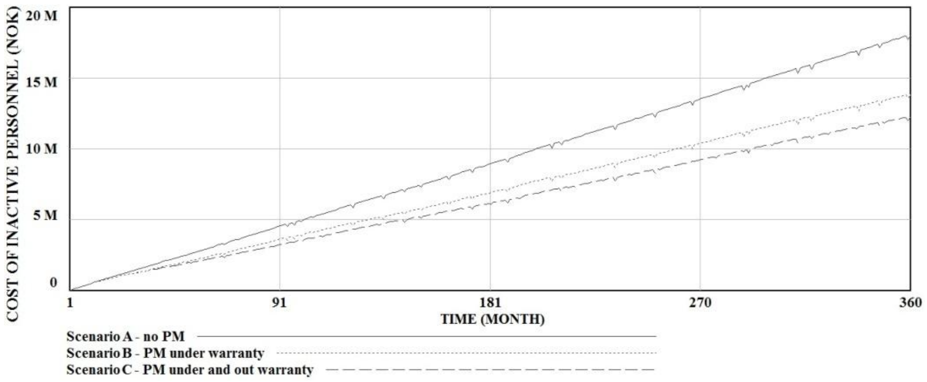

Figure 5. Cost of inactive personnel in the product life cycle for the three simulated scenarios

Conclusions and further developments

This paper aims at contributing to the research in the field of PSS, which is a still a quite relatively new topic and not yet consolidated, and it proposes a SD model to answer to the need of adopting new tools to design the product-service bundle. More in detail, a general SD model has been developed to quantitatively simulate how the provision of PSS can affect the service performance of a company. Within this paper, this model has been applied to a specific case study in order to show some of its potentialities. For this reason, different scenarios have been examined to evaluate how the introduction of PM contracts may affect the total service performance of the studied company. For this particular case, given the initial assumptions made for the analysis and the exogenous data provided by the manufacturer and used for the simulations, it comes out that introducing PM contracts is advantageous to the company. It turns out that the higher the application of PM is, the higher the expected results are: even though the company incurs in higher operational costs, this is more than balanced by the improvement of several results, such as the increase of the overall service profit, the reduction of the inactive personnel costs and the reduction of the spare parts backlog costs. Further analyses can be conducted on this case study in order to define which is the best maintenance strategy to adopt, the optimal number of preventive cycles to carry out during the warranty period, the benefit of extending the warranty period, etc.
Regarding the developed general SD model, future work may be addressed to further test its potentialities through its application to other companies which operate in the service business and have to deal with the provision of PSSs.

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References

Alexander, W.L., Dayal, S., Dempsey, J.J., Vander Ark, J.D.: The secret life of factory service centers. The McKinsey Quarterly, 3, 106 – 115 (2002).

Baveja, S.S., Gilbert, J., Ledingham, D.: From products to services: why it's not so simple. Harvard Management Update, 9, 4, 3 – 5 (2004).

Brandstotter, M., Haberl, M., Knoth, R., Kopacek, B., & Kopacek, P.: IT on demand – towards an environmental conscious service system for Vienna (AT). In: Third

International Symposium on Environmentally conscious design and inverse manufacturing – EcoDesign, pp. 799–802 (2003).

Cohen, M.A., Agrawal, N., Agrawal, V.: Winning in the Aftermarket, Harvard Business Review (2006).

Crespo Marquez A.: Dynamic modelling for supply chain management – Dealing with front-end and back-end and integration issues. Springer-Verlag, London (2010).

Djamaludin, I., Murthy, N.P., Kim, C.S.: Warranty and preventive maintenance. International Journal of Reliability, Quality and Safety Engineering, 8, 2, 89-107 (2001).

Gebauer, H., Fleisch, E., Friedli, T.: Overcoming the Service Paradox in Manufacturing Companies. European Management Journal, 23, 1, 14 – 26 (2005).

Oliva, R., Kallenberg, R.: Managing the transition from products to services. International Journal of Service Industry Management, 14, 2, 160 – 172 (2003).

Quinn, J.B.: Intelligent Enterprise. Free Press, New York, NY (1992).

Santos, S.P., Belton, V., Howick, S.: Adding value to performance measurement by using system dynamics and multicriteria analysis. International Journal of Operations & Production Management, 22, 11, 1246 – 1272 (2002).

Sterman, J.: Business dynamics: system thinking and modelling for a complex world. McGraw-Hill (2000).

Sweetser, A.: A Comparison of System Dynamics (SD) and Discrete Event Simulation (DES). In: Proceedings of 17th International Conference of the System Dynamics Society and 5th Australian & New Zealand Systems Conference. Wellington, New Zealand (1999).

Wise, R., Baumgartner, P.: Go Downstream - the New Profit Imperative in Manufacturing. Harvard Business Review, September-October (1999).

A Performance Measurement System for After-Sales Service processes

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Abstract

Companies have progressively realised that complementing industrial goods with the provision of value added services can be an important lever to prosper on those markets affected by weak demand, hard competition and decreasing margins. Among the different forms of service provisions, After Sales (AS)[1] service has acquired a strategic role as a source of revenues and competitive advantage. This trend calls for the creation of expertise, structures and processes new to the product manufacturer. The design and use of adequate Performance Measurement Systems (PMS)[2] are one of the major challenges which contributes significantly to the competitive advantage of a company. Aim of this paper is to propose an integrated PMS designed to span the different peculiarities of the AS area, linking corporate strategic objectives with AS strategies and goals and promoting a consistent set of performance measures and indicators. Its implementation in an agri-machine company is reported to verify its consistency and robustness.

Keywords

Product-services, After-Sales service, Processes, Performance Measurement System

1. Introduction

The fierce competition coming from the emerging countries, the saturation of the demand in mature Western markets, the fast reproducibility of technological breakthroughs are some of the most relevant factors which motivate manufacturers to find new strategic avenues for achieving a sustainable competitive advantage. Developing and offering an outstanding product could be no more sufficient for surviving in the market arena. In fact, consumers are better informed, more aware of their rights and conscious of the importance of relying on a reliable and trustworthy relationship with a provider [1]. Properties as maintainability, serviceability, recyclability are becoming distinctive factors which drive the decision making process of a customer.

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[1] After Sales: its abbreviation is AS
[2] Performance Measurement System: its abbreviation is PMS

For being competitive, a product needs to be equipped with a customised and value-added portfolio of connected services, which make it perceived as unique, not easily replaceable and qualified for setting premium prices.
As revealed by Neely [2], who analysed the incidence of this phenomenon through an extensive survey of manufacturing companies worldwide, more than 30% of industrial companies operating in developed economies are mixing their traditional offer with the provision of value-added services. A number of recent contributions ([0, 0, 5, 6, 7, 8], to mention a few) has motivated the expected benefits in terms of profitability, competitive advantage, customer retention and environmental sustainability. One of the most challenging outcome is related to the profits being generated by the offer of a service menu: the service market, in fact, can be four or five times larger than the market for products [9] and may generate at least three times the turnover of the original purchase during a given product life cycle [10,11], contributing to about 40%–50% of the total revenue, and to a profitability of up to 20%–25% [11, 12, 13].
However, although services are assumed to deliver higher margins, most organisations find quite problematic to manage the transition from a traditional product-centric orientation to the provision of an integrated product-service solution. A Bain & Co's survey [14] reveals that only 21% of the sampled companies have declared a real success with their service strategy; according to Neely's survey, 53% of firms which declared bankruptcy were "mixed" firms. In most cases, they neglected the high risks related to the empowerment of their portfolio with bundled services. Unlike the expectation, introducing intangible services requires an important amount of investments whose pay-back times could be even longer than those related to a manufactured product [2, 15, 16].
As a result, in order to avoid being spiralled into the "service paradox", companies venturing in the provision of new services have to radically change the way they operate [17, 1]. They need to mature the culture and the capability to design and deliver service contents. New knowledge, organisational principles, metrics and incentives which firms do not possess are necessary to be developed [7, 14]. A fundamental requirement lies in laying down the appropriate processes along their service chain, either as a part of the company's operations or through third parties, as well as a set of rigorous and specific performance indicators which monitor the main critical trends.
Measuring the performance of organisations according to their decision-making processes is a well investigated and consolidated practice, especially in the field of operations management. However, if we specifically refer to the service area, scarce attention has been devoted in the past in literature. Examples of PMS applications in companies are even less [18, 19].
Goal of this paper is to contribute in filling this gap by proposing an integrated PMS designed to span the different peculiarities of After Sales service context, linking corporate strategic objectives with AS strategies and goals and promoting a consistent set of performance measures and indicators.
The paper is organised as follows: Section 2 provides a description of the main issues related to selling product-services with a specific focus on AS services. Section 3 proposes a detailed literature review on performance measurement in the AS service context. Section 4 reports the structure of a PMS specifically designed for the AS needs, while Section 5 discusses its application to an industrial case study. Finally, Section 6 draws some conclusions and insights on future developments.

2. From products to services: a focus on After Sales Services

According to Hewitt [20], "the popular advice to manufacturers is that, to sustain competitiveness, they should move up the value chain and focus on delivering knowledge intensive products and services". Oliva and Kallenberg [7] maintain that the transition from pure-product to pure-service providers is a continuum (Figure 1). It is a long-term gradual process which drives companies from being pure manufacturers towards being, firstly, suppliers of simple services as product add-ons (e.g. repair, maintenance and upgrading and take-back, etc.) and, in a second instance, providers of more forward-looking solutions, wherein customers benefit from the functionalities and/or utilities created by the product-service package (e.g. energy service contracting, car-sharing, etc.) [21, 22]. Both product and services are used to fulfil customers' needs, but the ratio between the "product value" and the "service value" can vary, according to the market specifications and the customers' needs. In some contexts the value embedded in the product can still comparatively play a relevant role for the client; conversely, other markets would consider the product a mere commodity, shifting the judgement on the portfolio of services provided [23, 24].

(Insert Figure 1 about here)

As companies go along an appropriate service culture development, they can determine their current positioning along the product-service axis and accurately identify the pathway (target position) along which they gradually increase - or decrease - their "service value" ratio.

In any case, both the provision of simple services and the provision of more complex solutions require the definition of specific business models, the creation of proper organisational structures, the definition of appropriate processes and activities to carry out and the design of a particular set of metrics to evaluate and monitor the results coming from this business.

Regarding the scope of this paper, research has been addressed to the first step of this transition, where products are sold in a traditional manner and include, in the original act of sale, additional services to guarantee functionality and durability of the product owned by the customer. These services are usually provided and managed during the middle and end of life phases of a product life cycle, and are devoted to supporting customers in the usage and disposal of the goods [25]. For this reason, they are also called After-Sales (AS) services.

They represent a wide portfolio of activities: Goffin [26] attempts to classify them according to each specific stage of the product life cycle. Four categories are identified:

1. *services associated with selling the product* – they are required during the process of transferring the ownership of the product to the customer in order to make it work. They can be: installation, training, product documentation, financial or insurance services and extension or customization of the warranty.
2. *services associated with the use of the product* – they are required to facilitate and improve the procedures for an efficient use of the product by the user as well as to assess periodically any unforeseen issues that may arise. They can be: customer care, upgrades and product check-up.
3. *services associated with the recovery of product functions* – they include all activities, mainly of technical nature, for maintenance and repair of products and replacement of defective parts, in order to restore the functionality of the product.

4. *services associated with the disposal of the product* – they refer to absorbing EU regulations regarding the sustainable dismissal of the products at the end of their useful life span.

The third type of services is definitely the most common one, often quoted as *technical support*; it is requested by the customer or offered by the producer following (or anticipating) a malfunction of the product. Cavalieri and Corradi [27] and Legnani et al. [28] identify different typologies of support according to the service level offered, the type of product sold, the level of involvement of the customer and the sustained costs. The support processes can be:

- *passive (or indirect)* - the company provides an appropriate documentation to the customer who is able to autonomously perform the diagnosis, identification and application of the solution;
- *collaborative* - the customer autonomously sorts out the problem with the help of an expert through a remote connection;
- *turn-key* - the customer is not able to solve the problem and needs the support of an expert who solves the problem. This support can be of two types: off-site, when the company collects the faulty product through its assistance channel, repairs and gives it back to the customer; on-site when the intervention is performed at the location where the defective item is installed.

Being successful in handling these AS services requires a careful design of the beneath processes and a steady and constant monitoring of the results coming from their provision. In this paper a specific PMS for measuring the performance of technical support services is proposed.
The following literature review highlights the main research gaps in this field.

3. Literature background

As reported by [2929], a PMS – also defined as Business Performance Measurement (BPM) system - can be read according to three different dimensions:

- *features*, which are the properties or elements that make up a PMS, such as the performance measures, the objectives, the supporting infrastructure, the targets, the causal models, the hierarchy, the performance contracts and the rewards;
- *roles*, which are the purposes or functions that are performed by a PMS, such as the internal communication, the performance improvement, the progress monitoring, the benchmarking, etc.;
- *processes*, which are the series of actions that are combined together to constitute a PMS, such as data capturing, target setting, data analysis, decision making and performance evaluation.

Objective of this paper is to present the main characteristics of a PMS specific for the needs of the AS area. Therefore the emphasis of this literature analysis is mainly on the *features* dimension and in particular on the “performance measures” attribute which includes characteristics such as multi-dimensionality, efficiency and effectiveness, internal and external perspectives, vertical and horizontal integration and multi-level structures.

Literature concerning PMS features in industrial organisations is wide, various and heterogeneous. From the early 80's up to the 90's, most of the developed frameworks focused on the definition of performance attributes [30, 31] and on the classification of the related measures.
Different frameworks addressing both the corporate level and the strategic business areas [32, 33, 34] were proposed, while activities and processes were identified as relevant aspects of performance [35, 36, 37, 38]. It was also stressed the necessity to consider both tangible and intangible aspects, efficiency and effectiveness, innovation as well as the need to complement traditional financial measures with non financial ones [39, 40]. Dynamic, relevant, suitable, multidimensional, internal and external performance measures were introduced in order to benchmark the results of an organisation with the competitors' performance [41, 42].
The necessity of integrating operative actions, mission and strategic objectives, drove also researchers and industrial managers to address their efforts mainly on developing and deploying integrated PMSs able to link the strategy formulation to its implementation, to combine financial and operational measures, as well as long-term oriented metrics, with financial short-term oriented indicators. Balanced and multidimensional frameworks and methodologies, such as the Performance Measurement Matrix [43], the Results and Determinants framework [44], the SMART Pyramid [42], the Balanced Scorecard [32, 33], and the EFQM framework [45, 34], were therefore developed in order to encompass the different functional areas and the related value added processes of a company.
However, despite the increasing importance of AS service as a key ingredient of the competitive success of manufacturing companies [46], contributions on PMSs specifically designed for capturing and measuring the typical performance dimensions of the AS domain present a very fragmented picture. In particular, according to [47] and [29]:

- *management accounting* literature shows that a noteworthy number of research works have dealt with the analysis of financial accounting and long-term oriented perspective in order to evaluate the contribution of AS to the creation of value along with the product life-cycle [48, 49, 50]. Proposed methodologies and frameworks have been focused mainly on cost, adopting either the perspective of the supplier, such as life-cycle costing [51, 52] or of the customer, such as total cost of ownership [53]. In such cases performance measurement approaches have mainly embraced the strategic business level, while scarce attention has been devoted to operative and nonfinancial metrics;
- *from a strategic control perspective* it emerges that in general an integrated view of the performance measurement has not been adopted when dealing with the AS strategy. In this case frameworks and recommendations suggested by the authors have been directed on how to design the service mix [54, 55, 56], to adopt pricing decisions [57], or to design the AS service organisation [58] and network [59, 60]. Performance evaluation has been considered only at the strategic business level, with a general perspective, but no detail has been given on the definition of relevant metrics and their drill-down to operational ones. Only few authors have suggested sets of performance metrics as tools to test and verify the coherence between the strategic objectives and the effect of the actions undertaken [61].
- *in the operations* works oriented to the development and deployment of performance measurement frameworks dealing with AS processes, service supply chains and

networks remain still fragmented [62, 63, 25], despite a natural extension of performance measurement from the single firm to supply chains and networks emerged in recent years as a relevant research topic [64, 65]. Also the well known and widespread Supply Chain Operations Reference (SCOR) model [66] does not formalise AS as a consistent set of well established processes. Numerous and detailed performance measures have been proposed to analyse the spare parts logistics area [67, 68, 69, 70, 71]. However, performance measurement has been limited to very specific efficiency [72] or effectiveness indicators, which are usually operative and generally oriented to internal service level metrics, often neglecting the assessment of the level of service as perceived by the end customer

According to several authors [41, 39, 44, 42, 40, 32, 73, 74], an effective PMS has: i) to be articulated according to different levels of analysis, considering both strategic and operational decision making levels, such as strategic business areas, processes and organisational units; ii) to balance financial and non financial indicators; iii) to jointly consider long term and short term results, tangible and intangible aspects, efficiency and effectiveness.

As a consequence, also a PMS specifically thought to capture all the critical aspects of the AS area needs to be organised in such an integrated structure. This is one of the most challenging issues related to the design of a PMS for the AS service needs.

Some valuable contributions have been recently proposed to fill this gap. An interesting input regards the results achieved by the EU-funded project InCoCo-S [75], where a reference model for the collaboration between service providers and manufacturers has led to the definition of processes, metrics and related best practices to perform. In addition, Gaiardelli et al. [76] introduce a framework which integrates the features of some existing models [32, 42, 66] to carry out an all embracing PMS for AS services. The framework, conceived for a single company operating in a service network, addresses several performance areas into strategic, process, activity and development/innovation areas, giving emphasis to both efficiency and effectiveness measures as well as to internal and customer-oriented ones.

However, following the analysis proposed by [29], it is argued that a PMS is not self-standing if its performance measure architecture is not embedded with a supporting infrastructure. This can vary from simplistic manual methods to sophisticated IT systems and supporting procedures [77]. Therefore, integrating performance measures with a supporting infrastructure represents a further managerial challenge to face.

4. A Performance Measurement System for After-Sales services

Goal of this section is to introduce a Performance Measurement System which has been defined considering the current challenges reported in the previous section, related to the features and supporting infrastructure that a PMS should present to measure the results of the AS service area. The PMS has been designed considering a proper equilibrium between strategic and operational objectives, financial and non-financial indicators, efficiency and effectiveness dimensions. Moreover, a related supporting dashboard has been designed to enhance data acquisition, analysis and reporting.

The PMS has been developed and tested according to the following steps:

1. Collection of information through literature analysis, focused group activities and seminars with academicians and practitioners members of the Supply Chain Council, for understanding the main gaps regarding applications of PMS in the AS area;

2. Development of a suitable and specific PMS for the AS area;
3. Testing of the PMS through case studies (as suggested by Voss [78]); a specific one will be thoroughly described in the following section;
4. Analysis of the feedbacks gathered during the testing phase and further refinement of the PMS.

The PMS is designed to measure and monitor the overall results that a single company, which operates through a vertical structure, or an entire service supply chain perform when dealing with their respective final customers. Relational indicators which measure the quality of the relations between the different actors of the service supply chain are not considered.
The PMS presents two different arrangements: (i) a hierarchical structure which measures the overall results of the AS area through a set of performance categories and (ii) a process-diagnostics structure which measures the results of the single process/activity carried out in the AS area.

4.1 Hierarchical structure

A multi-levelled set of performance indicators has been built according to the semantic structure and formalism adopted by the SCOR model [66]. Metrics are hierarchically organised, ranging from strategic indicators used to monitor the overall AS performance of the company to more diagnostic measures used to identify critical processes. In detail the PMS architecture is made up by:
• *performance attributes*, which are groupings for metrics used to explain company's strategies and to analyze and evaluate them for performing internal or external benchmarking;
• *level 1 metrics*, which are strategic indicators (Key Performance Indicators - KPIs) used to monitor the overall performance of the company according to the performance attribute to which they are associated;
• *level 2* and *level 3 metrics*, respectively tactical and operational indicators, which serve as diagnostic measures to identify critical processes and variations in performance against the plan.

Six performance categories, which encompass both internal-facing and customer-facing perspectives, have been identified to measure the AS area: reliability, responsiveness, agility, assets, costs and growth. Their relative definitions are reported in Table 1 together with the corresponding Level 1 metrics (KPIs).

(Insert Table 1 about here)

Six hierarchical structures have been created to synthetically evaluate the final outcome, represented by the associated performance attribute category. A set of relevant KPIs and diagnostics indicators (Level 2 and Level 3) has been identified to measure and control each attribute category. As an example, an insight of the *Reliability* (RL) attribute and its relative set of indicators is reported in Figure 2.

(Insert Figure 2 about here)

The main advantage of this structure is its multi-faceted nature, since it provides aggregate and strategic information, normally useful to the management, and at the same time more detailed and specific information which is measurable and understandable by all the process decision makers operating through a service supply chain.

4.2 Process-diagnostics structure

In addition to the hierarchical arrangement of the metrics, a remarkable set of indicators is proposed to measure each process/activity involved in the provision of a technical support. In order to create this structure, it turned out to be necessary the definition of all the underlying processes and activities. The result is reported in a previous work [28], where the main AS processes have been designed according to a matrix which relates the product characteristics with the most suitable typologies of assistance to accomplish the tactical and operational levels.
The processes have been conceived according to the different roles of both the customer and the assistance provider in the diagnosis and solution of a support inquiry, as already reported in section 2.
In detail, processes and activities have been grouped according to the following three categories:

- *Passive Assist* - monitors and updates contract-related information, documents performance expectations, and offers pre-packaged solutions to products/services inquiries or issues, as diagnosed solely by the customer.
- *Collaborative Assist* - monitors and updates contract-related information, documents performance expectations, and offers pre-packaged or custom solutions to products/services inquiries or issues, as diagnosed jointly by the customer and the assistance-provider.
- *Turn-key Assist* - monitors and updates contract-related information, documents performance expectations, and implements pre-packaged or custom solutions to products/services inquiries or issues, as diagnosed either primarily or solely by the assistance-provider.

For each of these process categories a detailed list of activities has been defined in order to be evaluated through proper indicators.
Regarding their measurement, efforts have been addressed to create a link within these processes/activities and the diagnostic indicators identified in the metric hierarchical structure (Level 2 and 3). This structure helps companies in identifying those crucial processes associated to critical values of the performance indicators. An application of this process-diagnostic structure is reported in the following section through the description of a case study.

The suggested PMS and the relative proposed list of metrics have been designed to be general, as a reference guide for those companies which need to develop, implement and use adequate performance indicators to evaluate their AS results. As reported in the case study of next section, each company can adapt the PMS according to its necessities, selecting from the list those indicators which best suit its requirements and possibly define new ones specific to its needs.

5. Case study

The case study refers to a North European company which manufactures and assembles farm machinery with a considerable presence both in Europe and in the rest of the world. Its main market regards the production, selling and repairing of round balers which are used to compress grass and maize feed for cows, industrial waste and garbage. Sales of round balers count around 50% of the turnover and another considerable part is given by its AS activities; around 240 balers are manufactured a year and almost 50% of them are exported. Its main customers are farmers, either contractors or little homesteaders. To support its worldwide business it makes use of a tight network of technical assistance centres and dealers spread around the world.

The company provides maintenance and spare parts supply and one of its key issues is to improve and optimize the provision of these services related to the sales of round balers. A round baler standing idle might cause losses for the customers: the harvest season has to be completely exploited and a quick repair has to be assured by the company. This means that, since the company encompasses a series of primary and supporting processes and involves different departments and independent organisations, its goal is to enhance its AS processes in order to increase the profits coming from this business and retain its customers to secure itself with future sales. However, the analysed company did not have any indicators to measure and control its AS performance; since the evaluation of results and identification of corrective actions against defined objectives are elements that cannot be neglected for the success of any organisation, this pushed the company to test and evaluate the PMS proposed in the previous section. The PMS has been applied to yield a systematized and structured system into the organisation. Several interviews with the company service managers allowed to select, among all the indicators available in the general PMS model, those suitable for the company's needs. Some new metrics have also been tailored for its specific characteristics.

In particular, following the PMS hierarchical structure, six different forms have been created to evaluate each attribute dimension (reliability, responsiveness, agility, assets, costs and growth).

After a detailed mapping of the AS processes and activities carried out by the company, following the PMS process-diagnostics structure, appropriate Level 2 and Level 3 indicators have been selected and associated to the relative processes in order to measure their criticality.

In Figure 3, an excerpt of the process mapping is reported, while the relative diagnostic indicators have been highlighted in Table 2, considering the turn-key scenario.

(Insert Figure 3 about here)

(Insert Table 2 about here)

The analysis revealed that scheduling the resources to make turn-key interventions on-site is one of the most risky and costly activities, especially during the harvest season. Since these corrective repair services are completely unplanned and difficult to handle, some indicators related to its measurement provided warning values. This has suggested to move towards the additional provision of a preventive support to be performed with more regularity during all the year.

The performed analysis has led to the implementation of a web-based dashboard for performance calculation and visualization. It has been developed in a WAMP (Windows Apache Mysql PHP) environment for allowing information access through an ordinary browser. It evaluates metrics following the two structures of the proposed PMS: it displays and calculates metrics according to the described hierarchical structure and it also suggests and assesses a set of metrics for the processes mapped. This tool uploads data from the company databases, calculates metrics, compares metrics with a set target and creates synthetic reports which summarize the main company trends.

6. Conclusion and further developments

In several manufacturing industries AS is recognised as a key of competitive success. Hence, companies need to move from a pure product orientation to a product-service one. It is proved that this shift is very challenging and it can be very difficult if companies do not develop an appropriate service culture and the capability to design and deliver services in an effective and efficient way. A key issue is to monitor and control all the processes and activities which are carried out after the sale of a product: service measures need to be implemented and applied consistently by all the parties involved in the service network in order to enhance its overall effectiveness.

This work aims at contributing to a better understanding of the peculiarities of a PMS in the AS area and at answering to the need of having an integrated and multi-attribute set of measures and a supporting tool. A PMS has been developed following two different arrangements: (i) a hierarchical structure which drills down indicators according to different levels of analysis, and measures the overall results of the AS area through a set of performance attributes; (ii) a process-diagnostics structure which measures the results of the single process/activity carried out in the AS area.

The paper presents an application of the PMS for a manufacturer of farm machines where AS plays a key role. The company aims at enhancing the profit coming from this business and, consequently, at reducing the main costs. Since it lacked a PMS to control its performance, the developed PMS has been applied and tailored to its specific needs. According to [29], the existence of a PMS is determined by the application of both performance measures and supporting infrastructure. A dashboard has been developed in order to enable an automatic calculation of the values of the PMS indicators, and a graphical visualization of the achieved results, comparing them with a pre-established target.

One of the limits of this PMS is that it is developed to measure the results that a single company, or rather an entire service supply chain, achieves when providing AS services to its final customers. Indicators which measure the relations between the different actors of the network are missing. Further work should be addressed to the definition of these indicators and the relative beneath processes. In this sense a first contribution is proposed by [79].

Another future development of this work is to explore the causal relations which lie within the defined PMS in order to understand the non-linear relations among all those processes that are involved when providing a product-service bundle. Several authors claim that efforts should be addressed to identify the relationships between measures [80, 81, 74]. In reality, in spite of the recognised importance of understanding the relationships among the various performance indicators in developing a comprehensive measurement system, too many organisations still define their measurement systems

without understanding the dynamic interdependencies and trade-offs between measures and, ultimately, the process underlying the performance generation [82]. By performing a System Dynamics analysis [83], it is possible to understand the main factors and causal relations that generate changes in the AS service systems and the impact that these changes could exert on the company's results. These considerations can be arranged in a cockpit where the effect of future operational decisions on the performance of AS service systems can be visible and adjustable as knobs on a control panel.
The developed PMS has been created to measure and control processes and activities carried out for providing technical support services (e.g. repair, maintenance and upgrading, replacement of defective parts, etc.). Further developments of this research regard the extension and adaptation of the PMS to measure and control the provision of more advanced product-service solutions where customers benefit from the functionalities and/or utilities created by the product-service package.

References

1. R. Panizzolo, A methodology to measure the value of services provided to customers in manufacturing firms, Measuring Business Excellence. 12 3 (2008) 3-15.
2. A. Neely, Exploring the financial consequences of the servitization of manufacturing, Operations Management Research. 1 2 (2009) 103-118.
3. J.C Anderson, J.A Narus, Capturing the value of supplementary services, Harvard Business Review. 73 1 (1995) 75-83.
4. R. Cooper, When Lean Enterprises Collide. Competing through Confrontation, Harvard Business School Press, Boston, MA, 1995.
5. M.A. Cohen, S. Whang, Competing in product and service: a product life-cycle model, Management Science. 43 4 (1997) 535-45.
6. V. Mathieu, Service strategies within the manufacturing sector: benefits, costs and partnership, International Journal of Service Industry Management. 12 5 (2001) 451-475.
7. R. Oliva, R. Kallenberg, Managing the transition from products to services, International Journal of Service Industry Management. 14 2 (2003) 160-172.
8. T.S. Baines, H.W. Lightfoot, O. Benedettini, J. Kay, The servitization of manufacturing: A review of literature and reflection on future challenges, Journal of Manufacturing Technology Management. 20 5 (2009) 547-567.
9. R.G. Bundschuh, T.M. Dezvane, How to make after sales services pay off, The McKinsey Quarterly: The Online Journal of McKinsey & Co. 4 (2003).
10. R. Wise, P. Baumgartner, Go Downstream - the New Profit Imperative in Manufacturing, Harvard Business Review. September-October (1999).
11. W.L. Alexander, S. Dayal, J.J. Dempsey, Ark J.D. Vander, The secret life of factory service centers, The McKinsey Quarterly. 3 (2002) 106 - 115.
12. M. McClusky, Service Lifecycle Management (Part 1): The Approaches and Technologies to Build Sustainable Advantages for Services, AMR Research, August (2002).
13. D. Craemer-Kühn, M. Junghans, J. Krönig, BER revised – The aftermarket battle, a McKinsey presentation. (2002).
14. S.S. Baveja, J. Gilbert, D. Ledingham, From products to services: why it's not so simple, Harvard Management Update. 9 4 (2004) 3-5.

15. H. Gebauer, E. Fleisch, T. Friedli, Overcoming the Service Paradox in Manufacturing Companies, European Management Journal. 23 1 (2005) 14 - 26.
16. I. Visnjic, B. Van Looy, Manufacturing firms diversifying into services: A conceptual and empirical assessment, Working Paper. Faculty of Business and Economics, K.U.Leuven, 2009.
17. U. Karlsson, Service based manufacturing strategies implications for product development, productions and service operations in global companies, in: Proc. of POMS College of Service Operations and EurOMA Conference, 2007.
18. A. Neely, Mills J., Platts K., Richards H., Gregory M., Bourne M., Performance measurement system design: developing and testing a process-based approach, International Journal of Operations & Production Management. 20 10 (2000) 1119-1145.
19. I. Lange, M. Schnetzler, O. Schneider, P. Osadsky, Design of a performance measurement system for industrial service operations, in: Proc. of 2nd International Conference on Changeable, Agile, Reconfigurable and Virtual Production (CARV 2007), July, Toronto, Ontario, Canada.
20. P. Hewitt, The Government's manufacturing strategy, Department of Trade and Industry. 4 April 2002.
21. T.S. Baines, H.W. Lightfoot, S. Evans, A. Neely, *et al.*, State-of-the-art in Product-Service systems, Journal of Engineering Manufacture. 221 (2007) 1543-1552.
22. G. Pezzotta, S. Cavalieri, P. Gaiardelli, Product-Service Engineering: State of the Art and Future Directions, in: Proc. of 13th IFAC Symposium on INformation COntrol problems in Manufacturing (INCOM), (June), Moscow, 2009.
23. M. Goedkoop, C. van Halen, H. Te Riele, P. Rommens, Product service systems: ecological and economic basics, VROM, The Hague, 1999.
24. K. Hockerts, N. Weaver, Towards a theory of sustainable product service systems, INSEAD-CMER Research Workshop on Sustainable Product Service Systems, 2002.
25. L. Patelli, M. Pelizzari, A. Pistoni, N. Saccani, The after-sales service for durable consumer goods. Methods for process analysis and empirical application to industrial cases, in: Pre-Prints. of 13th International Working Seminar on Production Economics, Igls (Innsbruck), Austria, 16-20 February, 3, 2004, pp. 289-299.
26. K. Goffin, Customer support: a cross-industry study of distribution channels and strategies, International Journal of Physical Distribution & Logistics Management. 29 6 (1999).
27. S. Cavalieri, E. Corradi, L'evoluzione del servizio di assistenza del post-vendita: modelli di supporto, aspetti logistici ed opportunità IT (in Italian), in: Atti del XXVIII Convengo Nazionale ANIMP, Spoleto 25-26 Ottobre 2002.
28. E. Legnani, S. Cavalieri, S. Ierace, A framework for the configuration of after-sales service processes, Production Planning and Control. 20 2 (2009) 113 - 124.
29. M. F. Santos, M. Kennerley, P. Micheli, V. Martinez, S. Mason, B. Marr, D. Gray, A. Neely, Towards a definition of a business performance measurement system, International Journal of Operations and Production Management. 27 8 (2007) 784 – 801.
30. N. Venkatraman, V. Ramanujam, Measurement of Business Performance in Strategy research: a Comparison of Approaches, Academy of Management Review. 4 (1986).

31. P. Voyer, Tableaux de Bord de gestion et indicateurs de performance, Presses de L'Uiversité du Quebec, 1999 (in French).
32. R.S. Kaplan, D.P. Norton, The Balanced Scorecard. Measures that Drive Performance, Harvard Business Review, 1992.
33. R.S. Kaplan, D.P. Norton, The Balanced Scorecard. Translating Strategy into Action, Harvard Business School Press, Boston, 1996.
34. N.G. Olve, J. Roy, M. Wetter, Performance Drivers. A practical guide to using the Balanced Scorecard, Chichester, John Wiley & Sons, 1997.
35. R.S. Kaplan, H.T. Johnson, Relevance Lost – The Rise and Fall of Management Accounting, Harvard Business School Press, Boston, 1987.
36. H.T. Johnson, Relevance Regained, The Free Press, New York, 1992.
37. P. Lorino, Comptes et récits de la performance', Les Editions d'Organisation, Paris, 1995 (in French).
38. P.D. Wright, D.P. Keegan, Pursuing Value: the Emerging Art of the Reporting on the Future, PW Papers, Price Waterhouse LLP, 1997.
39. R.G. Eccles, The Performance Measurement Manifesto, Harvard Business Review. January-February (1991).
40. G.B. Stewart, The Quest for Value: The EVATM Management Guide, HarperCollins Publishers, Inc., 1991.
41. J.R. Dixon, A.J. Nanni Jr., T. E. Vollmann, The New Performance Challenge: Measuring Operations for World-Class Manufacturing, Business One Irwing, Homewood (Ill.), 1990.
42. R.L. Lynch, K.F. Cross, Measure Up – The Essential Guide to measuring Business Performance, Mandarin, London, 1991.
43. D.P. Keegan, R.G. Eiler, C.R. Jones, Are your performance measures obsolete?, Management Accounting. June (1989) 45-50.
44. L. Fitzgerald, R. Johnston, S. Brignall, R. Silvestro, C. Voss, Performance Measurement in Service Businesses, CIMA, 1991.
45. EFQM -European Foundation for Quality Management, EFQM self-assessment guidelines, 1998.
46. M.A. Cohen, H.L. Lee, Out of touch with customer needs? Spare parts and after sales service, Sloan Management Review. Winter (1990) 55-66.
47. P. Gaiardelli, N. Saccani, L. Songini, Performance measurement systems in the after-sales service: an integrated framework, International Journal of Business Performance Measurement. 9 2 (2007) 145-171.
48. W.J. Fabrychy, B.S. Blanchard, Life-Cycle Cost and Economic Analysis, Prentice Hall, Englewood Cliffs, NJ, 1991.
49. M.D. Shields, S.M. Young, Managing product life cycle costs: an organizational model, Cost Management. Fall (1991) 39–52.
50. K.A. Artto, Life Cycle Cost Concepts and Methodologies, Cost Management, Fall, 1994.
51. R. Cooper, R. Slagmulder, Supply Chain Development for the Lean Enterprise: Interorganisational Cost Management, Productivity Press, Portland, 1999.
52. R. Cooper, R. Slagmulder, Strategic cost management: expanding scope and boundaries, Journal of Cost Management. January–February (2003).
53. L.M. Ellram, Total cost of ownership. An analysis approach for purchasing, International Journal of Physical Distribution and Logistics Management. 25 8 (1995) 4–23.

54. R.T. Frambach, I. Wels-Lips, A. Gundlach, Proactive product service strategies, Industrial Marketing Management. 26 (1997) 341-352.
55. V. Mathieu, Product Services: from a Service Supporting the Product to a Service Supporting the Client, The Journal of Business and Industrial Marketing. 16 (2001) 39-58.
56. H. Yamashina, S. Otani, Cost-optimized maintenance of the elevator – single unit case, Journal of Quality in Maintenance Engineering. 7 1 (2001) 49-70.
57. B. Kim, S. Park, Optimal pricing, EOL (end of life) warranty, and spare parts manufacturing strategy amid product transition, European Journal of Operations Research. 188 3 (2008) 723-745.
58. H. Gebauer, P. Benke, E. Fleisch, Service performance strategies in companies producing capital goods, ZWF Zeitschrift fuer Wirtschaftlichen Fabrikbetrieb. 102 2 (2008) 865-869.
59. C. Armistead G. Clark, A framework for formulating After-sales support strategy, International Journal of Operations and Production Management. 11 3 (1991) 111-124.
60. N. Löfberg, L. Witell, A. Gustafsson, Service strategies in a supply chain, Journal of Service Management. 21 4 (2010) 427-440.
61. S. Agnihothri, N. Sivasubramaniam, D. Simmons, Leveraging technology to improve field service, International Journal of Service Industry Management. 13 1 (2002) 47-68.
62. J.D. Patton, W.H. Bleuel, After the sale, The Solomon Press, New York, 2000.
63. A. Brun, G. Novakova, P. Gaiardelli, D. Corti, R. Pinto, Design of a performance measurement architecture for integrated after-sales processes, in: Proc. of Performance Measurement Association (PMA'04) Conference, EICC, Edinburgh (UK), 28-30 July, 2004, pp. 163-170.
64. B. Beamon, Measuring supply chain performance, International Journal of Operations and Production Management. 19 3 (1999) 275–292.
65. F. Chan, Performance Measurement in a Supply Chain, International Journal of Advanced Manufacturing Technology. 21 (2003) 534–548.
66. Supply Chain Council (SCC), Supply Chain Operations Reference model (SCOR), version 9.0, Customer Chain Operations Reference model (CCOR), www.supply-chain.org, 2008.
67. H.T. Papadopoulos, A Field Service Support System Using a Queueing Network Model and the Priority MVA Algorithm, Omega. 24 (1996) 195 – 200.
68. W.J. Hopp, R.Q. Zhang, M.L. Spearman, An easily implementable hierarchical heuristic for a two-echelon spare parts distribution system, IEEE Transactions. 31 (1999) 977 – 988.
69. J. Huiskonen, Maintenance spare parts logistics: Special characteristics and strategic choices, International Journal of Production Economics. 71 (2001) 125 – 133.
70. R.Q. Zhang, W.J. Hopp, C. Supatgiat, Spreadsheet Implementable Inventory Control for a Distribution Center, Journal of Heuristics. 7 (2001) 185 – 203.
71. M. Bijvank, G. Koole, I.F.A. Vis, Optimising a general repair kit problem with a service constraint, European Journal of Operational Research. 204 1 (2010) 76-85.
72. F. Persson, N. Saccani, Managing the after sales logistic network – a simulation study of a spare parts supply chain, IFIP International Federation for Information Processing. 246 (2007) 313-320.

73. L. Fitzgerald, P. Moon, Performance measurement in service industries: making it work, CIMA, London, 1996.
74. U.S Bititci, T. Turner, C. Begemann, Dynamics of performance measurement system, International Journal of Operations & Production Management. 20 6 (2000) 692-704.
75. P. Osadsky, A. Garg, B. Nitu, O. Schneider, S. Schleyer, Improving service operation performance by a cross-industry reference model, in: Proc. of the IFIP International Federation for Information, Advances in Production Management Systems, eds. Olhager J., Persson F., Springer, Boston, 246, 2007, pp. 397-404.
76. P. Gaiardelli, N. Saccani, L. Songini, Performance measurement of the After-Sales Service network. Evidences from the automotive industry, Computers in Industry. 58 7 (2007) 698-708.
77. A.D. Neely, Measuring business performance: why, what and how, The Economist and Profile Books Ltd., London, UK, 1998.
78. C. Voss, Case research in operations management, in: Researching operations management, edited by Karlsson C., Routledge, New York, 2009.
79. D. Corti, P. Gaiardelli, E. Legnani, N. Saccani, Managing and controlling processes in product-based service networks, in: Proc. Of 11th International Conference MITIP, Bergamo, Italy, 15-16 October 2009.
80. S.D. Flapper, L. Fortuin, P.P. Stoop, Towards consistent performance management systems, International Journal of Operations & Production Management. 16 7 (1996) 27-37.
81. A. Neely, The performance measurement revolution: why now and what next?, International Joutnal of Operations & Production Management. 19 2 (1999) 205-228.
82. S.P. Santos, V. Belton, S. Howick, Adding value to performance measurement by using system dynamics and multicriteria analysis, International Journal of Operations & Production Management. 22 11 (2002) 1246 – 1272.
83. J. Sterman, Business dynamics: system thinking and modelling for a complex world, McGraw-Hill, 2000.

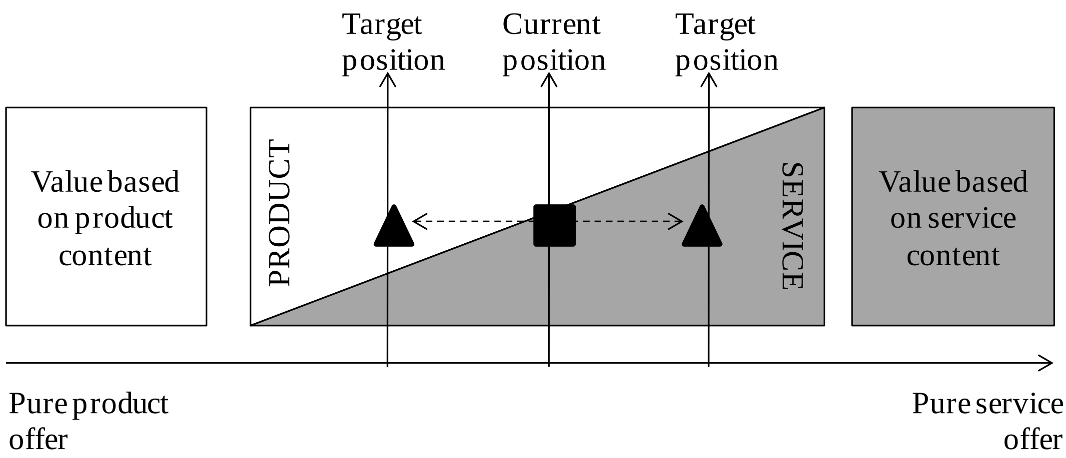

Figure 1 – The product-service continuum (adapted from Oliva and Kallenberg 2003)

PERFORMANCE ATTRIBUTES	DEFINITION	LEVEL 1 METRICS
Reliability (RL)	The performance of the service network to offer the right products/services at the right time, to generate the right contractual agreements in place, to provide the right answers to customer enquiries.	RL1.1: Perfect Assist Completion
Responsiveness (RS)	The speed at which customer enquiries are resolved by the service network.	RS.1.1: Assist Cycle Time for Turn-Key assist RS.1.2: Assist Cycle Time for Collaborative assist
Agility (AG)	The agility of a service network in responding to marketplace changes to gain or maintain competitive advantage.	AG.1.1: Reaction time to unplanned events AG.1.2: Adaptability to the increase of unplanned requests for Collaborative assist AG.1.3: Adaptability to the increase of unplanned requests for Turn-Key assist AG.1.4: Adaptability to customized requests
Costs (CO)	The costs reported by a company and associated with operating the service network in order to resolve customer enquiries.	CO.1.1: Total Assist Cost
Asset Management (AM)	The effectiveness of a company in managing fixing and working capital assets to resolve customer enquiries.	AM.1.1: Return on Assist Assets AM.1.2: Assist Cash-to-Cash Cycle Time AM.1.3: Return on Assist Working Capital
Growth (GR)	The ability of a company to grow along the time and generate a net income on a consistent and sustainable basis.	GR.1.1: Assist operating margin growth GR.1.2: Customer loyalty GR.1.3: Growth of maintenance contracts GR.1.4: Call variance

Table 1 – After-Sales performance attributes and relative Level 1 metrics

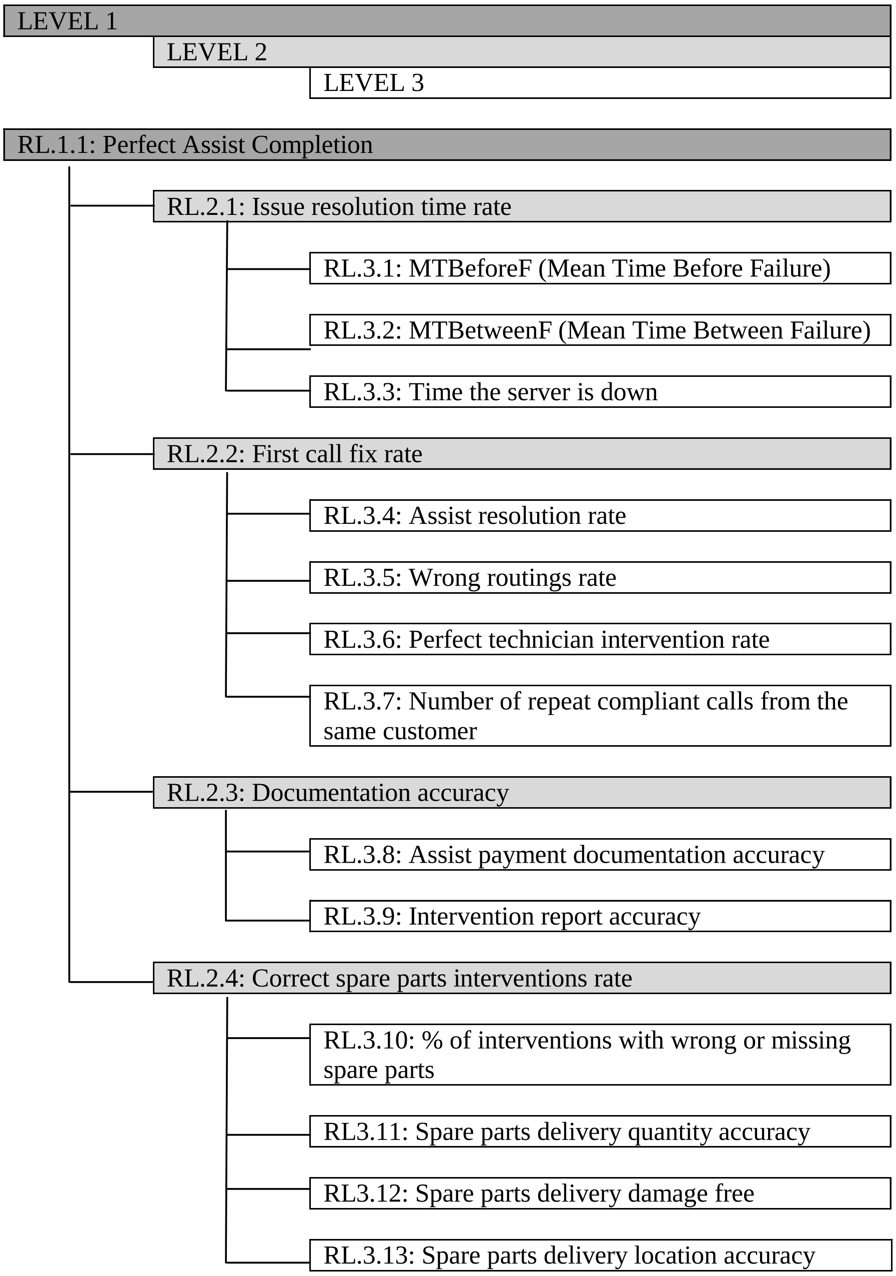

Figure 2 - Hierarchical structure for *Perfect Assist Completion*

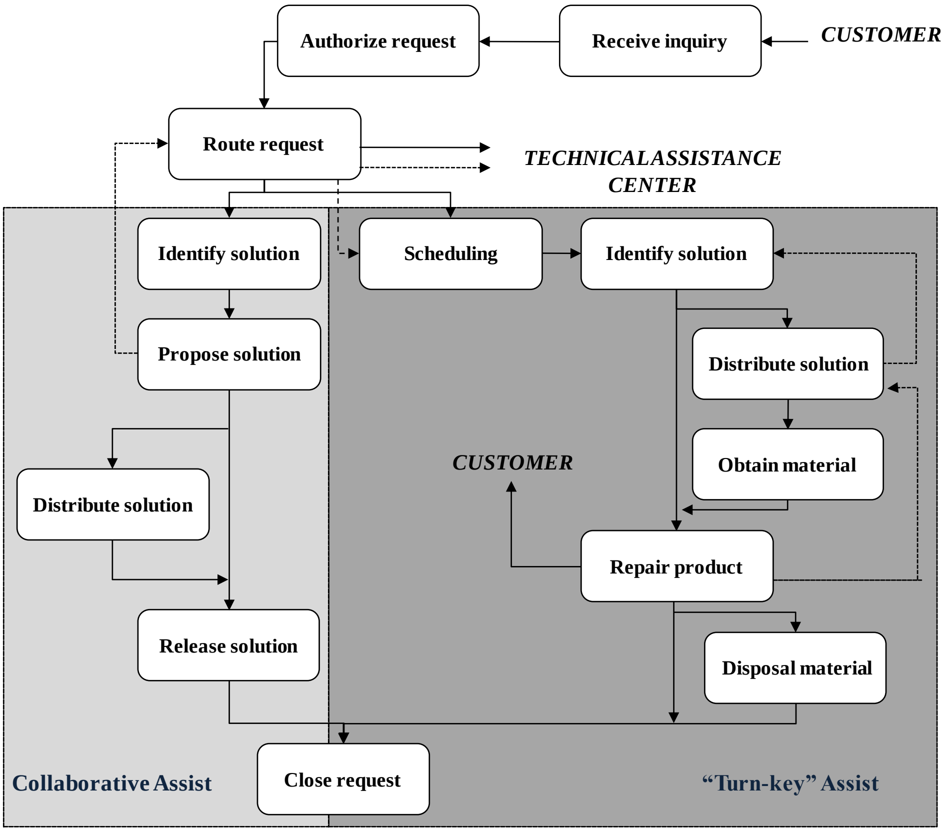

Figure 3 – Application of a process-diagnostics structure

'Turn-Key' Assist	
Receive inquiry/request	
Authorize request	
Route request	
Scheduling	
RS.2.4: Average time for scheduling technical assistance	Responsiveness
AG.3.3: % of last minute interventions added in the scheduling	Agility
Identify solution	
Distribute solution	
Obtain materials	
AM.2.2: Spare Parts Inventory Days of Supply (IDS) AM.3.1: Spare part Inventory turns in the warehouse AM.3.2: Spare part Inventory turns on the van	Asset Management
Repair product or obtain customer agreement	
RL.3.1: Mean number of bales before failure RL.3.2: Mean number of bales between failures	Reliability
RS.2.8: MTTR (Mean Time To Repair) a machine RS.2.9: MTTR (Mean Time To Repair) each machine per technician	Responsiveness
AG.2.5: Time required to perform a new and customized request	Agility
CO.3.4: Average repair intervention cost	Cost
Dispose materials	

Close request	
RS.2.14: Average number of turn-key interventions during out of peak season RS.3.1: Number of average turn-key interventions for technician during out of peak season	Responsiveness
AG.2.4: Average number of turn-key interventions during peak season AG.3.2: Number of average turn-key interventions for technician during peak season	Agility

Table 2 – Level 3 processes associated with Level 2 and Level 3 metrics for the "Turn-Key" Assist process