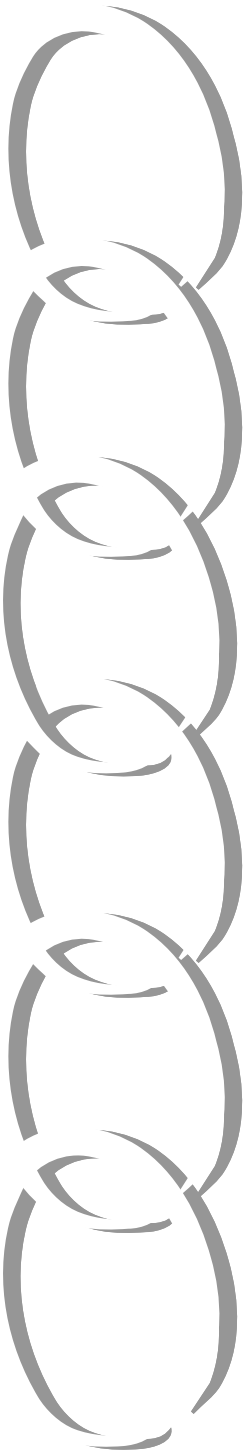
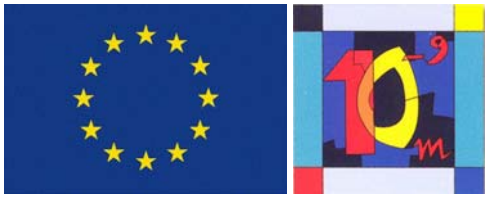


InCoCo-S

Innovation, Coordination and Collaboration
in Service Driven Manufacturing Supply Chains

Deliverable Nr. DL 4.1

Formulation of the MoP for Service-Supply Chain



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Executive Summary

The goal of the deliverable is to define key design features (including a first list of key performance indicators) and goal definitions for an effective performance measurement system which expressly addresses the service-supply chain.

This document will therefore represent the basis for the complete definition of a service performance measurement system (SPMS) which will be realized later on in the InCoCo-S project (DL.4.2).

In order to achieve this goal an investigation on the existing academic and business literature in the area of performance measurement systems (and in particular in the supply chain and virtual enterprise domain) has been carried out and is here presented. The intent is to identify strengths and weaknesses of the presently available performance measurement solutions and point out interesting ideas, aspects and concepts which could be useful to depict a first concept for the future InCoCo-S SPMS.

Later on an analysis of the industrial requirements in terms of performance measurement needs is presented, where the key results from the InCoCo-S business cases, from the InCoCo-S survey and from expressly designed interviews to the InCoCo-S industrial partners are summarised. The identified requirements will set the boundaries and the direction for the design of the InCoCo-S SPMS.

1 Introduction

Organizations measure their performance in order to learn what is happening and in order to identify problems, and make corrections. Performance measurement addresses such matters as the extent to which an organization's initiatives have been successful, whether they can be improved, whether they should continue, and whether there are more cost-effective alternatives. Ultimately, performance measurement is a tool that improves analysis, communication, learning, and understanding. Moreover organizations of all types are increasingly being asked to not only do more with less, but also to prove that they are doing it. This means that they need to measure their performance to both manage their operations and to demonstrate to others how well they are doing.

Several research activities and industrial projects have been and are currently carried out in the area of performance measurement. The importance of performance measurement practices for the decision-making processes of organizations is generally well documented in the field of operations management and supply chain management. Moreover, although it is evident from the generic management literature that performance measurement is a contextually defined phenomenon, there is a limited number of detailed studies into performance measurement practices in service businesses in general and even less in the industrial service sector in particular.

From the business cases carried out with the industrial partners of the InCoCo-S project as well as from the InCoCo-S survey a strong need for novel performance measurement systems which are expressly designed to address the service supply chain emerged.

Later on in this deliverable the requirements coming from the InCoCo-S business cases in terms of desired characteristics for a new performance measurement system will be summarized.

According to the InCoCo-S survey (DL.2.1) hardly any of the current performance measurement systems in use fits the needs of service companies. Although the majority of service companies is using a performance measurement system, even more than 50% of the companies states to be not satisfied with their use. The same percentage of companies confirms this statement by indicating a high potential for improvement of the current performance measurement system.

Thus, the aim of this work is to explore the existing academic and business literature in the area of performance measurement systems (and in particular in the supply chain domain), to identify strengths and weaknesses of the presently available solutions and, starting from this basis, to depict a first concept for the future InCoCo-S service performance measurement system (SPMS) having in mind the boundaries and goals set by the industrial requirements identified.

2 Research on the state of the art on performance measurement systems for the supply chain

2.1 Glossary

Three terms will be used throughout this work.

- A performance indicator (**PI**) is a variable that expresses quantitatively the effectiveness or efficiency or both, of a part of or a whole process, or system, against a given norm or target (synonymous: Measures of performance, MoP).
- Performance Measurement (**PM**) is the activity of measuring performance using PIs.
- A Performance Measurement System (**PMS**) is an organised set of PIs optionally supported by a system (software, databases, and procedures) to execute PM in a consistent and complete way.

2.2 Structure and approach of the SOTA research

The literature research is organised according to the structure shown in Figure 1.

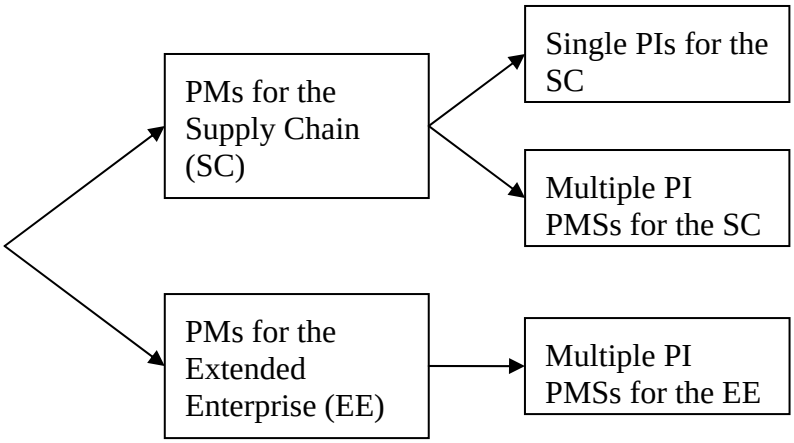

Figure 1 Structure of the literature research

2.3 Approach of the SOTA research on PM in the SC and EE

Current studies of inter-organisational PM usually focus on supply chain PM; extended enterprise PM has been touched only briefly by the PM literature. A supply chain PM system focuses on what are termed by Brewer and Speh (2000) traditional logistics performance measures (i.e. measures such as order fill rates, error rates, inventory costs, delivery time, etc.). By focusing almost completely on the logistics control system, supply chain PM cannot answer a number of wider ranging, more holistic questions. For example: How effectively are the firms in the supply chain interacting? How does this supply chain fare compared to competing supply chains? How flexible is the entire supply chain in responding to requests for customised packages, orders and products? To what extent are decisions within the supply chain motivated by power rather than by mutual trust? (Brewer and Speh, 2000).

These questions are tackled by an extended enterprise PM system, which in effect, incorporates the structural aspects of the supply chain PM system and adds a number of non-logistic perspectives to its measurement arena (for example, internal process measures, intangible measures, measures of financial performance, etc.). The supply chain PM system maintains a more traditional arms length relationship with suppliers and customers by requesting data only upon issues of immediate concern from the logistics functions of participating companies. The extended enterprise PM system may theoretically present data

from all aspects of the participating companies' functions. However, developing an extended enterprise PM system also requires the development of a robust conceptual supply chain PM framework, thus the two concepts are integral to each other.

2.4 Introduction to PM in the Supply Chain (SC) and the Extended Enterprise (EE)

Bititci et al (2005) define an EE as a knowledge-based organisation which uses the distributed capabilities, competencies and intellectual strengths of its members to gain competitive advantage to maximise the performance of the overall extended enterprise.

While a SC is a customer-supplier chain of individual enterprises, each operating as an individual enterprise trying to maximise its own corporate goals, thus sub-optimising the overall performance, an EE is a chain of enterprises, which essentially behave as a single enterprise trying to maximise the corporate goals of the extended enterprise, thus optimising the performance of each individual enterprise. This difference is illustrated in the following figure.

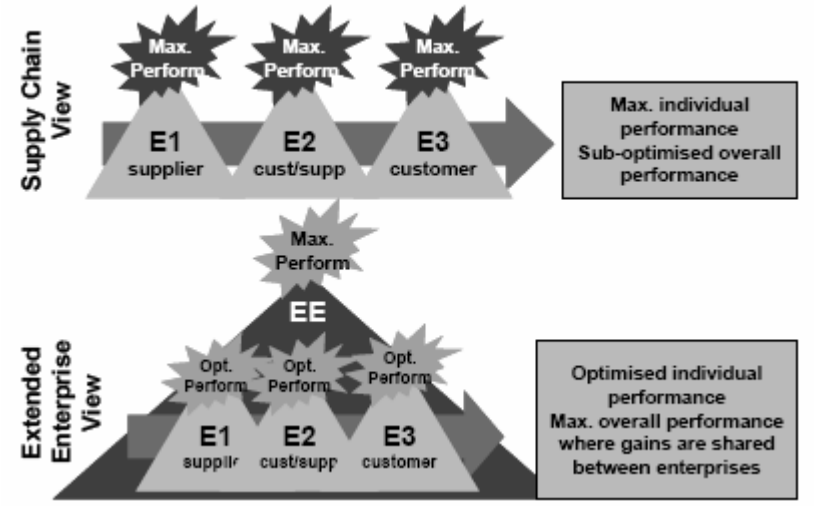

Figure 2 – Supply chains and Extended Enterprises (source: S. Cavalieri, P. Valckenaers, U. Bititci, R. Bandinelli, K. Mendibil; Performance measurement systems in manufacturing: state of the art and future trends; Proceedings of the International IMS Forum 2004)

A review of PMSs in SC and EE has been conducted and is presented in the followings.

2.5 SOTA in SC PM

2.5.1 Single PIs for SC

Supply chain models have predominately utilized two different performance measures: cost and a combination of cost and customer responsiveness. Costs may include inventory costs and operating costs. Customer responsiveness measures include lead time, stockout probability, and fill rate. The table below summarizes the supply chain models available in the literature and the corresponding performance measures used. These models use the listed performance measures as objectives that are either minimized or maximized, subject to various operational constraints.

Measure	Author(s)	
Cost	Cohen and Lee (1988)	Pyke and Cohen (1993)
	Cohen and Lee (1989)	Pyke and Cohen (1994)
	Cohen and Moon (1990)	Tzafestas and Kapsiotis (1994)
	Lee and Feitzinger (1995)	
Cost and Activity Time	Arntzen et. al. (1995)	
Cost and Customer	Altoik and Ranjan (1995)	Newhart, Stott, and Vasko (1993)
Responsiveness	Christy and Grout (1994)	Towill (1991)
	Cook and Rogowski (1996)	Towill, Naim, and Wikner (1992)
	Davis (1993)	Wikner, Towill, and Naim (1991)
	Ishii et. al. (1988)	
Customer Responsiveness	Lee and Billington (1993)	
Flexibility	Voudouris (1996)	

Table 1 – Single PI PMSs

Other performance measures have been identified as appropriate for supply chain analysis, but have not yet been used in supply chain modelling research. Although these measures may be important characteristics of a supply chain, their use in supply chain models is challenging, since the qualitative nature of such measures make them difficult to incorporate into quantitative models. Examples of such measures are: customer satisfaction (Christopher, 1994), information flow (Nicoll, 1994), supplier performance (Davis, 1993), and risk management (Johnson and Randolph, 1995).

The use of a single performance measure is attractive because of its simplicity. However, one must ensure that if a single performance measure is utilized, this measure adequately describes the system performance. Beamon (1996) identified and evaluated various individual supply chain performance measures. The author concluded that significant weaknesses were present in each of the performance measures evaluated, based on such criteria as “inclusiveness, universality, measurability, and consistency”. Repeatedly, the most consistent weakness for these performance measures was inclusiveness. In order for a measure to be inclusive, it must measure all pertinent aspects of the supply chain. Consider an example in which a company decides to use cost as the measure of supply chain performance. Although the supply chain may be operating under minimum cost, it may simultaneously demonstrate poor customer response time performance, or lack flexibility to meet random fluctuations in demand. Nevertheless cost is the performance measure of choice for many supply chain models.

Although cost as a resource measure is important, there are downfalls to relying on cost as the sole performance measure.

Maskell (1991) suggests that the type of performance measures required for a manufacturing organization is directly related to the manufacturing strategy chosen by the company. The two reasons cited for establishing and maintaining this relationship are: the company may determine if its performance is meeting its strategic goals, and people in the organization will concentrate on what is measured, thus the performance measure will steer company direction.

Consider the strategic goal examples in the table below and the corresponding implied performance measures. Strategic goals seldom imply only one performance measure; they usually point to many, and are not always clearly defined. For example, product quality can

be measured in many different ways. Although it may be difficult to choose the individual performance measures, it is vital that the performance measures are related to the strategic goals of the organization.

Strategic Goals	**Implied Performance Measurement System**
High quality custom-designed product at the lowest possible cost.	Cost Product Quality
Manufacture of product and consistently delivery to the customer on time and at a low cost.	Cost Product Lateness
High quality product which will meet future customer demands.	Product Quality Flexibility

Table 2 – Relationship between strategic goals and PMSs

Chan and Qi (2003_2)

Quite often single PIs are obtained through the combination of different sets of measure, combined in diverse ways. These PIs are usable to perform and overall comparison of 2 SCs but they do not support in understanding SC's strong and weak areas and to implement corrective actions.

Chan and Qi have been particularly active in this research field and have come out with some proposals.

Chan et al. (2003_2) propose a mathematical model that employs fuzzy-set theory to measure the integrated performance of complex supply chain though the adoption of a single performance parameter. Fuzzy set-theory is used to address the real situation in judgement and evaluation processes. It can deal with imprecise information to aid decision making. The procedure of the evaluation is as follows: after selection of the appropriate performance measures, data should be collected for analysis. The performance measures are weighted by finding the normalised importance weight through a geometric scale of triangular fuzzy number. Then, fuzzy performance grade is defined to find the fuzzy measurement result and a performance score can be calculated. Finally the measurement results can be de-fuzzied to a performance index, which can be used to indicate the performance of the system under evaluation.

Chan and Qi (2003_3)

Chan et al. (2003_3) propose moreover an alternative solution to calculate a single PI based on an analytic hierarchy process (AHP) algorithm.

To obtain the best and most optimum supply chain for different industries is very difficult. The importance of each performance measure is different in various industries. Thus, weightings have to be assigned to each performance measure according to its contribution to the performance of a given supply chain.

Both quantitative and qualitative measurements can be represented as input data for the application of the AHP. The AHP is a commonly used tool for solving multi-criteria decision-making problems, developed by Saaty. The AHP provides a framework to cope with multiple criteria situations involving tangible and intangible, quantitative and qualitative aspects. It consists of three steps:

1. Decomposing the complex problem into a hierarchy of different levels of elements.
1. Using a measurement methodology to establish priorities among the elements.
2. Synthesising the priorities of elements to establish the final decision.

2.5.2 Multi-PIs PMS for the SC

Beamon (1998)

Beamon (1998) identifies a list of performance measures, mainly gathered from literature, which can be defined as quantitative or qualitative and proposes the following PM framework.

Qualitative performance measures

Qualitative performance measures are those measures for which there is no single direct numerical measurement, although some aspects of them may be quantified. These are:

- Customer satisfaction: The degree to which customers are satisfied with the product and/or service received, and may apply to internal customers or external customers. Customer satisfaction is comprised of three elements:
  - Pre-transaction satisfaction: satisfaction associated with service elements occurring prior to product purchase.
  - Transaction satisfaction: satisfaction associated with service elements directly involved in the physical distribution of products.
  - Post-transaction satisfaction: satisfaction associated with support provided for products while in use.
- Flexibility: The degree to which the supply chain can respond to random fluctuations in the demand pattern.
- Information and material flow integration: The extent to which all functions within the supply chain communicate information and transport materials.
- Effective risk management: All of the relationships within the supply chain contain inherent risk. Effective risk management describes the degree to which the effects of these risks are minimized.
- Supplier performance: With what consistency suppliers deliver raw materials to production facilities on time and in good condition.

Quantitative performance measures

Quantitative performance measures are those measures that may be directly described numerically. Quantitative supply chain performance measures may be categorized by: objectives that are based directly on cost or profit and objectives that are based on some measure of customer responsiveness.

Measures based on cost are:

- Cost minimization: The most widely used objective. Cost is typically minimized for an entire supply chain (total cost), or is minimized for particular business units or stages.
- Sales maximization: Maximize the amount of sales dollars or units sold.
- Profit maximization: Maximize revenues less costs.
- Inventory investment minimization: Minimize the amount of inventory costs (including product costs and holding costs).
- Return on investment maximization: Maximize the ratio of net profit to capital that was employed to produce that profit.

Measures based on customer responsiveness are:

- Fill rate maximization: Maximize the fraction of customer orders filled on time.

- Product lateness minimization: Minimize the amount of time between the promised product delivery date and the actual product delivery date.
- Customer response time minimization: Minimize the amount of time required from the time an order is placed until the time the order is received by the customer. Usually refers to external customers only.
- Lead time minimization: Minimize the amount of time required from the time a product has begun its manufacture until the time it is completely processed.
- Function duplication minimization: Minimize the number of business functions that are provided by more than one business entity.

The following table summarises some key PIs found in literature, presenting the source of each PI.

Basis	**Performance measure**	**Author(s)**
Cost	Minimize cost	Camm et al. Lee et al. Lee and Feitzinger Tzafestas and Kapsiotis Pyke and Cohen Pyke and Cohen Lee et al.] Svoronos and Zipkin Cohen and Moon Cohen and Lee Ishii et al. WilliamsWilliams
	Minimize average inventory levels	Altiok and Ranjan Towill and Del Vecchio
	Maximize profit	Cohen and Lee
	Minimize amount of obsolete inventory	Ishii et al.
Customer	Achieve target service level (Þll rate)	Lee and Billington Lee et al. Towill and Del Vecchio
Responsiveness	Minimize stockout probability	Altiok and Ranjan Ishii et al.
Cost and customer responsiveness	Minimize product demand variance or demand amplification	Newhart et al. Towill et al. Towill Wikner et al.
	Maximize buyer/supplier benefit	Christy and Grout
Cost and activity time	Minimize the number of activity days and total cost	Arntzen et al.
Flexibility	Maximize available system capacity	Voudouris

Table 3 – Key PIs found n literature by Beamon (1998)

Beamon (1999)

Beamon, reviewing previous supply chain design models, suggests that the most used competitive priorities were cost (and hybrids of cost: with time or with customer responsiveness), followed by customer responsiveness and flexibility. The quantitative nature of cost makes it more appealing than other measures such as flexibility and customer responsiveness, which are qualitative in nature. Beamon concludes that it is unlikely that a single performance measure will be adequate for an entire supply chain, and that a system of performance measures is required for accurate measurement of supply chain systems.

Therefore, Beamon (1999) proposes an alternative framework, comprising of three types of performance measures: resource measure, output measures and flexibility measures. She argues that supply chain PMS must contain at least one individual measure from each of the identified types.

Each of these three types of performance measures has different goals, as illustrated in the table below. The supply chain PMS must measure each of the three types (R, O, and F), as each type is vital to the overall performance success of the supply chain.

Performance Measure Type	Goal	Purpose
Resources	High level of Efficiency	Efficient resource management is critical to profitability.
Output	High level of Customer Service	Without acceptable output, customers will turn to other supply chains.
Flexibility	Ability to Respond to a Changing Environment	In an uncertain environment, supply chains must be able to respond to change.

Table 4 – Performance measure types: goals and purposes

Although many individual supply chain performance measures exist for resources and output, the number of flexibility measures actually applied to supply chains is few. Therefore, Beamon (1999) develops volume flexibility and delivery flexibility measures for supply chains, and presents existing measures for mix flexibility and new product flexibility.

The individual measures chosen from each type must coincide with the organisations strategic goals. This measurement system can then allow study of the interactions among the measures or can at least ensure a minimum level of performance in different areas.

Some examples of PIs for each category are here reported (for a more detailed definition please refer to the article itself listed in the Bibliography at the end of this document).

Resource:

- Total Cost: Total cost of resources used.
- Distribution Costs: Total cost of distribution, including transportation and handling costs.
- Manufacturing Cost: Total cost of manufacturing, including labour, maintenance, and rework costs.
- Inventory: Costs associated with held inventory.
- Inventory Investment: Investment value of held inventory.
    - Inventory Obsolescence: Costs associated with obsolete inventory; sometimes includes spoilage.
    - Work-in-Process: Costs associated with work-in-process inventories.
    - Finished Goods: Costs associated with held finished goods inventories.
- Return on Investment (ROI): Measures the profitability of an organization. The return on investment is generally given by the ratio of net profit to total assets.

Output:

- Sales: Total revenue.
- Profit: Total revenue less expenses.
- Fill Rate: Proportion of orders filled immediately.

  - Target Fill Rate Achievement: To what extent a target fill rate has been achieved.
  - Average Item Fill Rate: Aggregate fill rate divided by the number of items.
- On-Time Deliveries: Measures item, order, or product delivery performance.
  - Product Lateness: Delivery date minus due date.
  - Average Lateness of Orders: Aggregate lateness divided by the number of orders.
  - Average Earliness of Orders: Aggregate earliness divided by the number of orders.
  - Percent on-time deliveries: Percent of orders delivered on or before the due date.
- Back Order/Stockout: Measures item, order, or product availability performance.
  - Stockout Probability: Instantaneous probability that a requested item is out of stock.
  - Number of Backorders: Number of items backordered due to stockout.
  - Number of Stockouts: Number of requested items that are out of stock.
  - Average Backorder Level: Number of items backordered divided by the number of items.
- Customer Response Time: Amount of time between an order and its corresponding delivery.
- Manufacturing Lead Time: Total amount of time required to produce a particular item or batch.
- Shipping Errors: Number of incorrect shipments made.
- Customer Complaints: Number of customer complains registered.

Flexibility

Flexibility can measure a SC's ability to accommodate volume and schedule fluctuations from suppliers, manufacturers, and customers.

Four types of flexibility can be identified:

- *Volume Flexibility*: The ability to change the output level of products produced. A generalization of volume flexibility is to measure the range of volumes in which the organization can run profitably. For manufacturing systems, the development of volume flexibility measures has generally considered the costs associated with volume changes. For the development of a supply chain volume flexibility measure, we are interested in how much of the demand can be met considering only the range of volumes that are profitable. The volume flexibility measures the proportion of demand that can be met by the supply chain system.
- *Delivery Flexibility*: The ability to change planned delivery dates. This ability allows the supply chain to accommodate rush orders and special orders, and will be described as delivery flexibility. Delivery flexibility will be expressed as the percentage of slack time by which the delivery time can be reduced.
- *Mix Flexibility*: The ability to change the variety of products produced. Generally, mix flexibility measures either the range of different product types that may be produced during a particular time period, or the response time between product mix changes. More specifically, Slack (1991) discusses measuring mix flexibility as: (1) the number of different products that can be produced within a given time period (product mix flexibility range) or (2) the time required to produce a new product mix (product mix flexibility response).
- *New Product Flexibility*: The ability to introduce and produce new products (this includes the modification of existing products). New product flexibility is defined as

the ease with which new products are introduced to the system. The introduction of new products will generally involve some time for development and set-up. Sethi and Sethi (1990) discuss measuring product flexibility as either the time or cost required to add new products to existing production operations.

Dreyer (2000)

Dreyer (2000) does not present a specific list of PIs, nevertheless it presents a comprehensive framework for PMS design, which can be useful for InCoCo-S purposes.

Dreyer (2000) has suggested a three-step supply chain PM framework (with associated advice) to develop a successful supply chain PM system based on operational, tactical and strategic measures.

The three steps are:

- Understand the current state of the supply chain.
- Recognize what is important to the business.
- Clarify who uses which measures and why.

Understand the Current State

The first step in developing and maintaining an effective set of metrics is to have a clear picture of the key supply chain processes. At the highest level, these will include:

- Procurement—supplier selection and contracting.
- Ordering—placing orders for materials with suppliers.
- Processing—performing value-added supply chain tasks such as assembly and warehousing.
- Distribution—moving product to the customer.

When a company has a clear picture of these processes, it will be able to reassess and redesign the supply chain performance metrics.

When mapping a supply chain, both processes (for example, purchasing practices and order management) and operational facilities (warehouses, distribution centres, and so forth) should be portrayed. By possessing a clear understanding of the various components and relationships within the supply chain, the company will then be better able to identify important measures of performance.

Once a company has mapped the major processes and related facilities, it is useful to quantify the network. For example: How many suppliers are there? What are the order frequencies and volumes? What modes of transportation are used?

The pace of supply chain changes dictates a regular review of the current state so that you can quickly identify the related opportunities and threats. As a company models its current supply chain, it can put in place some formal steps to keep the information current.

Recognize What Is Important

The steps to follow are:

- Look at company's vision and mission statements to understand what elements the organization values.
- List the key existing metrics to get a clear idea of what is currently measured. Typically, these metrics include the majority of the important supply chain levers—for example, safety, quality, cost, and responsiveness. For each of these qualities, look for specific metrics at each point in the supply chain.
- By taking a high-level look at the fundamental principles underlying the business, ensure that the organization measures factors that really matter (top management

should define the core business and principles of the organization and then determine what should be measured).

- Once it's known what is already measured, ask what should be measured. To assure to have a complete list and to increase organizational buy-in, conduct brainstorming sessions on the metrics with all of the stakeholders, including suppliers and customers.
- Continuously documenting and reviewing metrics reinforces the key issues to be addressed or recognized. In a changing environment, a regular review of key metrics lets reassess what is most important to the success of the business.

Clarify Who Uses What Metrics and Why

Good measurements help people at every level focus on improving and innovating. Measurements must be appropriate for the specific user's area of influence. That's why it is so important to clarify who uses what information and for what purpose. People should be able to take action on the measurements they receive.

Companies often become mired in operational measures and neglect broader metrics. Yet metrics need to be put in place at all levels: operational, tactical, and strategic. At all levels good metrics help people focus on the issues for which they are responsible.

Operational measures. Operational measures give operators feedback on their performance. To illustrate, if a key metric is productivity, an operational measure might focus on pieces produced per hour by an operator on a specific machine.

The operational timeframe is short: hourly or daily. The focus is support for the operator, the clerical staff, the sales personnel, and others who touch the product and the customer.

Tactical measures. Tactical measures make it possible to address variations from operational performance. They examine whether or not a business's basic tactics are accomplishing the planned objective.

Tactical measures typically examine a wider perspective than do operational measures and extend out over a longer timeframe. For example, to examine productivity at the tactical level, we may measure a collection of operators who make up a department, rather than a single operator. Rather than hourly metrics, tactical measures would look at performance over a shift, a day, a week, and so forth. These broader measures make it possible to detect variation in performance quickly.

Tactical measures would help a frontline manager answer the following kinds of questions: When sales deviate from the norm, is this unusual or not? Does the sales incentive program need to be modified in light of changes in sales performance? Has a change in some portion of the delivery process caused a slowdown in order response time?

Strategic measures. Strategic measures support evaluation of the underlying business strategy. Typically, strategic measures look at monthly and annual performance.

When strategic measures show improvement or deterioration, companies need to be able to drill back to the tactical and operational levels to gain insight into the underlying causes.

Understanding the differences between operational, tactical, and strategic reporting is essential to the efficient operation of any organization. In the hierarchy of stakeholders within the supply chain, everyone must play his or her position. Executives are responsible for strategy. Management is responsible for tactical success. Operators are responsible for their individual performance and must have feedback on that performance. All parties need to

concentrate on their respective roles while having confidence that the other members of the team will do the same.

Lapide (2000)

Lapide (2000), such as Dreyer (2000), does not present a specific list of PIs, nevertheless its framework for PMS design can give good hints for InCoCo-S purposes.

Lapide (2000) proposes a two-tier supply chain PM framework, which depicts the relationship between what the author terms Executive level metrics and Managerial level metrics in the supply chain. The former can be considered to be cross-functional (and inter-organisational), process-based measures; the latter are function-based diagnostic measures.

Lapide (2000) starts from the assumption that financial accounting measures, while important in assessing an enterprise's financial health, are insufficient to measure supply chain performance for the following reasons:

- The measures tend to be historically oriented, lacking a forward-looking perspective.
- They do not relate to strategic performance.
- The measures are not directly tied to operational effectiveness/efficiency.

A balanced scorecard approach to PM addresses these deficiencies.

Some key considerations are given by Lapide (2000):

- *Measures aligned with strategies.* A key balanced scorecard principle is that the measures should be aligned with strategic objectives.
- *Measure Process, Not Just Functions***.** Yet these objectives differ for every company depending on its current competencies and stage of development. Historically, however, most performance-measurement efforts have remained at the functional level. Each department measures performance in its own terms. Its members are evaluated on their ability to meet objectives consistent with departmental goals. Not surprisingly, then, they drive operations toward improving performance in their own department, often at the expense of other functional areas. When each area sets its performance measures in isolation from others, narrow functional interests often conflict with broader organizational goals. This doesn't mean eliminating function-based measures. But it does mean focusing on overall process performance first and then using functional measures to provide "drill-down" diagnostic information.
- *Include Inter-enterprise Measures.* The cross-functional approach to supply chain measurement applies to inter-as well as intra-enterprise processes. Fundamentally, the two most important measures of overall supply chain performance relate to availability of products at the point of consumption and total landed costs to get products to the point of consumption. Typically, multiple trading partners in the supply chain will affect these key measures. To ensure that inter-enterprise processes are effective, you need to measure the performance of supply chain operations that lie outside your enterprise. This leads to the question of whether you should measure what you cannot directly control. Actually it makes sense to measure what you cannot control to uncover deficiencies in your supply chain's performance that can be addressed by inter-enterprise initiatives.
- *Limit the Number of Metrics.* Measuring everything is impractical and administratively cumbersome. To establish a rational set of performance measures, start by understanding top management's strategic supply chain objectives. Once these objectives are understood, you can develop a limited, balanced set of executive-level measures directly aligned with these strategic objectives. These should include a balance of strategic objective and diagnostic-type metrics to help executives

determine specific process areas that might need to be improved. Management also needs performance measures that track tactical and operational activities and are aligned with strategic executive-level measures. Using the lower-level measures, managers can gauge how well they are doing relative to overall strategic goals set in place by the executive team. These metrics also provide executives with drill-down functionality into the more diagnostic metrics shown in the exhibit.

- *Update PMs*. PM also requires updating as goals change and new programs and initiatives are undertaken.

Gunasekaran et al. (2001, 2004)

Gunasekaran et al. (2001, 2004) propose a series of performance metrics for performance evaluation of SCs. The measures and metrics are arranged in three levels (strategic, tactical and operational) and along the five elements of an integrated supply chain: plan performance, source performance, production performance, deliver performance and customer satisfaction. This is rather similar to the hierarchical PM structure used within the SCOR model (Stewart, 1995; Gunasekaran et al., 2001, SCOR).

Measures are grouped in cells at the intersection of the supply chain activity and planning level. For example, Supplier delivery performance can be found at the intersection of the Source activity and Tactical planning level indicating that it pertains to sourcing activities (source) and the tactical planning level. Supplier delivery performance would thus be a measure useful in analyzing the performance of mid-level managers as they undertake sourcing activities— mid-level managers who are generally the ones responsible for tactical decisions.

Some measures appear in more than one cell, indicating that measures may be appropriate at more than one management level. Measures used at different management levels will most assuredly require adjustment to tailor them to planning and control needs of the different levels. For example, appropriate measurement may require that data used by the lower level of management be aggregated in some form or fashion to make the data appropriate for the next higher level (convert data into information appropriate for the context). There is nothing novel about this approach, as it has been used for years in management planning and control systems.

Supply chain activity/ process	**Strategic**	**Tactical**	**Operation**
Plan	Level of customer perceived value of product, Variances against budget, Order lead time, Information processing cost, Net profit Vs productivity ratio, Total cycle time, Total cash flow time, Product development cycle time	Customer query time, Product development cycle time, Accuracy of forecasting techniques, Planning process cycle time, Order entry methods, Human resource productivity	Order entry methods, Human resource productivity
Source		Supplier delivery performance, supplier lead time against industry norm, supplier pricing against market, Efficiency of purchase order cycle time, Efficiency of cash flow method, Supplier booking in procedures	Efficiency of purchase order cycle time, Supplier pricing against market
Make/ Assemble	Range of products and services	Percentage of defects, Cost per operation hour, Capacity utilization, Utilization of economic order quantity	Percentage of Defects, Cost per operation hour, Human resource productivity index
Deliver	Flexibility of service system to meet customer needs, Effectiveness of enterprise distribution planning schedule	Flexibility of service system to meet customer needs, Effectiveness of enterprise distribution planning schedule, Effectiveness of delivery invoice methods, Percentage of finished goods in transit, Delivery reliability performance	Quality of delivered goods, On time delivery of goods, Effectiveness of delivery invoice methods, Number of faultless delivery notes invoiced, Percentage of urgent deliveries, Information richness in carrying out delivery, Delivery reliability performance

Table 5 – List of PIs presented by Gunasekaran et al. (2004)

Gunasekaran et al (2005)

Gunasekaran et al. (2005) propose a PMS which could be applied to the enterprises of the 21st century where:

- Activities are difficult to trace because of the distributed nature of the virtual enterprise or supply chain environment;
- Many indirect costs will become direct costs and many direct costs will become indirect costs;
- Logistics costs are a major portion of the total cost;
- Many costs are hidden, and thus difficult to measure;

- Knowledge management and information technology costs will be major costs in the virtual enterprise or supply chain environment;
- A complex cost system will not likely work with the supply chain/virtual enterprise—a cost system similar to back flush costing may be suitable for new enterprise models.

The PBC (Performance Based Costing) system developed by Gunasekaran et al. (2005) does not directly refer to a SC or an EE, nevertheless interesting hints can be found for the development of an InCoCo-S PMS.

Gunasekaran et al. (2005) propose a PBC system which focuses on performance (in terms of financial and non-financial) rather than activities themselves, which avoids distorted product cost information produced by the application of traditional costing systems in the virtual enterprise/supply chain environment. PBC provides more accurate cost information. The basic principle of PBC is to identify the business areas that add value to an organisation and to calculate direct materials, direct labour, overhead, etc., for the purpose of accurately estimating product cost. Indeed ABC and traditional cost accounting methodologies lack the capability to capture the value of some of the value creating activities. The product cost depends on the value added and costs incurred in those areas.

The accuracy of product cost depends upon the costs of value creation areas and corresponding drivers. Based on this principle, the steps required to design a PBC system are:

- Step 1: Develop objectives for the performance based costing system
- Step 2: Develop PBC team
- Step 3: Address issues of organization
- Step 4: Identification of value-adding areas and CSFs (critical success factors)
- Step 5: Identification of CSF drivers in areas
- Step 6: Critical success factors cost pools
- Step 7: Secondary cost drivers
- Step 8: Cost object

Gunasekaran et al. (2005) describe in detail these steps and propose a list of PIs which can be applied to the new value creation areas of the 21st century enterprise.

The following table provides examples of value creation areas in new enterprises, critical success factors, performance measures and CSF drivers.

Value creation areas	Critical success factors	Performance measures	Drivers of CSF
Networking	Experience, Education, Conferences, New Initiatives, Joint Projects	Knowledge workers, Number of conferences or meetings attended, Number of joint projects, Number of new products introduced	Investment in Skilled workers, Support for exhibitions and Product promotions, New products
Partnership formation	Communication, Trust, Infrastructure, Past performance, Selection of business strategy, B2B	Data mining, Data Warehousing, Number of partners/suppliers, Training and Education	Investment in KM workers, Investment in IT, Training and Education in Virtual Enterprise
Knowledge management	Information technologies (Internet, EDI, WWW), Training and Education	Number of IT trained Managers, The age of the website, Integration of B2C and B2B, ERP, BPR, E-Commerce	Investment in training and education, Strategic alliances with high tech companies, Investment in knowledge capital
Information technology	Selection of suitable IT, Integration of suppliers/partners,	Number of Software, Number of PCs, Budget for IT training and Education, ERP system, and Investment in IT	Business strategy, agility focused, E-commerce enabled SCM, Global manufacturing, Global outsourcing, Global market
Trust creation	Long-term relationship, Transparency, Good communication, Meetings and Contracts	Number of years in business, IT investment, Past performance, Repeat orders, Delivery performance	Strategic alliances, ERP, Constant meetings between partners, Long-term business contracts, Technological support
Purchasing & logistics	Inventory control, Warehousing, Shipping and Transportation	Selection of partners for logistics service and suppliers for goods, Time to deliver products, Logistics cost, Time to Process orders	Warehousing operations strategy, Outsourcing of logistics service, Number of partners/suppliers, Number of products, IT in purchasing and logistics
Customer Relationship Management (CRM)	B2C, Customer service, Good IT skills, Communication skills, Knowledge of Products and Services, Knowledge about technical content of the product	Time to respond to customer enquiries, CRM system, Budget for training and education, Number of meetings, Workshops, Incentives	Invest in IT and KM systems, Training and Education, Strategic alliances to facilitate better CRM, Invest in communication technologies, Incentives for good job

Table 6 – List of PIs proposed by Gunasekaran et al. (2005)

Chan and Qi (2003_1)

Chan and Qi (2003_1) propose a process-based PM framework for the supply chain based upon six so-called ‘‘processes’’: suppliers, inbound logistics, core manufacturer, outbound logistics, marketing and sales, and end customers. Each of these processes is subjected to a decomposing process that progressively decomposes the process into sub-processes and activities, and decomposes the associated goals and responsibility functions into ever-more

detailed prescriptions. Measurements may then be applied to the activities, which in turn, may be aggregated upwards into sub processes, and finally into the core process.

Chan and Qi (2003_1) suggest a system perspective in the management of PM in the supply chain environments. A process-based approach has been proposed, with the objectives of identifying the participants and analysing the structure of supply chain.

Beside structure analysis, this approach is used to build the process-based PM of SCM. This kind of PMS achieves many advantages, such as supporting continuous improvement and facilitating communication of goals and progress. A new method of selecting and employing performance measure has been suggested, based on metrics board, which consists of the holistic dimensions of activity performance. These dimensions include inputs, outcomes and other critical aspects of activity performance from the viewpoint of both suppliers and customers. The method of POA (performance of activity) proposed by Chan and Qi (2003) is aimed to facilitate identifying and employing the performance measures and indicators from a systematic access, aggregating the existing or new performance measures into the holistic, integrated system in order to assess the supply chain.

Chan et al. (2003_2, 2003_3)

Chan et al. (2003_2, 2003_3) propose a new framework for PM in the supply chain based on quantitative and qualitative measurements. Some performances are simply quantitative and can be observed easily. This means that they are easily understood as they are usually represented numerically, such as cost represented by money. It is no doubt understood that a lower cost would be preferred in most cases. Qualitative criteria, such as trust and visibility, which are more conceptual, also have an influence on the performance. There is no recognised definition of qualitative criteria and when it can be appropriately applied to the supply chain. Thus, these qualitative concepts are quantified in this work to give an overview of all the attributes of the performance. A total of seven attributes are identified as important measures for supply chain performance. Two of them are direct quantitative measures (i.e. cost, and resource utilisation), and the other five are qualitative (i.e. quality, flexibility, visibility, trust, and innovativeness).

Many quality assurance systems have been launched to approve products or services as meeting the above standard. The measurements should be quantified as time and accuracy.

In the environment of supply chains, the involvement of different companies has also relied on their trust and visibility. These two concepts have not been discussed in detail in previous works. They are also qualitative, but can be measured.

Two other concepts are also the current issue in any business; they are the flexibility and innovativeness. They are still new issues and can be investigated for the development of a good supply chain.

The PIs are summarised in the following table.

	Sub criteria level 1	**Sub criteria level 2**	**Performance measurements**
A. Quantitative **Cost**		Distribution cost	The transportation and handling cost, safety stock cost and duty.
		Manufacturing cost	Labour, maintenance and re-work costs. Also, there are purchased materials, equipment charges and supplier's margin.
		Inventory cost	The work-in-process and finished goods inventories.

		Warehouse cost	Associated with allocation from one tier to another.
		Incentive cost and subsidies	Taxes and subsidies.
		Intangible cost	Quality costs, product adaptation or performance costs and coordination.
		Overhead cost	Total current landed costs.
		Sensitivity to long-term cost	Productivity and wage changes, exchange rate changes, product design and core competence.
Resource Utilisation		Labour, machine, capacity, energy	Investigate the percentage of excess or lack of that particular resource within a period.
B. Qualitative **Quality**		Customer dissatisfaction	The number of customer complaints registered.
	Time	Customer response time	The amount of time between an order and its corresponding delivery.
		Lead time	The time required once the product began its manufacture until the time it is completely processed
		On-time delivery	The percentage of orders delivered on or before the due date.
		Fill rate	The proportion of orders that can be filled immediately.
		Stockout probability	The instantaneous probability that a requested item is out of stock while number of backorders is the number of items backordered due to stockout.
		Accuracy	Percentage of accurate goods delivered to clients.
Flexibility	Input	Labour	The number of tasks a worker can perform.
		Machine	The efficiency by using a more flexible machine to the traditional switching over machine. Both time and cost saved can be used to express its efficiency.
	Process	Material handling	The number of existing paths between processing centres and the variety of material which can be transported along those paths without incurring high transition penalties or large changes in performance outcomes.
		Routeing	The number of products which have alternative routes and the extent of variation among the routes used without incurring other high costs in performance outcome.
		Operation	The number of products which have alternative sequencing plans without incurring high costs or large changes in performance outcome.

	Output	Volume	The extent of change and the degree of fluctuation in aggregate output level which the system can accommodate without incurring high costs or large changes in performance outcome OR The demand which can be profitably sustained.
		Mix	The number and variety of products which can be produced without incurring high costs or large changes in performance outcomes. OR The time required to produce a new product mix.
		Delivery	The percentage of slack time by which the delivery time can be reduced.
	Improvement	Modification	The number and variety of product modifications which are accomplished without incurring high transition penalties or large changes in performance outcomes.
		New product	Time or cost required to add new products to the existing production operation OR The number and heterogeneity or products which can be produced without involving high transition penalties or large changes in performance outcomes.
		Expansion	The number and variety of expansions which can be accommodated without involving high cost or large changes in performance outcomes.
Visibility		Time	Time required from when the designer changes his idea to when the product starts being processed in the new way.
		Accuracy	The percentage waste of wrong products made after the new design is launched.
Trust		Consistency	The percentage of late or wrong delivery to the next tier which led to an inconsistent supply. For late delivery, it is the percentage of time delayed whereas for wrong delivery, it is the percentage of returned goods.
Innovativeness		New launch of product	Compare the number of products launched by a particular company within a period. OR The percentage sales of a new product to the whole sales within a period for a company.
		New use of technology	The percentage decrease in time necessary for producing the same product.

Table 7 – List of PIs proposed by Chan et al. (2003_2, 2003_3)

Otto and Kotzab (2003)

Otto and Kotzab (2003) propose a goal-oriented approach to measure performance in the SC. In particular they suggest differing between six perspectives on SCM. Each perspective follows a particular set of goals, which consequently leads to a particular set of performance metrics. The various perspectives refer to these disciplines, which contributed the most to the development of SCM: Systems Dynamics, Operations Research/Information Technology, Logistics, Marketing, Organization and Strategy.

1. The ‘‘System Dynamics’’-perspective is the primary basis of the entire discussion in this field. The seminal works of Forrester (1958) and Burbidge (1991) stamp its character. Their contributions are still today among the most attractive ones regarding the transformation into practice. Although many scholars (Towill, 1996; Mason-Jones et al., 1997; Lee et al., 1997; Austin et al., 1997) seized their outcomes as a vantage point for current research.
2. The Operations Research-perspective can be characterized as a primarily method- or algorithm oriented approach towards SCM. A supply chain is perceived as a resource network. SCM has to configure this network and to program the flows within the configuration according to a specific objective function based on algorithms (Tayur et al., 1999).
3. The supply chain is seen from a Logistics perspective as a sequence of generic processes, as introduced in part by Klaus (1998).
4. Marketing recognized SCM in the past as a part of distribution (Stern et al., 1996), but recently it gained strategic importance as a potential driver for marketing’s positive effect on the shareholder value (Srivastava et al., 1999). SCM is the tool to connect customers with products.
5. From an Organization point of view, a supply chain appears as a set of inter-organizational relationships (Skjott-Larsen, 1999; Christopher, 1999).
6. Strategy perceives SCM as a mean to vary certain competencies in a chain in order to maximize profits (Fine, 1998; Hamel and Prahalad, 1996; Gadiesh and Gilbert, 1998).

Perspective	Purpose of SCM	Focal area of improvement
System Dynamics	Managing trade-offs along the complete supply chain	Order management
Operations Research	Calculating optimal solutions within a given set of degrees of freedom	Network configuration and flow
Logistics	Integrating generic processes sequentially, vertically, and horizontally	Integration of processes
Marketing	Segmenting products and markets and combine both using the right distribution channel	Fit between product, channel and customer
Organization	Determining and mastering the need to coordinate and manage relationships	Intra-enterprise segmentation
Strategy	Merging competencies and re-locating into the deepest segments of the profit pool	Ability to partner; positioning in the chain

Table 8 - Goal-oriented approach to measure performance in the SC from Otto and Kotzab (2003)

PRIME (Providing Real Integration in Multi-disciplinary Environments) (2006)

The PRIME project aims at the development of a Virtual Business Environment (VBE) that simulates a global business environment where the player is responsible for the management of a company (Business Unit).

A full set of PIs has been developed to support the evaluation of the performances of the BUs.

Several co-called performance models have been investigated, from the performance equation of Sink and Tuttle (1989), the performance pyramid of Lynch and Cross (1991) to Kaplan and Norton's the balanced scorecard (1996). Each of these in different ways emphasize that performance is much more than financial figures and, as clearly implied by the term "balanced scorecard", that a PMS must present a balanced view of performance. As of 2005, typical performance dimensions encompass:

- Cost.
- Time.
- Quality.
- Flexibility/adaptability.
- Innovation.
- Customer satisfaction.
- Employee satisfaction and safety.
- Environmental impact.
- Business ethics.

When developing the PRIME PIs, these dimensions have been kept in mind.

Here below some examples of PIs for the distribution function are presented:

Variable Name / Short name	**Unit**	**Description/Formula**
Order fulfilment lead time (OFLT)	Days	The average time across all products from placing an order to delivery of that order to the customer (received by the customer). The definition includes that the customer has accepted the product and the invoice.
Distribution lead time ratio to total order delivery time (DLTR)	Ratio %	The duration for the distribution process within the overall (throughput) time across all products for fulfilling an order.
Distribution cost ratio total order delivery costs (DCRODC)		
Outgoing delivery completeness (ODC)	Ratio %	
Delivery performance to agreed delivery date (DP)		
Number of orders not delivered complete (ONC)	Number	
Finished goods inventory days of supply (FGI)		
Transportation costs (TC)	EURO	
Costs of breakage during distribution (CB)	EURO	

Table 9 - Examples of PIs for the distribution function (PRIME project)

St. Gallen case studies on service providers (2006)

The University of St. Gallen has carried out in 2006 a series of 12 case studies on service providers in Switzerland. Several PIs have been developed to assess the performance of the service provision. The case studies did not focus on PIs, but on the organisational arrangement of the service-unit. Therefore a holistic framework for PM has not been developed. Nevertheless, and despite the fact that the PIs were specifically studied for each company, some interesting examples are here below reported.

Revenues and costs:

- Service revenue
- Share of service revenue to total revenue
- Share of services on total profits
- Service margin
- Number of machines sold with maintenance-contracts
- Net sales/order intake for Sales and Service (incl. subscription units)
- % sales increase/reduction in % of gross sales

Quality of the service:

- "Work done right the first time" - to reach 100% quality in service and avoid trouble-shooting
- Immediate order fill and inventory turnover
- Delivery time
- Reaction time
- Customer satisfaction
- Rate of on-time delivery
- Maintenance fulfilment
- Service availability
- Rate of complaints
- Success of market-introduction of new service-products

Efficiency of service provision process/unit:

- Employee fluctuation
- Inventory turnover
- Receivables turnover
- Resource utilisation
- Spare parts cycle time
- Process lead times
- Standard of knowledge (service-engineers vs. technicians)

2.6 SOTA in EE PM

Brewer and Speh (2000, 2001)

The first significant extended enterprise PM framework that has attempted to move beyond the use of “traditional logistics performance measures” solely—as in supply chain PM frameworks—is located in the work of Brewer and Speh (2000, 2001).

Having complained about the drawbacks of using these logistics-focused measures only, they introduce a modified balanced scorecard (BSC) framework which incorporates “integrated measures” in each of the four perspectives of the BSC to include the “inter-functional” and “partnership” perspectives, and thereby “linking the Balanced Scorecard to Supply Chain Performance”. These types of measures are supposed to “show all members how the chain is performing” and foster “incentives to work with other members of the chain”.

In particular Brewer and Speh (2000) present a SC application of the BSC approach, coming at the end to the definition of a specific PMS for the SC. The following figure synthesises their achievements. The approach may be very interesting for the InCoCo-S purposes.

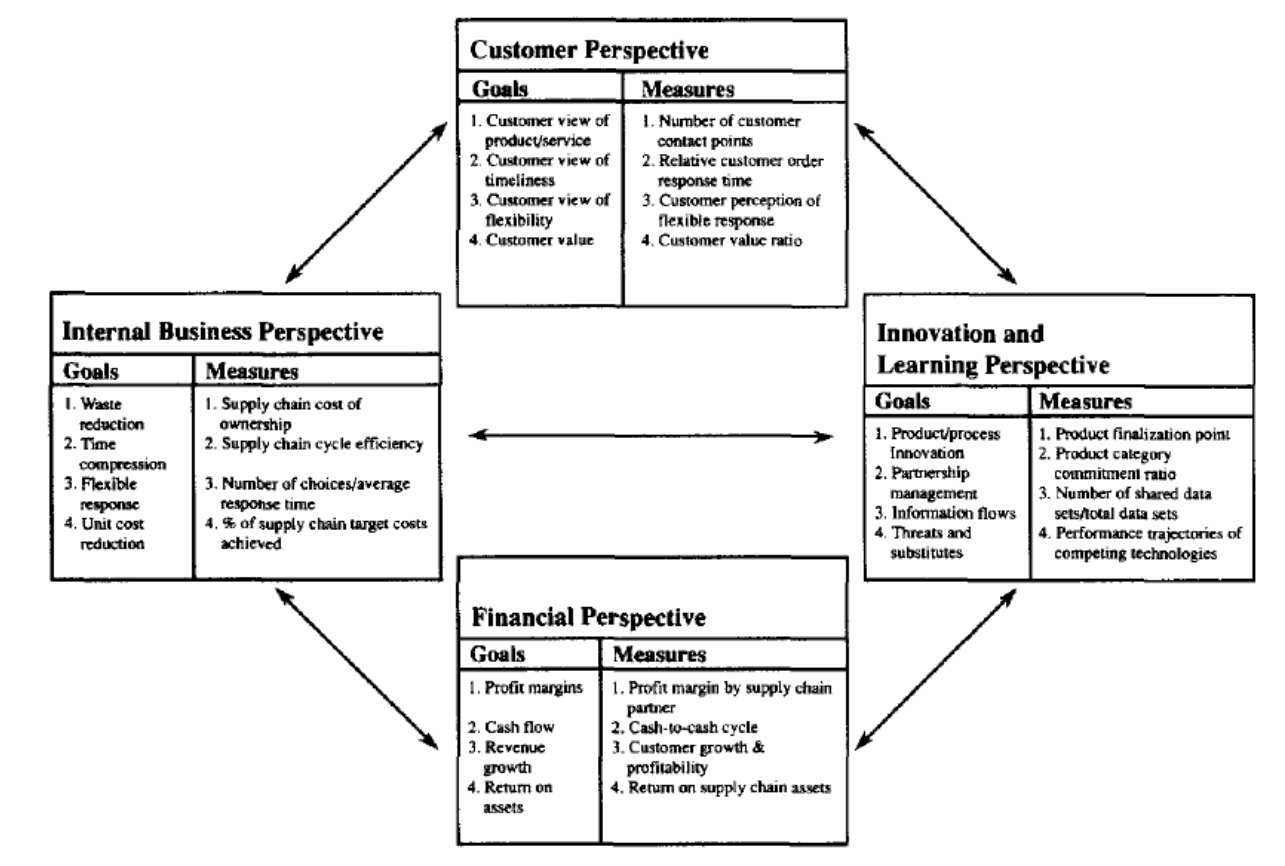

Table 10 - Balanced scorecard (BSC) framework from Brewer and Speh (2000, 2001)

Brewer and Speh (2001) deals instead with the implementation of a BSC approach in a SC. A stepwise solution is presented where the steps are:

- Step 1: Formulate Strategy and Build Consensus
- Step 2: Select Measures that are Consistent with the Strategy
- Step 3: Link and Communicate the Measures
- Step 4: Drive Managers to Attain Desired Results through
  - Establishing accountability.
  - Setting targeted rates of improvement.
  - Creating action plans.
  - Performing progress reviews.
  - Embedding the scorecard into the organization.

Brewer and Speh (2001) moreover describe the application of a balanced scorecard framework to supply chain management, discuss the implementation hurdles that complicate the usage of the balanced scorecard in a supply chain context and suggest some implementation tactics that can help supply chain partners successfully implement a chain-spanning balanced scorecard.

Bititci et al. (2005)

In a review of the literature on PM in extended enterprises Bititci et al. (2005) concluded that:

- None of the current strategic models and frameworks for PM, such as Balanced Scorecard, Performance Prism, IPMS, Smart Pyramid etc consider PM and management from an extended enterprise perspective.
- Other works into PM in supply chains, extended enterprises and virtual enterprises specify a range of performance measures, which should be used in managing supply chains and virtual organisations but fail to integrate these within a strategic PM framework.
- Inter-enterprise coordinating (or partnership) measures are essential to ensure that various partners within an extended enterprise coordinate effectively and efficiently to ensure that the performance of the extended enterprise is maximised.
- None of the current strategic models and frameworks for PM (such as balanced scorecard, performance prism, IPMS and so on) explicitly considers the need for inter-enterprise coordinating measures.

Based on these conclusions they suggested a possible vision of an EE PM Model for supporting collaborative strategies between enterprises.

In this model, the EE PMS comprises of a series of scorecards. These are:

- Enterprise Scorecards, which are specific to each enterprise collaborating in the extended enterprise. Essentially, these are conventional strategic scorecards.
- Business Unit Scorecard, corresponding to the collaborating business unit of an enterprise.
- Business Process Scorecards (EB Sub-Process Scorecard), these are operational scorecards internal to each enterprise.
- Extended Enterprise or Meta Level Scorecard, which includes strategic inter-enterprise coordinating measures
- Extended Business Process Scorecards (EBP Scorecard), which includes operational inter-enterprise coordinating measures

Table 11 – Scorecard approach from Bititci et al. (2005)

IFIP WG5.7 and CE-Net Consortium (2004)

The IFIP WG5.7 and CE-NET consortium (Concurrent Enterprising Consortium – http://www.ce-net.org/) members concentrated their studies on the following key-areas:

- Actual situation: what is the state-of-the art in EE Performance Management?
- Vision: What is the ideal scenario in EE Performance Management?
- Gaps: What areas of research and practice on EE Performance Management are still to be understood and further developed?
- Research needs: How can research facilitate the transition from the actual situation to the vision?

Based on these dimensions, the subject of EE performance management was analysed from 4 perspectives:

- EE PMSs
- EE Infrastructure
- EE People and Organisation
- EE Culture and Behaviour

Actual situation	Vision	Gap	Research need
Extensive knowledge on PMSs on single organisation	Extensive knowledge about EE PMSs	Lack of body of knowledge on PMSs in EE	Develop a better understanding on how to design, implement, use and review PMS in a EE A dynamic process for managing the performance of EE
Most organisations are unable/unwilling to measure/manage performance collaboratively	PMSs are used to translate the vision and objectives of the EE at all levels of each individual organisations Collaborative PMSs use both local measures and inter-enterprise measures in order to maintain the relevance and effectiveness of the collaborative enterprise business model	Lack of a generally applicable approach to collaborative PM and management	
The vast majority of metrics measure local performance		Lack of empirical studies on the application of collaborative PMSs	
		Little understanding of relevant measures for EE	Define performance measures which are relevant and meaningful
The limited visibility of real demand is a major problem in Collaborative Enterprises	Collaborative performance management helps accelerate order-to-cash cycles, free up resources and expedite the execution of routine processes across the EE	Current performance management systems do not allow a more complete and accurate analysis	Design performance management systems that enable real time planning and control of the operations of the EE

Table 12 – CE-Net vision on EE performance management

These research needs are based on the fact that the extensive knowledge on PM currently available focuses on the needs of single organisations and as a result it does not entirely suit to the needs of EE. Although there have been a number of studies looking at PM from a collaborative perspective (Gunasekaran et al 2001, SCOR, Beamon 1999, and Bititci et al. 2005) further research is needed to develop the body of knowledge in this area.

The importance of ICT on performance management has been highlighted by several authors. As a result, EE will need to develop ICT infrastructures that facilitate critical aspects for the success of performance management including interoperability, process integration, knowledge sharing and strategic conversation.

Actual situation	Vision	Gap	Research need
Current information and communication technologies do not meet the needs of EE	EE have shared applications with high level of meaning and interoperability	Lack of understanding on how to develop, implement and use enterprise systems that support the performance management process of a EE Lack of integrated management systems	Develop enterprise systems that facilitate interoperability, process integration, knowledge sharing and strategic conversation An open platform allowing implementation of business processes, performance measures and collaboration strategies

Table 13 – CE-Net vision on ICT on performance management

For an EE performance management system to be successful it is critical to carefully design organisational and people practices. The appropriate definition of the structure of the processes that cut across enterprise boundaries and the teams responsible for managing them will support the implementation of the EE performance management system.

Actual situation	Vision	Gap	Research need
Extensive knowledge on organisational design in single organisations	Extensive knowledge on organisational design in EE	Lack of body of knowledge on organisational design on EE	Develop a better understanding on how to design the organisational structure of EE
Teamwork practices mainly focus on single organisations	Inter-enterprise teams are responsible for managing the strategy and operations of the EE	Effective inter-enterprise teamwork not fully understood	Inter-enterprise teamwork dynamics fully understood
Performance appraisals and rewards used at a single organisational levels	Performance appraisal and reward systems used across the EE	Lack of understanding of the impact of appraisal and reward systems on the performance management process of EE Lack of understanding on how to develop effective appraisal and reward system for EE	Understand the impact of appraisal and reward system on the performance management process of EE Develop effective appraisal and reward systems for EE
Team performance measured at a single organisational level	Inter-enterprise team performance is continuously measured and managed	Lack of understanding on how to measures and manage inter-enterprise team performance	Improve the understanding on how to measures and manage inter-enterprise team performance

Table 14 – CE-Net vision on inter-enterprise process integration

In the last few years there has been a growing interest on the study of inter-enterprise teamwork, more commonly known as virtual or distributed teamwork [e.g. Lipnack and Stamps, 1997].

Still, there are a several aspects of EE organisational design that need to be further studied due to their impact on the success of performance management systems. These include aspects such as inter-enterprise team performance management, performance appraisal and reward systems.

Recent studies on performance management have highlighted the importance of organisational culture and behaviours on performance management [Bourne et al, 2002; Franco and Bourne, 2003; Mendibil, 2003; Scott et al, 2003; Bititci et al, 2004]. These studies also suggest that further research is required to understand the relationship between organisational culture, behaviours and performance management.

The multicultural aspect of a CE is another area that requires further study. Currently seen as a barrier to performance, the vision is that multicultural environments will play a key role in fostering innovation.

Actual situation	Vision	Gap	Research need
People do not generally behave proactively in collaborative environment	People behave proactively in collaborative environments Collaborative culture embedded in the organisation	Lack of collaborative behaviour Collaborative culture unevenly implemented in the EE	Improve the understanding on collaborative behaviour in EE Develop EE wide educational systems
The impact of organisational culture and people's behaviour on the performance management process is not fully understood	The impact of culture and behaviours is understood, which facilitates the development of effective performance management processes for the EE	Lack of understanding of the impact of organisational culture and people's behaviour on the performance management process	Develop a better understanding of the impact of organisational culture and people's behaviour on the success of a performance management process
Multicultural environment	Multicultural interaction	Lack of understanding of the	Understand the influence of
perceived as a negative	perceived as a competitive	impact of multicultural	multicultural interaction on the
influence to the overall	advantage	interaction on the performance	performance management
performance of the EE		management process	process of a EE
			Understand how to increase
			the potential benefits of multicultural interaction from
			using the performance
			management process
Decision-making based on performance information from single organisations	Decision-making based on EE performance management process	Lack of understanding on how the EE performance management process affects decision-making	Understand the influence of the performance management process on the decision-making of a EE

Table 15 – CE-Net vision on organizational culture, behaviours and performance management

From the research needs identified above we can identify a number of research questions that will drive the EE performance management research agenda during the coming years.

At a generic level, the key research need is to develop a better understanding of effective and efficient performance management processes in EE. Understanding the characteristics of these processes will be a key step towards successful collaboration.

At a more specific level, there are a number of areas and issues that need to be studied.

2.7 Other interesting contributions

Van Hoek (1998)

A preliminary framework for a supply chain measurement system was proposed by van Hoek (1998). This framework provides a first indication of how, in the supply chain approach to PM, the content of a measurement system may differ, depending on the supply chain operating format and strategy approach or the evolution of strategies; it points out that supply chain PM systems may have to be developed to suit different levels and that a one-size-fits-all approach will probably not do.

The preliminary framework for a supply chain measurement system is summarised in the following figure.

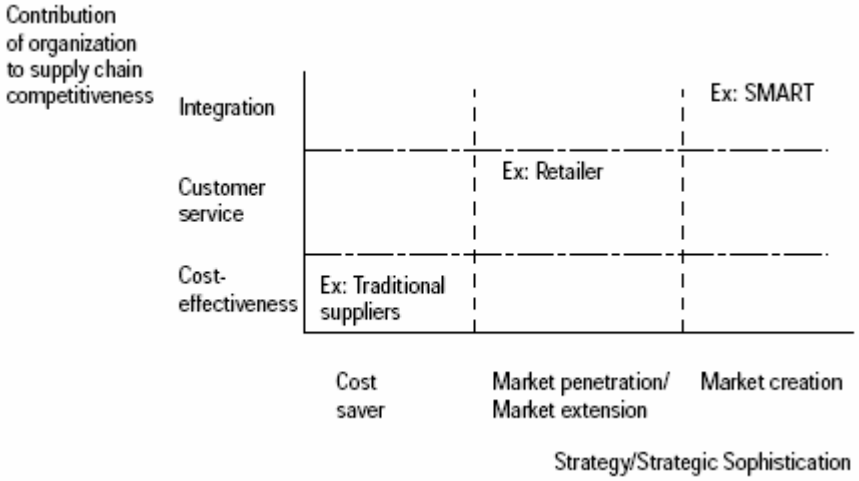

Figure 3 – Van Hoek's framework for a supply chain measurement system

Cravens et al. (2000)

Many authors have attempted to extend intra-organisational PM frameworks into the inter-organisational arena. Cravens et al. (2000) have used the balanced scorecard concept in their assessment of strategic alliances based upon previous efforts by Kaplan and Norton with joint ventures.

This framework is particularly relevant, since the strategy selected for the alliance drives the development of the balanced scorecard. Similarly, since financial measures may not be sufficient to reflect the true performance of the relationship in either the short- or long-term, the balanced scorecard framework forces managers to consider other measures of performance.

Cravens et al. (2000) article deals with PM in strategic alliances, therefore the focus in not perfectly in line with the one of InCoCo-S. Nevertheless the approach of adopting the BSC at strategic level may give interesting suggestions.

Holmberg (2000)

Holmberg (2000) has suggested that a lack of systems thinking has plagued supply chain PMS design and development: he suggests that measurement activities in the supply chain should not be managed as one system, but as several independent, fragmented, firm-sized systems that are ultimately managed, upon the supply chain level, through the co-ordination of information exchange.

Kleijnen and Smits (2003)

Kleijnen and Smits (2003) have analysed how economic theory has treated multiple supply chain performance measures, and has shown that, within this theory, these may ultimately be—through the use of various aggregating scoring methods—aggregated into one final performance measure, termed utility.

Kleijnen and Smits (2003), using the balanced scorecard approach, postulate that since each company is an economic—and legal—entity, each should have its own scorecard, while communication and coordination within the supply chain should be applied to overcome the obstacles created by this independent scorecard development process.

No specific PMS is here presented (some PIs are presented as a result of two business cases) nevertheless some useful information for InCoCo-S purposes can be extracted.

Hamilton (2004)

Hamilton (2004) develops a PMS implementation strategy based on the balanced scorecard concept to be applied to service value networks (the network is here intended as a multitude of units belonging to the same tier (single-echelon), the example used is a network of hundreds of pharmacies). (It is therefore not directly suitable to InCoCo-S approach, nevertheless it may give some good tips.)

Having in mind the balanced scorecard approach, Hamilton (2004) states that:

- The customers must receive their expected outcomes, the business block must develop its skills (and knowledge), and provide improved solutions.
- The internal processes must meet all legislative and business specific requirements (like dispensing provisions).
- Finally, a set of financial outcomes (tangible and intangible) must be delivered. These financial outcomes, if correctly established, pursued and delivered allow the service value network to develop as a viable solution set.

3 Framework for the evaluation of the identified PMSs: strengths and weaknesses

A review of PMSs in SC and EE has been conducted with a whole bunch of criteria (e.g. approach to PM, drivers adopted, interdependencies among the drivers adopted, suggestions for drivers which could be best fit to InCoCo-S purposes, strengths and weaknesses of the PMS, is it based on existing Best Practices, does it have practical applications, does it foresee benchmarking opportunities) and is presented in the followings.

Brewer and Speh (2000, 2001)

Author/Year	**Brewer and Speh (2000, 2001)**
General description/definition	Brewer and Speh (2000, 2001) is the first significant extended enterprise PM framework that has attempted to move beyond the use of "traditional logistics performance measures" solely—as in supply chain PM frameworks. They introduce a modified balanced scorecard (BSC) framework which incorporates "integrated measures" in each of the four perspectives of the BSC to include the "inter-functional" and "partnership" perspectives, and thereby "linking the Balanced Scorecard to Supply Chain Performance". These types of measures are supposed to "show all members how the chain is performing" and foster "incentives to work with other members of the chain". In particular Brewer and Speh (2000) come at the end to the definition of a specific PMS for the SC.

		Brewer and Speh (2001) deals more with the implementation of a BSC approach in a SC. A stepwise solution is presented where the steps are: - Step 1: Formulate Strategy and Build Consensus - Step 2: Select Measures that are Consistent with the Strategy - Step 3: Link and Communicate the Measures - Step 4: Drive Managers to Attain Desired Results through o Establishing accountability. o Setting targeted rates of improvement. o Creating action plans. o Performing progress reviews. o Embedding the scorecard into the organization. Brewer and Speh (2001) moreover describe the application of a balanced scorecard framework to supply chain management, discuss the implementation hurdles that complicate the usage of the balanced scorecard in a supply chain context and suggest some implementation tactics that can help supply chain partners successfully implement a chain-spanning balanced scorecard.
Approach to performance measurement		
	Activity vs. Process based	Process based
	SC vs. EE oriented	Mainly supply chain oriented but with interesting considerations which move the model into a virtual enterprise optic.
	Inter-enterprise process vs. Intra-enterprise process oriented	Inter-enterprise processes.
Drivers adopted		Some examples of drivers adopted are: Customer perspective: - Number of customer contact points - Relative customer order response time - Customer perception of flexible response - Customer value ratio Internal Business Perspective: - Supply chain cost of ownership - Supply chain cycle efficiency - Number of choices/average response time - % of supply chain target costs achieved Financial Perspective: - Profit margin by supply chain partner - Cash-to-cash cycle - Customer growth and profitability - Return on supply chain assets Innovation and Learning Perspective:

	- Product finalisation point - Product category commitment ratio - Number of shared data sets/total data sets - Performance trajectories of competing technologies
Interdependencies among the drivers adopted	Major correlations among: - Financial oriented PIs all the other indicators. - Customer oriented PIs and Internal business oriented indicators. These aspects are nevertheless not explicitly addressed in the study.
Suggestions for drivers which could best fit to InCoCo-S purposes	Customer perspective: - Number of customer contact points - Relative customer order response time (e.g. breakdown maintenance intervention time) - Customer perception of flexible response Financial Perspective: - Profit margin by service supply chain partner - Cash-to-cash cycle - Customer growth and profitability - Return on service supply chain assets
Strengths of the PMS	The Balanced Scorecard approach is a consistent and industry validated approach. Clear definition of supply chain goals and correlated PIs. Comprehensive set of PIs which could be translated (even i f with minor adjustments) to the service supply chain context.
Weaknesses of the PMS	It comes from a PM best practice which was not developed to assess inter-enterprise process performances. This implies that some coordination and collaboration aspects are not fully taken into consideration (e.g. overall supply chain efficiency, overall supply chain service level, etc.).
Is it based on existing Best Practices?	Balance Scorecard
Does it foresee benchmarking opportunities?	No
Does it have practical applications?	Not at the time when the model was proposed. (Of course the Balanced Scorecard, which the present PMS strictly relies on, has got extensive industrial validation.)
Comments	None

Table 16 Brewer and Speh (2000, 2001)

Beamon (1998, 1999)

Author/Year	**Beamon (1998, 1999)**
General description/definition	Beamon starts its work for the proposal of a new PMS from an extensive literature review whose results were published in 1998. Beamon (1998) identifies therefore a list of performance measures which can be defined as

(Beamon 1998)	quantitative or qualitative and proposes the following PM framework. Qualitative performance measures are those measures for which there is no single direct numerical measurement, although some aspects of them may be quantified. These are: - Customer satisfaction: The degree to which customers are satisfied with the product and/or service received, and may apply to internal customers or external customers. Customer satisfaction is comprised of three elements: o Pre-transaction satisfaction: satisfaction associated with service elements occurring prior to product purchase. o Transaction satisfaction: satisfaction associated with service elements directly involved in the physical distribution of products. o Post-transaction satisfaction: satisfaction associated with support provided for products while in use. - Flexibility: The degree to which the supply chain can respond to random fluctuations in the demand pattern. - Information and material flow integration: The extent to which all functions within the supply chain communicate information and transport materials. - Effective risk management: All of the relationships within the supply chain contain inherent risk. Effective risk management describes the degree to which the effects of these risks is minimized. - Supplier performance: With what consistency suppliers deliver raw materials to production facilities on time and in good condition. Quantitative performance measures are those measures that may be directly described numerically. Quantitative supply chain performance measures may be categorized by: objectives that are based directly on cost or profit and objectives that are based on some measure of customer responsiveness. Measures based on cost are: - Cost minimization: The most widely used objective. Cost is typically minimized for an entire supply chain (total cost), or is minimized for particular business units or stages. - Sales maximization: Maximize the amount of sales dollars or units sold. - Profit maximization: Maximize revenues less costs. - Inventory investment minimization: Minimize the amount of inventory costs (including product costs and holding costs). - Return on investment maximization: Maximize the ratio of net profit to capital that was employed to produce that profit. Measures based on customer responsiveness are: - Fill rate maximization: Maximize the fraction of customer orders filled on time. - Product lateness minimization: Minimize the amount of time between the promised product delivery date and the actual product delivery date. - Customer response time minimization: Minimize the amount of time required from the time an order is placed until the time the order is received by the customer. Usually refers to external customers only. - Lead time minimization: Minimize the amount of time required from the time a product has begun its manufacture until the time it is completely processed. - Function duplication minimization: Minimize the number of business functions that are provided by more than one business entity.

General description/definition **(Beamon 1999)**		In a second moment (1999) Beamon proposes an alternative framework for PM, comprising of three types of performance measures: resource measure, output measures and flexibility measures. She argues that supply chain PMS must contain at least one individual measure from each of the identified types. Each of these three types of performance measures has different goals. - Resource measure: o Goal: High level of Efficiency o Purpose: Efficient resource management is critical to profitability. - Output measures: o Goal: High level of Customer Service o Purpose: Without acceptable output, customers will turn to other supply chains. - Flexibility measures: o Goal: Ability to Respond to a Changing Environment o Purpose: In an uncertain environment, supply chains must be able to respond to change. The supply chain PMS must measure each of the three types (R, O, and F), as each type is vital to the overall performance success of the supply chain. Although many individual supply chain performance measures exist for resources and output, the number of flexibility measures actually applied to supply chains is few. Therefore, Beamon (1999) develops volume flexibility and delivery flexibility measures for supply chains, and presents existing measures for mix flexibility and new product flexibility. The individual measures chosen from each type must coincide with the organisations strategic goals. This measurement system can then allow study of the interactions among the measures or can at least ensure a minimum level of performance in different areas.
Approach to performance measurement		
	Activity vs. Process based	Both
	SC vs. EE oriented	Supply chain oriented
	Inter-enterprise process vs. Intra-enterprise process oriented	Prevalently intra-enterprise
Drivers adopted		Resource: - Total Cost: Total cost of resources used. - Distribution Costs: Total cost of distribution, including transportation and handling costs. - Manufacturing Cost: Total cost of manufacturing, including labour, maintenance, and rework costs. - Inventory: Costs associated with held inventory. - Inventory Investment: Investment value of held inventory. o Inventory Obsolescence: Costs associated with obsolete inventory; sometimes includes spoilage.

	o Work-in-Process: Costs associated with work-in-process inventories. o Finished Goods: Costs associated with held finished goods inventories. - Return on Investment (ROI): Measures the profitability of an organization. The return on investment is generally given by the ratio of net profit to total assets. Output: - Sales: Total revenue. - Profit: Total revenue less expenses. - Fill Rate: Proportion of orders filled immediately. o Target Fill Rate Achievement: To what extent a target fill rate has been achieved. o Average Item Fill Rate: Aggregate fill rate divided by the number of items. - On-Time Deliveries: Measures item, order, or product delivery performance. o Product Lateness: Delivery date minus due date. o Average Lateness of Orders: Aggregate lateness divided by the number of orders. o Average Earliness of Orders: Aggregate earliness divided by the number of orders. o Percent on-time deliveries: Percent of orders delivered on or before the due date. - Back Order/Stockout: Measures item, order, or product availability performance. o Stockout Probability: Instantaneous probability that a requested item is out of stock. o Number of Backorders: Number of items backordered due to stockout. o Number of Stockouts: Number of requested items that are out of stock. o Average Backorder Level: Number of items backordered divided by the number of items. - Customer Response Time: Amount of time between an order and its corresponding delivery. - Manufacturing Lead Time: Total amount of time required to produce a particular item or batch. - Shipping Errors: Number of incorrect shipments made. - Customer Complaints: Number of customer complains registered. Flexibility Flexibility can measure a SC's ability to accommodate volume and schedule fluctuations from suppliers, manufacturers, and customers. Four types of flexibility can be identified: - Volume Flexibility: The ability to change the output level of products produced. A generalization of volume flexibility is to measure the range of volumes in which the organization can run profitably. For manufacturing

	systems, the development of volume flexibility measures has generally considered the costs associated with volume changes. For the development of a supply chain volume flexibility measure, we are interested in how much of the demand can be met considering only the range of volumes that are profitable. The volume flexibility measures the proportion of demand that can be met by the supply chain system. - Delivery Flexibility: The ability to change planned delivery dates. This ability allows the supply chain to accommodate rush orders and special orders, and will be described as delivery flexibility. Delivery flexibility will be expressed as the percentage of slack time by which the delivery time can be reduced. - Mix Flexibility: The ability to change the variety of products produced. Generally, mix flexibility measures either the range of different product types that may be produced during a particular time period, or the response time between product mix changes. More specifically, Slack (1991) discusses measuring mix flexibility as: (1) the number of different products that can be produced within a given time period (product mix flexibility range) or (2) the time required to produce a new product mix (product mix flexibility response). - New Product Flexibility: The ability to introduce and produce new products (this includes the modification of existing products). New product flexibility is defined as the ease with which new products are introduced to the system. The introduction of new products will generally involve some time for development and set-up. Sethi and Sethi (1990) discuss measuring product flexibility as either the time or cost required to add new products to existing production operations.
Interdependencies among the drivers adopted	Mainly between Output and Flexibility measures. No interdependency is nevertheless highlighted among specific PIs.
Suggestions for drivers which could best fit to InCoCo-S purposes	Most of the above listed performance measures may be applied to the service supply chain (even if adaptations are required). Among the ones which are particularly interesting it is possible to mention: Output (opportunely modified to be adopted in a service supply-chain context): - Customer Response Time: Amount of time between an order and its corresponding delivery (for InCoCo-S purposes in terms of time to service provision). - Shipping Errors: Number of incorrect shipments made (for InCoCo-S purposes in terms of correct service interventions executed, for example breakdown maintenance interventions). - Customer Complaints: Number of customer complains registered. Flexibility (opportunely modified to be adopted in a service supply-chain context): - Volume Flexibility: The ability to change the output level of products produced (for InCoCo-S purposes for example in terms of number of planned interventions to execute, volume to be moved by the outbound logistics service, etc.) - Delivery Flexibility: The ability to change planned delivery dates (for InCoCo-S purposes in terms of service delivery). - Mix Flexibility: The ability to change the variety of products produced (for InCoCo-S purposes the ability to provide a broad service portfolio). - New Product Flexibility: The ability to introduce and produce new products (this includes the modification of existing products) (for InCoCo-S purposes in

	terms of ability to redesign a new service and adapt its processes in order to meet customer requirements).
Strengths of the PMS	Based on extensive literature review and fully described in details down to specific performance measures. Many of the performance measures identified by Beamon (1999) can be transposed (with appropriate modifications) to InCoCo-S context. Especially considering performance measures on flexibility novel ideas and new indicators are introduced by Beamon (1999). These ideas will be important for InCoCo-S to measure the flexibility of a service provision.
Weaknesses of the PMS	It lacks practical applications (at least at the moment when the PMS was proposed). The optic is very much supply chain and not extended enterprise oriented and most of the indicators proposed are actually intra-enterprise and not inter-enterprise oriented.
Is it based on existing Best Practices?	Based on extensive literature review but not on a specific best practice.
Does it foresee benchmarking opportunities?	No
Does it have practical applications?	Not at the time when the model was proposed

Table 17 Beamon (1998, 1999)

Bititci et al. (2005)

Author/Year	**Bititci et al. (2005)**
General description/definition	In a review of the literature on PM in extended enterprises Bititci et al. (2005) concluded that: - None of the current strategic models and frameworks for PM, such as Balanced Scorecard, Performance Prism, IPMS, Smart Pyramid etc consider PM and management from an extended enterprise perspective. - Other works into PM in supply chains, extended enterprises and virtual enterprises specify a range of performance measures, which should be used in managing supply chains and virtual organisations but fail to integrate these within a strategic PM framework. - Inter-enterprise coordinating (or partnership) measures are essential to ensure that various partners within an extended enterprise coordinate effectively and efficiently to ensure that the performance of the extended enterprise is maximised. - None of the current strategic models and frameworks for PM (such as balanced scorecard, performance prism, IPMS and so on) explicitly considers the need for inter-enterprise coordinating measures. Based on these conclusions they suggested a possible vision of an EE PM Model for supporting collaborative strategies between enterprises. In this model, the EE PMS comprises of a series of scorecards. These are: - Enterprise Scorecards, which are specific to each enterprise collaborating in the extended enterprise. Essentially, these are conventional strategic scorecards. - Business Unit Scorecard, corresponding to the collaborating business unit of an enterprise. - Business Process Scorecards (EB Sub-Process Scorecard), these are operational scorecards internal to each enterprise. - Extended Enterprise or Meta Level Scorecard, which includes strategic inter-

	enterprise coordinating measures. - Extended Business Process Scorecards (EBP Scorecard), which includes operational inter-enterprise coordinating measures.
Approach to performance measurement	
Activity vs. Process based	Process based.
SC vs. EE oriented	Virtual enterprise oriented.
Inter-enterprise process vs. Intra-enterprise process oriented	Both
Drivers adopted	No specific PIs are provided. The PMS specifies that a PMS system, in order to be applied to an EE context, must include PIs at different levels. These levels are: - Enterprise level (strategic level, intra-enterprise PIs). - Business Unit level (intermediate level, intra-enterprise PIs). - Business Process level (operational level, intra-enterprise PIs). - Extended Enterprise or Meta level (strategic, inter-enterprise PIs). - Extended Business Process Level (operational, inter-enterprise PIs)
Interdependencies among the drivers adopted	Interdependencies can be found on different levels: - Within a single scorecard among different typologies of PIs (please refer to the Balanced Scorecard best practice to identify these interdependencies). - Among the scorecards of different business units. - Among the scorecards of different enterprises. - Among the scorecards of different sub-processes in an extended business process / among different extended processes. - Among the scorecards at business unit level, at extended business level and at enterprise level. The problem is that it is not possible to reason on specific PIs (they are not given) and therefore more precise interdependencies cannot be highlighted.
Suggestions for drivers which could best fit to InCoCo-S purposes	No specific drivers are provided. Nevertheless the distinction among different levels of PIs could be taken into consideration for InCoCo-S purposes.
Strengths of the PMS	The real strength of this proposal for a new PMS is the attempt to develop a set of performance measures which don't address simply a traditional supply chain, instead they try to evaluate the performance of an extended enterprise. Please remember here that, while a SC is a customer-supplier chain of individually operating enterprises (thus sub-optimising the overall performance), an EE is a chain of enterprises, which essentially behave as a single enterprise trying to maximise the corporate goals of the extended enterprise.
Weaknesses of the PMS	The weakness of the proposed PMS is probably that it is still at an early stage of development and it still needs refinement (detailing performance measures in detail) and practical validation.
Is it based on existing Best Practices?	Balanced Scorecard. The model has been moreover developed as an evolution and combination of the works proposed by SCOR 5.0, Gunasekaran et al. (2001), Beamon (1999) and Kochhar and Zhang (2002).

Does it foresee benchmarking opportunities?	No
Does it have practical applications?	Not at the time when the model was proposed

Table 18 Bititci et al. (2005)

PRIME and IFIP WG5.7 (2006)

Author/Year		**PRIME project and IFIP WG5.7 members (2006)**
General description/definition		The PRIME project aims at the development of a Virtual Business Environment (VBE) that simulates a global business environment where the player is responsible for the management of a company (Business Unit). A full set of PIs has been developed to support the evaluation of the performances of the BUs. Several performance models have been investigated, from the performance equation of Sink and Tuttle (1989), the performance pyramid of Lynch and Cross (1991) to Kaplan and Norton's the balanced scorecard (1996). Each of these in different ways emphasize that performance is much more than financial figures and, as clearly implied by the term "balanced scorecard", that a PMS must present a balanced view of performance. As of 2005, typical performance dimensions encompass: - Cost. - Time. - Quality. - Flexibility/adaptability. - Innovation. - Customer satisfaction. - Employee satisfaction and safety. - Environmental impact. - Business ethics. When developing the PRIME PIs, these dimensions have been kept in mind.
Approach to performance measurement		
	Activity vs. Process based	Both but mainly oriented to the measurement of the performance of a business unit.
	SC vs. EE oriented	Mainly supply-chain oriented.
	Inter-enterprise process vs. Intra-enterprise process oriented	Mainly intra-enterprise oriented.
Drivers adopted		More than 150 performance measures have been developed for the business units: - production - sales - finance - product development

	- strategic marketing - distribution - human resources - information systems It is not possible to list all of them here. For the single PIs please refer to the PRIME PPT presentation.
Interdependencies among the drivers adopted	Reported in the PRIME PPT presentation. The relationship among some of the PIs presented is given.
Suggestions for drivers which could best fit to InCoCo-S purposes	A lot of performance measures developed within the PRIME project could be adapted to the InCoCo-S context. Among the most interesting it is possible to mention here some PIs developed for the distribution function (and which could be used within InCoCo-S to measure the outsourcing of the outbound logistics function): - Order fulfilment lead time (OFLT) - Distribution lead time ratio to total order delivery time (DLTR) - Distribution cost ratio total order delivery costs (DCRODC) - Outgoing delivery completeness (ODC) - Delivery performance to agreed delivery date (DP) - Number of orders not delivered complete (ONC) - Finished goods inventory days of supply (FGI) - Transportation costs (TC) - Costs of breakage during distribution (CB)
Strengths of the PMS	Extensive set of performance measures for each business unit.
Weaknesses of the PMS	Despite a lot of performance measures have been developed a comprehensive and coherent strategy and architecture for PMS has yet to be defined (the project it's still at his early stages). Moreover the focus is probably too much business unit oriented and this prevent from measuring the real performance of an inter-enterprise relationship. This can cause some problems when trying to move the PRIME measures into the InCoCo-S context.
Is it based on existing Best Practices?	Not explicitly even if several PMSs have been investigated: performance equation of Sink and Tuttle (1989), performance pyramid of Lynch and Cross (1991), Kaplan and Norton's the balanced scorecard (1996).
Does it foresee benchmarking opportunities?	Not up to now (the project is still ongoing and will be monitored in this sense).
Does it have practical applications?	It will be applied to a serious gaming virtual environment at the end of the project. Before the release of the software solution extensive testing will be performed.

Table 19 PRIME and IFIP WG5.7 (2006)

IFIP WG5.7 and CE-Net (2004)

Author/Year	**IFIP Wg5.7 and CE Net Consortium members (2004)**
General description/definition	Members of the IFIP WG5.7 and of the CE-NET consortium (Concurrent Enterprising Consortium – http://www.ce-net.org/) concentrated its studies on the following key-areas:

<table>
<tr><td colspan="2"></td><td>
- Actual situation: what is the state-of-the art in EE Performance Management?
- Vision: What is the ideal scenario in EE Performance Management?
- Gaps: What areas of research and practice on EE Performance Management are still to be understood and further developed?
- Research needs: How can research facilitate the transition from the actual situation to the vision?
Based on these dimensions, the subject of EE performance management was analysed from 4 perspectives:
- EE PMSs
- EE Infrastructure
- EE People and Organisation
- EE Culture and Behaviour
In particular if they concentrate on the issue "PMSs for the EE" the following topics are addressed:
<table>
<tr><th>Actual situation</th><th>Vision</th><th>Gap</th><th>Research need</th></tr>
<tr><td>Extensive knowledge on performance measurement systems on single organisation</td><td>Extensive knowledge about EE performance measurement systems</td><td>Lack of body of knowledge on performance measurement systems in EE</td><td rowspan="3">Develop a better understanding on how to design, implement, use and review performance measurement system in a EE
A dynamic process for managing the performance of EE</td></tr>
<tr><td>Most organisations are unable/unwilling to measure/manage performance collaboratively</td><td rowspan="3">Performance measurement systems are used to translate the vision and objectives of the EE at all levels of each individual organisations
Collaborative performance measurement systems use both local measures and inter-enterprise measures in order to maintain the relevance and effectiveness of the collaborative enterprise business model</td><td>Lack of a generally applicable approach to collaborative performance measurement and management</td></tr>
<tr><td>The vast majority of metrics measure local performance</td><td>Lack of empirical studies on the application of collaborative performance measurement systems</td></tr>
<tr><td rowspan="2">The limited visibility of real demand is a major problem in Collaborative Enterprises</td><td>Little understanding of relevant measures for EE</td><td>Define performance measures which are relevant and meaningful</td></tr>
<tr><td>Collaborative performance management helps accelerate order-to-cash cycles, free up resources and expedite the execution of routine processes across the EE</td><td>Current performance management systems do not allow a more complete and accurate analysis</td><td>Design performance management systems that enable real time planning and control of the operations of the EE</td></tr>
</table>
These research needs are based on the fact that the extensive knowledge on PM currently available focuses on the needs of single organisations and as a result it does not entirely suit to the needs of EE. Although there have been a number of studies looking at PM from a collaborative perspective (Gunasekaran et al 2001, SCOR, Beamon 1999, and Bititci et al. 2005) further research is needed to develop the body of knowledge in this area.
</td></tr>
<tr><td colspan="2">Approach to performance measurement</td><td></td></tr>
<tr><td></td><td>Activity vs. Process based</td><td>Process based</td></tr>
<tr><td></td><td>SC vs. EE oriented</td><td>Virtual enterprise oriented</td></tr>
<tr><td></td><td>Inter-enterprise process vs. Intra-enterprise process oriented</td><td>Intra-enterprise process oriented</td></tr>
<tr><td colspan="2">Drivers adopted</td><td>No drivers are presented. Only strategic considerations on PMS for the EE are presented. The information provided is not therefore very valuable for InCoCo-S. The general strategy for developing an innovative PMS for the EE can anyway be taken into consideration (especially the section referring to present gaps).</td></tr>
<tr><td colspan="2">Interdependencies among the drivers adopted</td><td>No specific drivers provided.</td></tr>
</table>

Suggestions for drivers which could best fit to InCoCo-S purposes	No specific drivers provided.
Strengths of the PMS	A novel strategy for the development of a PMS which is really oriented towards the EE and not the single enterprise.
Weaknesses of the PMS	It is just on a strategic level. No specific drivers are provided which could be used by InCoCo-S.
Is it based on existing Best Practices?	Based n an extensive literature research and experience of the participating experts, but it is not based on a specific best practice.
Does it foresee benchmarking opportunities?	Not really.
Does it have practical applications?	Not for the moment. It is only a roadmap at strategic level.
Comments	The roadmap presented for PMS in the EE can be taken into consideration by InCoCo-S. Major input to InCoCo-S can not anyway be expected.

Table 20 IFIP WG5.7 and CE-Net (2004)

Otto and Kotzab (2003)

Author/Year		**Otto and Kotzab 2003**
General description/definition		This article explores suitable metrics to measure the effectiveness of SCM. Therefore, six complementary perspectives were chosen: - System Dynamics (purpose: Managing trade-offs along the complete supply chain; focus: Order management) - Operations Research/Information Technology (purpose: Calculating optimal solutions within a given set of degrees of freedom; focus: Network configuration and flow) - Logistics (purpose: Integrating generic processes sequentially, vertically, and horizontally; focus: Integration of processes) - Marketing (purpose: Segmenting products and markets and combine both using the right distribution channel; focus: Fit between product, channel and customer) - Organization (purpose: Determining and mastering the need to coordinate and manage relationships; focus: Intra-enterprise segmentation) - Strategy (purpose: Merging competencies and re-locating into the deepest segments of the profit pool; focus: Ability to partner; positioning in the chain) The motivation of focusing on the perspectives is based on the assumption that the perspective pre-determines goals and metrics. Within a perspective, it might be appropriate to employ scorecard-like dimensions. By suggesting six perspectives, it is possible to establish a differentiated framework of perspective-bounded metrics to assess the performance of SCM.
Approach to performance measurement		
	Activity vs. Process based	Activity based
	SC vs. EE oriented	Supply-Chain
	Inter-enterprise process vs. Intra-	Intra enterprise

enterprise process oriented	
Drivers adopted	From each of the six perspectives, the following PIs were listed: System Dynamics - Capacity utilization - Cumulative inventory level - Stock-outs - Time lags - Time to adapt - Phantom ordering Operations Research/Information Technology - Logistics costs per unit - Service level - Time to deliver Logistics - Integration - Lead times - Order cycle time - Inventory level - Flexibility Marketing - Customer satisfaction - Distribution costs per unit - Market share/channel costs Organization - Transaction costs - Time to network - Flexibility - Density of relationships Strategy - Time to network - Time to market - ROI of focal organization
Interdependencies among the drivers adopted	The listed performance metrics are established for each perspective individually. Therefore there should be no dependency between them to other perspectives. Within one perspective, no system / method was presented that identifies or deals with the dependency of the metrics. Moreover, no formal structure of a PMS was presented (in terms of a hierarchy of the listed metrics).
Suggestions for drivers which could best fit to InCoCo-S purposes	All the listed PIs are interesting for the use within our project.
Strengths of the PMS	A PMS is generated that focus on the achievement of operational goal and

	therefore the execution of the supply chain process.
Weaknesses of the PMS	The article delivers a goal oriented PMS (in contrary to a profit oriented PMS). There is no approach given, in which way the achieved goals have any impact of the profit of the entire process. Moreover, the PMS has to be adapted or the metrics has to be weighted individually to each company because all of the six perspectives are not of equal importance in practice. For the implementation of the stated PMS, no procedure is provided.
Is it based on existing Best Practices?	The authors refer strongly to the model of an "organization as resource getting system", developed by Yuchtman and Seashore (1967)
Does it foresee benchmarking opportunities?	No - the PMS is generated individually.
Does it have practical applications?	The PMS is not practically validated. The authors argue, that their model should provide an orientation in establishing an own PMS.
Comments	Important for the development of a PMS: - Effectiveness measures the degree to which certain goals are reached (referring to Axtelle, 1956; Georgopoulos and Tannenbaum, 1957). - Thus, any consistent performance proposition must refer to a consistent goal. What is perceived as relevant will depend on goals. - In order to establish a sound basis for measuring the performance of SCM, one has first to identify the goals or the goal structure of SCM. To each of the perspective are problems and solutions in practice mentioned. These are not listed in this sheet because there is no relationship presented to the mentioned PI

Table 21 Otto and Kotzab (2003)

Gunasekaran et al. (2005)

Author/Year		**Gunasekaran, Williams, McGaughey (2005)**
General description/definition		The focus of this article is on the costing systems of companies. Due to increasing complexity of internal and external processes (logistics, outsourcing of services) the companies failed to adapt their costing system. Former systems were functionally designed and they were suitable for the application of one specific company. Transferred to virtual enterprises, these costing systems fail (because they don't focus on the process). Even newer costing systems like ABC costing (that focus on the processes) cannot be used in virtual enterprises. In this article, the reference framework for a Performance Based Costing (PBS) system was generated. Besides the considered process, the means of knowledge is integrated into this concept.
Approach to performance measurement		
	Activity vs. Process based	Process based
	SC vs. EE oriented	Virtual enterprise
	Inter-enterprise process vs. Intra-enterprise process oriented	Inter enterprise

Drivers adopted	Please see table below.
Interdependencies among the drivers adopted	This aspect is not highlighted in this article.
Suggestions for drivers which could best fit to InCoCo-S purposes	Past performance, repeat orders, delivery performance, time to deliver products, logistics costs, time to process orders, time to respond to customer enquiries, incentives.
Strengths of the PMS	A procedure is given to develop a PMS: 1) Develop Objectives of PBS System 2) Develop PBS Team 3)Adress organizational Issues 4) Identification of Value Creation Areas and Crucial Success Factors (CSF) 5) Identification of Drivers for CSF 6) Establish Valua Area Cost Pools 7) Identify Secondary Value Drivers 8) Realted Value Area / Object / CSF 9) Implement.
Weaknesses of the PMS	Crucial factors of the PMS are just given in examples (they are not generic ones and their foundation is not based on research experience).
Is it based on existing Best Practices?	Yes, Activity Based Costing is part of the new model.
Does it foresee benchmarking opportunities?	No, because a PBS is created individually to every company. It might be used for internal benchmarking purposes.
Does it have practical applications?	No practical application was mentioned.
Comments	Factors that influence the efforts to develop new PM, metrics and cost accounting systems: - Activities are difficult to trace because of the distributed nature of the virtual enterprise or supply chain environment - Many indirect costs will become direct costs and many direct costs will become indirect costs - Logistics costs are a major portion of the total cost - Many costs are hidden, and thus difficult to measure - Knowledge management and information technology costs will be major costs in the virtual enterprise or supply chain environment - A complex cost system will not likely work with the supply chain/virtual enterprise—a cost system similar to back flush costing may be suitable for new enterprise models.

Table 22 Gunasekaran et al. (2005)

Differences between traditional and networked organizations

Areas	Traditional organizations	Networked organizations
Strategy formulation	Focused on narrow market, centralized operations, Limited competitive performance objectives, Long-life cycle of products, horizontal organizational structure	Strategic alliances, Global market, Global outsourcing, Multiple competitive performance objectives, E-Commerce, Vertical Organizational Structure, Shorter product life cycle
Tactical decisions	Aggregate Production Planning, Accurate Forecasting, Stable Master Production Scheduling, and Make or buy decisions.	Purchasing of goods and services, Enterprise resource planning, Selection of partners/suppliers, Partnership formation, Information productivity
Operational controls	Make to stock, Pull/push scheduling, Quality assurance control systems, Large lot production	Agile Manufacturing/services, Scheduling of deliveries with Partners, Distributed inventory control
Purchasing and logistics	Domestic market, Less intensive competition, Lack of focus on logistics, Focus on cost and not customer service, Lack of communication and IT applications	Contract, Negotiations, Agility, e-Market, Timeliness is important, Reverse logistics, Customer service, Supplier development
Knowledge management	Knowledge workers, Less IT skills, Lack of Innovation, Less investment in knowledge capital, Human resource management	Invest in knowledge capital, Encourage to innovate, Training and educating employees to work in virtual enterprise, Multi-skilled workers
Information technology	CAD/CAM, Legacy systems, Functional integration, Investment in IT is internally focused	Integration of supply chain, ERP, Extended enterprise integration, Invest in IT. Select suitable IT system matching Business models, Investment in IT has both internal and external focus

Table 23 – Drivers identified by Gunasekaran et al. (2005) (1/2)

A framework for measuring performance in new enterprise

Value creation areas	Critical success factors	Performance measures	Drivers of CSF
Networking	Experience, Education, Conferences, New Initiatives, Joint Projects	Knowledge workers, Number of conferences or meetings attended, Number of joint projects, number of new products introduced	Investment in Skilled workers, Support for exhibitions and Product promotions, New products
Partnership formation	Communication, Trust, Infrastructure, Past performance, Selection of business strategy, B2B	Data mining, Data Warehousing, Number of partners/suppliers, Training and Education	Investment in KM workers, Investment in IT, Training and Education in Virtual Enterprise
Knowledge management	Information technologies (Internet, EDI, WWW), Training and Education	Number of IT trained Managers, The age of the website, Integration of B2C and B2B, ERP, BPR, E-Commerce	Investment in training and education, Strategic alliances with high tech companies, Investment in knowledge capital
Information technology	Selection of suitable IT, Integration of suppliers/partners,	Number of Software, Number of PCs, Budget for IT training and Eductaion, ERP system, and Investment in IT	Business strategy, agility focused, E-commerce enabled SCM, Global manufacturing, Global outsourcing, Global market
Trust creation	Long-term relationship, Transparency, Good communication, Meetings and Contracts	Number of years in business, IT investment, Past performance, Repeat orders, Delivery performance	Strategic alliances, ERP, Constant meetings between partners, Long-term business contracts, Technological support
Purchasing & logistics	Inventory control, Warehousing, Shipping and Transportation	Selection of partners for logistics service and suppliers for goods, Time to deliver products, Logistics cost, Time to Process orders	Warehousing operations strategy, Outsourcing of logistics service, Number of partners/suppliers, Number of products, IT in purchasing and logistics
Customer Relationship Management (CRM)	B2C, Customer service, Good IT skills, Communication skills, Knowledge of Products and Services, Knowledge about technical content of the product	Time to respond to customer enquiries, CRM system, Budget for training and education, Number of meetings, Workshops, Incentives	Invest in IT and KM systems, Training and Eductaion, Strategic alliances to facilitate better CRM, Invest in communication technologies, Incentives for good job

Table 24 - Drivers identified by Gunasekaran et al. (2005) (2/2)

Gunasekaran et al. (2004)

Author/Year	**Gunasekaran, Patel, McGaughy (2004)**
General description/definition	Although Supply Chain Management gains high interests of researchers and practitioners side, PM and PMS are not covered in literature on a detailed level. Therefore Gunasekaran et al. generated a framework for PMS in SCM which is based on a conducted survey. The survey aimed at deriving important / crucial metrics for SCM with respect to the following four basic sections: plan (introduce / strategy), source / supply (order), produce (make / assemble),

		delivery (to customer). All the considered metrics were put in a hierarchical structure that covers strategic, tactical and operational levels. Within the article, the reference framework was presented in a sheet which is added under this sheet.
Approach to performance measurement		
	Activity vs. Process based	Process based
	SC vs. EE oriented	Supply Chain oriented
	Inter-enterprise process vs. Intra-enterprise process oriented	Both
Drivers adopted		Below are these drivers mentioned which were evaluated of high (H) / moderate /low (L) importance within the survey. Strategic planning metrics: - (H) Level of customer perceived value of product - Variances against budget - Order lead time - Information processing costs - Net profit vs. productivity ratio - Total cycle time - Total cash flow time - (L) Level of energy utilization Order planning metrics: - (H) Customer query time - Product development cycle time - (L) Accuracy of forecasting - (L) Planning process cycle time - (L) Order entry methods - (L) Human resource productivity Supplier metrics: - (H) Supplier delivery performance - Supplier lead time against norm - Supplier pricing against market - Efficiency of purchase order cycle time - (L) Efficiency of cash flow method - (L) Supplier booking in procedures Importance of production metrics: - (H) Percentage of defects - (H) Cost per operation hour - (H) Capacity utilization

	- Range of products and services - (L) utilization of economic order quantity Delivery PIs: - (H) Quality of delivered goods - (H) In time delivery of goods - (H) Flexibility of service systems to meet customer needs - Effectiveness of enterprise distribution planning schedule - Effectiveness of delivery invoice methods - Number of faultless delivery notes invoiced - Percentage of urgent deliveries - Information richness in carrying out delivery - (L) Percentage of finished goods in transit - (L) Delivery of reliability performance
Interdependencies among the drivers adopted	The interdependencies can be derived from the framework. Within the framework, all the mentioned metrics above are assigned in a matrix either to strategic, tactical and operational levels and to the PLAN, SOURCE, MAKE / ASSEMBLE, DELIVER activities. See matrix underneath.
Suggestions for drivers which could best fit to InCoCo-S purposes	Most of the indicators can / should be used in InCoCo-S. Only minor changes were done here. Just one or two PM were stroked out. Strategic planning metrics: - Level of customer perceived value of product - Variances against budget - Order lead time - Information processing costs - Net profit vs. productivity ratio - Total cycle time - Total cash flow time Order planning metrics: - Customer query time - Accuracy of forecasting - Planning process cycle time - Order entry methods - Human resource productivity Supplier metrics: - Supplier delivery performance - Supplier lead time against norm - Supplier pricing against market - Efficiency of purchase order cycle time - Efficiency of cash flow method - Supplier booking in procedures

	Importance of production metrics: - Percentage of defects (in services: faults) - Cost per operation hour - Capacity utilization - Range of products and services - utilization of economic order quantity Delivery PIs: - Quality of delivered goods - In time delivery of goods - Flexibility of service systems to meet customer needs - Effectiveness of enterprise distribution planning schedule - Effectiveness of delivery invoice methods - Number of faultless delivery notes invoiced - Percentage of urgent deliveries - Information richness in carrying out delivery - Percentage of finished goods in transit - Delivery of reliability performance
Strengths of the PMS	The metrics are derived from a survey. Therefore metrics of major importance are mentioned for sure. The article contains information about the effect of implementing a Supply Chain Management, but benefits from a PMS are not mentioned here. Moreover, benefits from the application of the reference framework are not mentioned at all.
Weaknesses of the PMS	As mentioned above, the results are derived from a survey. Therefore, not all the metrics are mentioned that are used in practice. Furthermore no information is given about the branches the companies act in. Hence, it cannot be concluded whether the metrics are of generic nature or not.
Is it based on existing Best Practices?	Yes, PLAN, SOURCE, MAKE / ASSEMBLE, DELIVER activities that are used in common in Supply Chains.
Does it foresee benchmarking opportunities?	By measuring the process through the metrics above, a benchmarking is a stated goal of this framework.
Does it have practical applications?	No.

Table 25 Gunasekaran et al. (2004)

Supply chain performance metrics framework

Supply chain activity/ process	Strategic	Tactical	Operational
Plan	Level of customer perceived value of product, Variances against budget, Order lead time, Information processing cost, Net profit Vs productivity ratio, Total cycle time, Total cash flow time, Product development cycle time	Customer query time, Product development cycle time, Accuracy of forecasting techniques, Planning process cycle time, Order entry methods, Human resource productivity	Order entry methods, Human resource productivity
Source		Supplier delivery performance, supplier leadtime against industry norm, supplier pricing against market, Efficiency of purchase order cycle time, Efficiency of cash flow method, Supplier booking in procedures	Efficiency of purchase order cycle time, Supplier pricing against market
Make/ Assemble	Range of products and services	Percentage of defects, Cost per operation hour, Capacity utilization, Utilization of economic order quantity	Percentage of Defects, Cost per operation hour, Human resource productivity index
Deliver	Flexibility of service system to meet customer needs, Effectiveness of enterprise distribution planning schedule	Flexibility of service system to meet customer needs, Effectiveness of enterprise distribution planning schedule, Effectiveness of delivery invoice methods, Percentage of finished goods in transit, Delivery reliability performance	Quality of delivered goods, On time delivery of goods, Effectiveness of delivery invoice methods, Number of faultless delivery notes invoiced, Percentage of urgent deliveries, Information richness in carrying out delivery, Delivery reliability performance

Table 26 - Drivers identified by Gunasekaran et al. (2004)

Chan (2003_1)

Author/Year		**Felix T.S. Chan & H.J. Qi (2003)**
General description/definition		Chan proposes a hierarchical, process-based metric system for SCM, using the approaches of business process modelling and performance of activity. He indicates several methods to measure intangible metrics indirectly. Strong recommendation to not use financial metrics when assessing processes on lower hierarchy levels, only summarizing on a higher level. The system is quite flexible and supports developing a company specific system by guiding as a thread, giving a general hint and letting managers to identify focused metrics for every hierarchy level.
Approach to performance measurement		
	Activity vs. Process based	Both.
	SC vs. EE oriented	Virtual Enterprise oriented.
	Inter-enterprise process vs. Intra-enterprise process oriented	Inter-enterprise process oriented.
Drivers adopted		Cost, time, capacity, capability (effectiveness, reliability, availability, flexibility), productivity, utilization and outcome.
Interdependencies among		Interdependencies are realized through hierarchical structure, where e.g. intangible metrics are expressed through tangible metrics on the lower level. But

the drivers adopted	there is nothing written about interdependencies like "if the one…, then the other…".
Suggestions for drivers which could best fit to InCoCo-S purposes	Proposed methodology of first decomposing processes to activities and then adopting the measures with the "performance of activity" method seems to be reasonable also for InCoCo-S processes. "Soft" indicators can be expressed through a mix of sub-level "hard" PIs, such as "inventory availability" can be expressed through "order fill rate" (order availability) and "stockout rate" (stock unit availability). Another examples are "production flexibility", which can be measured through assessing "product volume flexibility" and "product mix production", and "delivery flexibility", which can be measured through assessing "delivery rate" and "errors rate".
Strengths of the PMS	The generic framework of PIs can be easily adopted to the management focus of a supply chain, so also to specific service clusters. The framework supports as a thread, to identify specific and relevant PIs.
Weaknesses of the PMS	It is a very long-lasting approach to first identify all the processes with the sub-processes and activities, and then identify the according metrics. But this is also true for InCoCo-S WP4.
Is it based on existing Best Practices?	The development of the hierarchical structure is based on business process design (incl. SCOR) and the performance of activity (POA) approach.
Does it foresee benchmarking opportunities?	Benchmarking possible among the processes on the same hierarchy.
Does it have practical applications?	There is no talk about a case study where this was implemented.
Comments	Author recommends to NOT use financial PIs when it comes to SCM, because these measures hinder true collaboration in decision making and on the operational level, including profit sharing and/or risk sharing. He recommends to only use these metrics assessing holistic performance of the entire supply chain.

Table 27 Chan (2003_1)

Chan (2003_2)

Author/Year		**Felix T.S. Chan et al. (2003)**
General description/definition		Development of an innovative PMS using fuzzy measurement, giving hints about the overall SC performance through indices.
Approach to performance measurement		
	Activity vs. Process based	Process based.
	SC vs. EE oriented	Virtual enterprise oriented.
	Inter-enterprise process vs. Intra-enterprise process oriented	Inter-enterprise process oriented, through fuzzy-combining intra-enterprise process measures.
Drivers adopted		Qualitative measures: 1) customer satisfaction, 2) flexibility, 3) information and material flow integration, 4) effective risk management and 5) supplier performance. Quantitative measures: 1) based on cost: cost, sales, profit, inventory investment, return on investment, 2) based on customer responsiveness: fill rate, product lateness, customer response time, lead time, function duplication and 3) based on productivity: capacity utilization and resources utilization.

Interdependencies among the drivers adopted	Interdependencies evaluated and defined through fuzzy-logic.
Suggestions for drivers which could best fit to InCoCo-S purposes	None.
Strengths of the PMS	PM teams for agreeing on importance weights for PIs. Trying to bring individual PIs into collaboration context with fuzzy measurement. Hierarchical model for PIs.
Weaknesses of the PMS	The holistic performance measure (de-fuzzied) does not indicate where to improve supply chain. The qualitative measures are not defined and left open.
Is it based on existing Best Practices?	No, complete new approach for a PMS.
Does it foresee benchmarking opportunities?	Performance indices provide managers with possibility to benchmark whole system.
Does it have practical applications?	No
Comments	The approach is too theoretical. It is hardly applicable because it would not be understood and therefore not be used in many companies

Table 28 Chan (2003_2)

Chan (2003_3)

Author/Year		**Felix T.S. Chan et al. (2003)**
General description/definition		Chan et al. propose the use of the AHP (analytic hierarchy process) for the development of a SCM PMS. They propose to include more qualitative aspects such as visibility, trust and innovativeness, additional to common qualitative measures as flexibility and quality, and quantitative measures as costs and resource utilization.
Approach to performance measurement		
	Activity vs. Process based	Both
	SC vs. EE oriented	Supply chain oriented
	Inter-enterprise process vs. Intra-enterprise process oriented	Intra-enterprise
Drivers adopted		Apart from the common criteria such as cost and quality, five other PMs are defined: resource utilisation; flexibility; visibility; trust; and innovativeness.
Interdependencies among the drivers adopted		Only weights for indicating relative importance of PIs.
Suggestions for drivers which could best fit to InCoCo-S purposes		Include customer satisfaction as qualitative measure (key indicator for success) - avoid focus on financial measures (as for example value added in terms of EVA would be). Comprehensive overview of performance measures.
Strengths of the PMS		Hierarchical PI system. Comprehensive by also including qualitative measures.
Weaknesses of the PMS		No interdependencies between different PIs.
Is it based on existing Best Practices?		AHP approach is commonly used for similar purposes. It consists of the three following steps: It consists of three steps:

	1. Decomposing the complex problem into a hierarchy of different levels of elements. 2. Using a measurement methodology to establish priorities among the elements. 3. Synthesising the priorities of elements to establish the final decision.
Does it foresee benchmarking opportunities?	Only indicates opportunities to use hierarchical structure to assess competing supply chains for individual supply branches.
Does it have practical applications?	System was used in the electronics industry.
Comments	Literature review: "Beamon, in his literature review, categorises the existing performance measures into two groups: qualitative and quantitative, involving customer satisfaction and customer responsiveness, flexibility, supplier performance, costs and those used in supply chain modelling. Beamon identifies three types of measure: resources; output; and flexibility. Gunasekaran et al. develops a framework for measuring the strategic, tactical, and operational level of performance in a supply chain, which deals mainly with supplier, delivery, customer service, and inventory and logistics costs."

Table 29 Chan (2003_3)

Lapide (2000)

Author/Year		**Lapide (2000)**
General description/definition		Lapide (2000) proposes a two-tier supply chain PM framework, which depicts the relationship between what the author terms Executive level metrics and Managerial level metrics in the supply chain. The former can be considered to be cross-functional (and inter-organisational), process-based measures; the latter are function-based diagnostic measures.
Approach to performance measurement		
	Activity vs. Process based	Two perspectives: process based (cross-function) and function oriented, diagnostic metrics.
	SC vs. EE oriented	Virtual enterprise oriented.
	Inter-enterprise process vs. Intra-enterprise process oriented	Both
Drivers adopted		Process-based: Perfect Order Process (% of orders flawlessly filled) // availability of products at the point of consumption and total landed costs to get product to the point of consumption Function-oriented: 1) Purchasing: material availability and materials quality, 2) Manufacturing: adherence to schedule, product quality and product availability, 3) Logistics: Warehouse picking accuracy, inventory accuracy, on-time shipments, paperwork accuracy and damaged shipments, 4) Customer Service/Sales: order-entry accuracy, invoice accuracy, payment accuracy
Interdependencies among the drivers adopted		None identified.
Suggestions for drivers which could best fit to InCoCo-S purposes		Overall SC performance: 1) availability of product (service) at the point of consumption and 2) total landed costs to get products (services) to the point of consumption.
Strengths of the PMS		Orientation towards overall SC strategy avoids sub-optimal, only individually

	optimised departments. However, these individual metrics still are considered important, but should be put in a framework of aggregated, process-oriented measures. Lapide gives hints on how to develop this framework top-down.
Weaknesses of the PMS	Lapide proposes only very few exemplary PIs, but does not even define them. He gives indications about interdependencies, but does not explain them further.
Is it based on existing Best Practices?	Refers to the Balance Scorecard approach.
Does it foresee benchmarking opportunities?	The top-down approach of first defining "executive" PIs and then "drill-down" functional PIs offers the opportunity to benchmark different individual players, being part of the overall PI and being comparable to their pendants.
Does it have practical applications?	1) Understand top management's strategic SC objectives, 2) develop a limited, balanced set of executive-level measures directly aligned with these strategic objectives, being balanced between strategic objectives and diagnostic-type metrics, 3) develop tactical and operational measures ("drill-down" measures), derived from the upper level, and 4) update PMS.
Comments	Remarkable: Lapide's thought about whether you want to measure what you cannot directly control - he says yes, because then you identify deficiencies in your SC performance that can be addressed by inter-enterprise initiatives.

Table 30 Lapide (2000)

Prodchain project members (2006)

Author/Year		**Sennheiser (2004), Schnetzler et al. (2006)**
General description/definition		Development of an hierarchical PMS based on a Supply Chain Design Decomposition (SCDD), which represents a systematically structured system of objectives and means related to SCM. The PMS that is value-based according to the methodology of Economic Value Added (EVA) and incorporates several levels of PIs of the target areas quality, reliability, time, flexibility, assets, and costs. The PIs are connected to the objectives in the SCDD. The SCDD itself is developed according to the methodology of Axiomatic Design that systematically distinguishes objectives and means and guides the development of a good design solution.
Approach to performance measurement		
	Activity vs. Process based	Related to the SCOR processes 'Source', 'Make', and 'Deliver'.
	SC vs. EE oriented	Supply chain oriented.
	Inter-enterprise process vs. Intra-enterprise process oriented	Primarily intra-enterprise.
Drivers adopted		High sales revenue: Perfect order fulfilment, service level, fill rate, turnover etc.; High delivery quality: faultless order fulfilment, return rate; High delivery reliability: service level, forecast accuracy, delivery time deviation etc.; Short lead time: total lead time, total lead time deviation etc.; High flexibility: Upside/downside production flexibility etc.; Low assets: inventory days of supply, asset turns, cash-to-cash cycle time etc.; Low costs: total logistics costs, cost of goods sold, total inventory costs, value-added productivity etc.
Interdependencies among the drivers adopted		There are several aspects of interdependencies taken into consideration: (1) The PMS is structured according to the methodology of Economic Value Added (EVA) showing the drivers of EVA and the contributions to the EVA; (2) The

	sequence of the target areas follows the 'sand cone model' that describes cumulative capabilities; e.g., first, quality should be mastered before optimising the other target areas. (3) Due to the foundation on Axiomatic Design, cause and effects on a generic level are mapped.
Suggestions for drivers which could best fit to InCoCo-S purposes	Adoption of some kind of a value-based approach; consideration of decomposition and specific target areas.
Strengths of the PMS	Holistic and generic, value-based approach, scientific foundation on different methodologies; hierarchical approach.
Weaknesses of the PMS	Regarding InCoCo-S: the focus is on supply chains, but the approach can be adapted to the requirements of service supply chains.
Is it based on existing Best Practices?	Refers to (1) Economic Value Added, (2) SCOR, (3) Axiomatic Design, (4) 'sand cone model'.
Does it foresee benchmarking opportunities?	Due to the exact definition of PIs, benchmarking is facilitated. Moreover, a generic benchmarking methodology is developed that assigns companies to clusters based on their logistics fingerprint, which describes their logistics and business issues. Subsequently, companies belonging to the same cluster can be compared regardless to which branch they belong.
Does it have practical applications?	Successfully applied in several case studies and projects.
Comments	Either the methodology itself could be adapted more or less directly to service supply chains or, more general, the approach, i.e. the core principles of the methodology, in particular the idea of decomposition.

Table 31 Prodchain project members (2006)

4 Industrial requirements

From the business cases carried out with the industrial partners of the InCoCo-S project a strong need for novel PMSs which are expressly designed to address the service supply chain emerged.

Here below a brief summary of the requirements identified during the InCoCo-S business cases in terms of PMSs is given.[1] Moreover specific interviews to the industrial partners of the InCoCo-S consortium are presented with the intent to identify which are the presently adopted practices in PM and which would be the requirements for a new PMS for the service supply chain.

4.1 Requirements from the business cases

The requirements coming from the InCoCo-S business cases (DL.2.3) can be summarized through the following list:

- PIs provide vital information to the organisation for tracking and predicting business performance against strategic objectives in a way that compliments financial measures.
- KPIs can be part of a corporate-wide Balance Scorecard implementation or can be used to monitor each individual business function. By measuring and monitoring operational efficiency, employee performance and innovation, customer satisfaction,

[1] For more information on the business cases please refer to Deliverable DL2.6 “Design of InCoCo-S Reference Model Structure”.

as well as financial performance, long term strategies can be linked to short term actions.

- There is a need to develop Key Performance Indicators to measure not only intra-enterprise performances (both from the service provider and manufacturer side) but also (presently missing) inter-enterprise ones to evaluate the efficiency of coordination (and in case collaboration) mechanisms.
- KPIs must be developed to measure not only operational efficiency but also financial performance, customer satisfaction, innovation ability and employee performance. In this way short term actions can be fully tracked and linked to long terms maintenance strategies.
    - It is vital to translate into objective numbers the level of satisfaction of the customer.
    - It is important to highlight the added value for the customer in outsourcing a specific service.
- The development of the KPIs should be intended to guarantee total transparency between service supplier and manufacturer. And this should be done directly from the early stages, that is, starting from the Adapt phase.
    - Performance measures must be accessible in real time by both the service supplier and the customer to share a common understanding.
- A system of PM and KPIs should be exploited as an instrument for applying continuous improvement policies to services processes both on the service provider and manufacturer side, as well as to inter-enterprise processes.

4.1.1 Interview with COMAU

Which service operations do you already measure?

Comau monitors processes at the interface with the customers who directly affect the performance of the service delivery and therefore the performance of the production function of the customer.

These processes include therefore:

- the service provision process itself (breakdown maintenance interventions and planned maintenance interventions) (e.g.: Mean Time to Repair, Manpower utilisation);
- the production processes (e.g.: Mean Time Between Failure, Mean Down Time).

The Comau performance monitoring systems can be split into :

- Key Performance Indicators contractually agreed with customers:
    - Downtime
    - CSI (Customer Satisfaction Index)
- Internal KPIs:
    - MTTR (Mean Time to Repair)
    - MTBF (Mean Time Between Failure)
    - MDT (Mean Down Time)

- Manpower utilisation

Which performance indicators do you use?

KPIs contractually agreed with customers

- *Downtime*

  Downtime is a rate expressed as a percentage of breakdown hours on production availability hours.

  The lack of a common system often generates debates on:

  - The correctness of figures;
  - The way to calculate related losses (like quality scraps due to breakdowns);
  - Production losses related to delays or repetitive small problems: boundary between maintenance and production responsibilities.

  Adopted policies:

  BONUS-MALUS

  It represents a development in the latest contracts. It is a boundary calculated on the downtime target according to which Comau will pay a malus on the tariff in case the target is not achieved or it takes a bonus if the final result of the downtime is below the target.

  CUSTOMER SATISFACTION SURVEY

  This survey has been lately introduced to give the customers the possibility to express a judgement on the main issues linked to the maintenance service.

  (Even if the technical downtime is respecting the target, customers can have a bad perception of the service.)

- *CSI (Customer Satisfaction Index)*

  The CSI intends to assess the quality of the serviced as perceived by the customer. The index is created through the submission of a questionnaire to the customer where the following parameters are quantified on a 1 to 10 satisfaction scale:

  - Integration Comau Service-Customer plant.
  - Reactivity on maintenance problem.
  - Efficacy of maintenance.
  - Technical efficiency of plant/machineries.
  - Implementation/extension of preventive maintenance.
  - Purchasing/maintenance spare parts management.
  - Propositivity towards improvements.
  - Respect of procedure and agreement.

  The parameters are also tracked along time to evaluate possible trends.

Internal KPIs

Maintenance performance is the result of the utilisation of resources in providing actions to restore an item to a condition in which it can perform the required function.

The maintenance performance is depending on influencing factors, internal and external, such as location, culture and service processes, and is carried out by implementing organisational methodologies and operating techniques.

Therefore Maintenance Performance is an outcome of complex activities which can be evaluated by appropriate indicators to measure the results: actual, expected and foreseen.

MTTR (Mean Time to Repair), MTBF (Mean Time Between Failure), MDT (Mean Down Time), Manpower utilisation are standard indicators.

Comau internal KPIs mainly refer to manpower utilisation making a comparison between what was forecast and what has been done.

On which time basis is each performance assessed (on-line monitoring, off-line monitoring on a daily basis, weekly basis …)

The PIs are assessed off-line.

Planned maintenance is not reactive therefore no monitoring via sensors is performed on-line.

Breakdown maintenance is performed after a call from the customer and therefore even in this situation no on-line monitoring is performed.

How do you evaluate the level of satisfaction of your customer?

Through questionnaires and the aggregation of the information into a CSI as explained above.

Are you dependent on information or activities from the customer, in order to perform your service efficiently and effectively? If yes, do you measure this and how?

Comau is dependent on the customer (both during the design of the service and the operation as well) but does not measure directly any indicator. The customer (operators, managers …) is always the interface to acquire information which will be used to define maintenance strategies and maintenance interventions.

Do you rely on any existing best practice (e.g.: balanced scorecard, SCOR …)?

No.

Do you assess your performances through benchmarking practices?

External benchmarking is performed on the cost of the service to compare Comau with its main competitors.

Internal benchmarking is instead planned but not yet performed to compare the performances among different Comau's service contracts. Despite the differences and uniqueness of each contract, communalities can be found which make a comparison feasible.

What are the basic requirements for your PMS?

The main requirement is the ability to show to the customer what is the added value of giving its maintenance activities in outsourcing to Comau, or in other words the ability to show which is the improvement in efficacy and efficiency guaranteed to the production function thanks to Comau.

Are these requirements satisfied or can you identify any weaknesses in your present PMS?

It is hard to acquire all the necessary information, assess the real priorities of the customer and therefore understand which is the optimal maintenance strategy. Therefore the perceived quality may be different from the one expected by Comau. It is hard to really assess the perceived quality of the service and quantify the added value given to the customer.

How would you improve your PMS and which requirements would you like to satisfy in the future?

Data collection should be improved. A system should be created to guarantee accessibility of data and transparency between Comau and its customers to avoid disagreements.

Customer discontent on the perceived quality should be assessed and interpreted even if these considerations cannot be included in the initial contract.

The added value for the customer is difficult to assess, especially because every situation is unique and a single way for quantifying it can be hardly identified.

4.1.2 Interview with SKF

Which service operations do you already measure?

Which performance indicators do you use?

On which time basis is each performance assessed (on-line monitoring, off-line monitoring on a daily basis, weekly basis …)

Please refer to DL2.3 ““As Is” Business Use Cases & Requirement Specification in the Service-Supply Chain domain for all the 4 business cases”.

How do you evaluate the level of satisfaction of your customer?

No distinct criterion exists that is being measured and checked regularly. Only in the preparation of offers, there might be indicators checked such as hit rate of outgoing offers (in terms of accepted or not accepted).

Are you dependent on information or activities from the customer, in order to perform your service efficiently and effectively? If yes, do you measure this and how?

There is no Service Level Agreement constituted. This topic will be considered in the working meetings for Task 3.1 and 3.2 (with guarantee of incorporating this issue).

Do you rely on any existing best practice (e.g.: balanced scorecard, SCOR …)?

No.

Do you assess your performances through benchmarking practices?

No.

What are the basic requirements for your SPMS (Service Performance Measurement System)?

Are these requirements satisfied or can you identify any weaknesses in your present SPMS?

How would you improve your SPMS and which requirements would you like to satisfy in the future?

A PMS is not existing.

How is the efficiency of services measured?

The amount of conducted / performed hours to fulfil the order in relation to the accounted hours (e.g. for rework and goodwill / acts of generosities). In general, there is no such indicator.

Would it be for interest to measure the effectiveness of services for the customer?

Yes, that would be helpful.

Are there any internal projects / experiences / contact persons within this field of interests?

No, the focus of our fields of interests is completely on technical issues.

4.1.3 Interview with SIGPACK

Which service operations do you already measure?

- Spare parts order delivery process.
- Modernization order process.

(For more information please refer to Deliverable DL2.3)

Which performance indicators do you use?

- Lead time
- On-time delivery
- Quotation follow-up

(For more information please refer to Deliverable DL2.3)

On which time basis is each performance assessed (on-line monitoring, off-line monitoring on a daily basis, weekly basis …)

Weekly basis.

How do you evaluate the level of satisfaction of your customer?

- Customer cockpit (For more information please refer to Deliverable DL2.3)
- Supplier evaluation (for new machine projects)

Do you rely on any existing best practice (e.g.: balanced scorecard, SCOR …)?

No

Do you assess your performances through benchmarking practices?

Only internal benchmarking (CoCs)

What are the basic requirements for your SPMS (Service Performance Measurement System)?

KPIs are already well defined (for the areas mentioned above), but the level of automation is too low, resulting in technical problems, which leads to high manual effort

Additional to the areas mentioned above there is a lack of an overall measure to assess the customer value, in order to convince him to new service contracts.

Are these requirements satisfied or can you identify any weaknesses in your present SPMS?

No KPI for customer value included yet, appropriate level of automation should be ensured (technical feasibility of relevant measures).

How would you improve your SPMS and which requirements would you like to satisfy in the future?

Please refer to the answer before.

4.1.4 Interview with UNITECH

Which service operations do you already measure?

Downtime and customer satisfaction are measured, only. Furthermore, feedback from customers is received by phone or fax concerning the quality of the machine and the skills of the specialists. Questionnaires are not used.

Which performance indicators do you use?

Currently PIs are not used. UNITECH derive the customer satisfaction by phone calls or personal talks. Each RETROFIT - project has a separate cost unit, after finishing the project the controlling department checks the balance of the project.

On which time basis is each performance assessed (on-line monitoring, off-line monitoring on a daily basis, weekly basis …)

On -line on a different basis, sometimes daily or weekly

How do you evaluate the level of satisfaction of your customer?

These information are gained by phone calls or by records of the experts (fitters /service engineers)

Do you rely on any existing best practice (e.g.: balanced scorecard, SCOR …)?

Best practices are not in use or considered. In the future, a deployment of Best Practices is desirable. UNITECH is interested in getting more information about Best Practices by participating within this project.

Do you assess your performances through benchmarking practices?

External benchmarking is conducted with respect to the costs in comparison to main competitors of UNITECH. Internally, a comparison of the contract price to final expenses is realized.

What are the basic requirements for your SPMS (Service Performance Measurement System)?

A SPMS should provide the customer value added information by retrofitting his machine, e.g. in the sequel of the increase of the output or the possibility to produce a larger range of products.

Are these requirements satisfied or can you identify any weaknesses in your present SPMS?

It is hard to acquire all information which assess the real and wished of the customer. Therefore, UNITECH assume that there is a difference of perceived and delivered quality of the retrofitting machine (and therefore the whole service delivery).

How would you improve your SPMS and which requirements would you like to satisfy in the future?

The data collection has to be improved to provide transparency between UNITECH and the customer. The added value resp. the benefit for the customer is difficult to assess but should be considered within a SPMS.

4.2 Requirements from the survey

Within the InCoCo project, a survey was conducted (DL.2.1) to gather information about detailed information about aspects of coordination and collaboration between Service Provider and Manufacturer. Besides general aspects, the questionnaire focused on Performance Measurement, coordination mechanisms and reference frameworks in use. The InCoCo team received 162 responses which are coincidentally divided equally between the service providers and manufacturers with 81 each.

The survey revealed a comprehensive view for Performance Measurement Systems (PMS) in the service domain. The majority of the asked service and manufacturing companies stated to use a PMS. Furthermore, these companies quote a high importance particularly to monitoring and controlling concepts for their processes. Quite contrary to this great importance, another conclusion out of the survey leads to the conclusion that although most of the service companies are not satisfied with their PMS. In order to get more detailed information insufficiencies, the PMS were compared with logistics domain. The results point out that cost and capacity planning is supported insufficiently in comparison to delivery time and quality information. Subsequently, the majority of both service provider and companies foresee a big potential in further improvement of their existing PMS. To validate this statement, both service provider and companies were asked about key issues that should be addressed within the InCoCo-S project. Service provider stated that the PMS is equally important to information exchange that composes the most important issue to be addressed. Opposed to this, manufacturers focus on coordination mechanisms and information exchange. Only 20% of them address PMS for further improvement.

Summarizing, the further development of Performance Measurement Systems is quite important especially for service providers to increase the level of delivered quality and to improve calculating of delivered services.

4.3 Conclusions: summary of requirements and requirements from the SMEs

In previous Chapter 3.1, the results of several interviews with our industrial partners were presented. This chapter summarizes and condenses these results to requirements stated by the industry.

In general, COMAU and SIGPACK established an advanced Performance Measurement System (PMS) that covers several Key Performance Indicators so that even service agreements are offered. The challenge in the further development of the PMS lies in the junction to existing computer systems so that additional performance indicators can be incorporated into the PMS.

In contrary, SKF and UNITECH have no PMS developed yet. The only indicator which is tracked permanently is cost information. Both anticipate results from the project so that initial steps towards a PMS can be taken. Hence, both partners need support within such activities.

All of the interrogated companies assume that there is discordance between the delivered service and the received service at the customer. Although this relationship has been duly examined in literature by the GAP model, all the companies don’t have a definite solution to solve this problem. Therefore, some of the companies estimated the customer satisfaction level for the delivered service in order to improve their services. COMAU for instance conducts regularly questionnaires to elevate such information. Comprising, a key requirement from the SME is to offer indicators that ensures the appropriate delivery and exercise of services according to the requirements of the customers. Performance Indicators should be developed that presents the added value activities by the service provider.

Furthermore, none of the companies are using a Best Practice for performance measurement so that mostly individual solutions are available. Consequently, the potential of current Best Practises, such as Balanced Scorecards, are not accessible. Therefore it might be helpful for companies to provide them more information about current Best Practices in that domain. Likewise, none of the companies is conducting an internal benchmarking so that the performance of internal processes is not measured and consequently not improved systematically. Summarizing, a PMS should enclose (Key) Performance Indicators that allow an internal benchmark.

5 Formalization of Measures of Performances

In this chapter all PIs relevant for the area of service have been collected. For this purpose the already presented literature was taken into account, as well as first workshops conducted with the industrial partners of InCoCo-S. The identified PIs were adapted to service specific terminology and definitions. For this purpose some manufacturing and process related PIs were reformulated to match the specific requirements coming from the specific nature of service operations, i.e.:

- a stress of the area of operational resources, especially PIs targeting the service personnel,
- a stress of process PIs – transaction and coordination aspects are highlighted because of the secondary character of many service operations (e.g. planning and consulting activities), and
- a reformulation of customer and supplier to (service) partner, because in many collaborative service environments the actors have no hierarchical relationship.

For the presentation of the pool of service-PIs a first attempt for a structure was undertaken.

5.1 Pool of Performance Measures for the Service Supply Chain

For the entire pool of service performance measures three major areas were identified:

- Company's assets/costs
- Service Operation
- Company's capabilities

In the following the PIs within these three major areas will be presented.

5.1.1 PIs for the Area of the Company's Assets and Costs

Within the area of assets and costs of the service providing company five main areas were identified:

- costs
- sales
- profit
- inventory investment
- return on investment (ROI)

Performance Indicators for the Area of Company's Assets and Costs			
Level 1	**Level 2**	**Level 3**	**(Explanation)**
Cost	Service distribution cost	Material transportation and handling cost	
		Personnel travel and subsidy costs	
		Material safety stock cost	
		Duty cost	(Penalties of late or wrong service deliveries)
		Service distribution cost ratio to total service delivery costs	

	Material manufacturing cost	Production labour cost	(ABC, e.g. for producing spare parts or retrofit)
		Machine maintenance cost	(maintaining own or partner's equipment)
		Material re-work cost	
		Purchased materials cost	(parts and consumables)
		Production equipment charges	(e.g. leased equipment)
		Partners' margins	(To see overall-SC improvement areas)
	Material Inventory cost	Work-in-process inventories cost	
		Finished goods inventories cost	
		Inventory days of supply	
		Inventory obsolescence costs	
		Asset turns	
	Warehouse cost	(associated with allocation from one tier to another)	
	Incentive cost and subsidies	Taxes	(costs for extrinsic motivation of service personnel)
		Subsidies	(associated with needed travel for conducting services)
	Intangible cost	Service quality cost	(costs for maintaining service quality through e.g. trainings)
		Service adaptation cost	(costs for developing improved services according to partners' changed requirements)
		Performance measurement cost	(costs for introducing and maintaining the SPMS)
		Service transaction cost	Service coordination cost
	Overhead cost	Total current landed cost	(total costs for departments and personnel not integrated in productive service operations)
	Sensitivity to long-term cost	Productivity changes cost	(costs for losses in productivity)
		Wage changes cost	(costs for increasing wages because of inflation or general raise in wage level)
		Exchange rate changes cost	(costs because of exchange rate

			risks when operating internationally)
		Service design cost	(costs of the service development department)
		Core competence maintenance and improvement cost	
Sales	Total revenue		
Profit	Profit margin	(service sales price minus service operating costs - overall and per service)	
	Cash-to-cash cycle time		
Inventory investment	(new investments in inventories)		
ROI			

5.1.2 PIs for the Area of the Service Operation

Within the area of the service operation two main differentiations were made. The first area identified is related to the service object, in most cases the production process, where physical equipment is utilized. So this area is the service operation equipment. The second area is in the environment of service operations (especially important: the area of service operation resources). This is the personnel, but also the required tangible resources such as spare parts.

PIs for the Area of Service Operation Equipment

Within the area of service operation equipment four main areas were identified:

- equipment flexibility
- equipment effectiveness
- equipment efficiency
- equipment lead time

Performance Indicators for the Area of the Service Operation Equipment			
Level 1	**Level 2**	**Level 3**	**(Explanation)**
Equipment flexibility	Input flexibility	Equipment input flexibility	(The efficiency by using a more flexible machine to the traditional switching over machine. Both time and cost saved can be used to express its efficiency)

	Production process flexibility	Material handling	Number of existing paths between processing centres
			Variety of material which can be transported along these paths without incurring high transition penalties or large changes in performance outcomes
		Routing	Number of products which have alternative routes
			Extent of variation among the routes used without incurring other high costs in performance outcome
		Operation	Number of products which have alternative sequencing plans without incurring high costs or large changes in performance outcome
	Output flexibility	Volume	Extent of change and the degree of fluctuation in aggregate output level which the system can accommodate without incurring high costs or large changes in performance outcome
			OR
			The demand which can be profitably sustained
		Mix	The number and variety of products which can be produced without incurring high costs or large changes in performance outcome
			OR
			The time required to produce a new product mix
		Delivery	The percentage of slack time by which the delivery time can be reduced
	Improvement	Modification	The number and variety of

	flexibility		product modifications which are accomplished without incurring high transition penalties or large changes in performance outcome
		New product	Time or cost required to add new products to the existing production operation
			OR
			The number of heterogeneity of products which can be produced without involving high transition penalties or large changes in performance outcome
		Expansion	The number and variety of expansions which can be accommodated without involving high costs or large changes in performance outcomes
Equipment effectiveness	Overall equipment effectiveness	(a standard metric using several PIs from the areas below)	
	Availability/ reliability	Adherence to schedule	(overall production line equipment)
		Unscheduled Downtime	Down time caused by technical reasons
			Machine stops caused by technical reasons
			Down time caused by organisational reasons
			Machine stops caused by organisational reasons
			Product availability
		Scheduled Downtime	Down time caused by technical reasons
			Machine stops caused by technical reasons
			Down time caused by organisational reasons
			Machine stops caused by

			organisational reasons
			Product availability
		Mean Time Before Failure (MTBF)	
		Mean Time Before Unscheduled Removal (MTBUR) of machine part	
		Effective run-time of machine	
	Equipment output	Nominal output	(Machine's nominal total output)
		Set-up output	(Machine's nominal total output for the specific set-up)
		Effective output	(Total effective output in a period)
		Operating output	(Total output when operating)
		Product quality	Number of defect products / amount of waste
Equipment efficiency	Cost per operation hour	Energy consumption	
		Operation hours	
	Production labour cost	(Operation hours times worker's wage rate)	
	Machine maintenance cost		
	Material re-work cost		
	Production equipment charges	(Either own calculated operating hourly rate or costs for leased equipment)	
	Operators' behaviour	(Operators' unnecessary delays in utilising equipment)	
Equipment lead time	Production lead time	Operation time	Set-up time
			Run time
		Interoperation time	Waiting time
			Inspection time
			Transportation time
		Administration time	

5.1.3 PIs for the Area of the Service Operation Resources

Within the area of the service operation resources four main areas were identified, which are according to the equipment structure:

- resources flexibility
- resources effectiveness
- resources efficiency
- resources lead time

Performance Indicators for the Area of the Service Operation Resources			
Level 1	**Level 2**	**Level 3**	**(Explanation)**
Resources flexibility	Employee flexibility	Number of tasks a worker can perform	Map of Knowledge
			Workforce degrees of expertise
		Investments in personnel training and education	
		(see also equipment flexibility)	
Resources effectiveness	Availability/reliability	Material availability	(parts and consumables)
		Inventory levels	(parts and consumables)
		Cumulative inventory level	(parts and consumables)
		Warehouse picking accuracy	
		Inventory accuracy	
		Paperwork accuracy	(Errors in documentation and invoicing)
		Raw material quality	
		IT availability	Availability of operation manuals
			Number of IT changes within a time period
			Unplanned downtime at the customer
	Resources output	Service quality	(see also customer satisfaction)
		Number of standard service operations performed	
		Number of customised service operations performed	
Resources efficiency	Cost per service operation hour	Labour hours	
	Service labour cost		
	Personnel training cost		

	Service correction cost		
	Charges from service operation partners		
	Employee behaviour		
	Employee satisfaction	Employee retention	
		Sickness rate	
Resources lead time	Delivery lead time	Material delivery lead time	
		Personnel travel time	(time needed for requested personnel to travel to the location of service encounter)

5.1.4 PIs for the Area of the Company's Capabilities

Within the area of the company's capabilities ten main areas were identified:

- company's flexibility
- company's effectiveness
- company's efficiency
- company's Time
- company's visibility
- company's innovativeness
- partnership / networking
- risk management
- information and material flow integration
- environmental impact

Performance Indicators for the Area of the Company's Capabilities			
Level 1	**Level 2**	**Level 3**	**(Explanation)**
Company's flexibility	Service operation flexibility	(see service operation flexibility - equipment and resources)	
	Service flexibility	(ratio of inquiries of standardised services to all the inquiries)	
	Service delivery flexibility	Service delivery rate	
		Errors rate	
Company's effectiveness	Partner satisfaction	- Please see extra table	

	Market share		
	Service level		
	Perfect service fulfilment		
	Availability of service at point of consumption		
	Order cycle time		
	Partner growth and profitability		
Company's efficiency	Inquiry processing effort	number of attended meetings of business managers towards the partner	
		number of workshops / meetings	
		number of inquiries for existing solutions	
		number and amount of unplanned additional effort for project execution	
		number of hours spent for pre-contract activities	
		return rate of service components	
	Operating efficiency	number of conducted analyses at partner's site	
		frequency of data measurements	
		operation activities that are non-conformant	
	Total landed costs to perform service		
	Profit margin per supply chain partner		
Company's Time	Partner response time	(The amount of time between a customer order and its corresponding service delivery)	
	Lead time	Service production lead time	(The time required once the service began its "production" until the time it is completely processed)
		Service distribution lead time	Distribution lead time ratio to total customer response time
	Service lateness		
Company's visibility	Time	(Time required from when the service designer changes his idea to when the service starts being processed in the new way)	
	Accuracy	(The percentage waste of wrong services delivered after the new design is launched)	

Company's innovativeness	New launch of service	Benchmark your number of new services launched within a period against the competitors	
		OR	
		The percentage sales of a new service to the whole sales within a period of time	
	New use of technology	The percentage decrease in time necessary for producing the same service	
Partnership / Networking	Number of partners		
	Number of joint projects		
	Number of collaborative meetings / workshops per project		
	Number of years in business		
	Repeat orders per partner	Number of repeat orders	
		Ratio of repeat orders to new orders	
	Partner performance	Delivery performance	
		Partner lead time against norm	
		Partner pricing against market	
Risk management	(Risk management process in place yes/no)		
Information and material flow integration	Information flow integration	Proportion of number of shared data sets to total data sets	
		Integration of B2C and B2B, ERP, BPR, e-commerce	
		Number of software applications running	
		Budget for IT training and education	
		Investment in IT	
	Material flow integration	Number of material suppliers and customers	
		Lead time per material path	
Environmental impact	Overall energy consumption		
	Overall level of emissions		

As indicated in the table, the area of partner's or customer's satisfaction goes into deeper levels. And because in service operations the customer perception plays a very important role, there is a need to put an even stronger focus on this subject.

Performance Indicators for the Area of Partner's (Customer's) satisfaction			
Level 3	**Level 4**	**Level 5**	**Level 6**
Partner dissatisfaction	Number of complaints	Number of wrong deliveries	
		Number of damaged deliveries	
		Number of late deliveries	
Inquiry success rate	ratio actual orders / inquiries		
Provided value added	(Partner's benefit from service minus service sales price)		
Level of customer perceived value of product			
Deviation of provided value added vs. customer perception			
Partner responsiveness	Function duplication		
	Service delivery reliability	Fill rate	(Proportion of orders which can be filled immediately)
		On-time delivery	Percentage of orders delivered on or before due date
			Delivery time deviation
		Stockout	Stockout probability
			Number of stockouts
		Backorders	Number of backorders
			Average backorder level
		Service delivery lead time	Order lead time
			Overdue trade receivables
			On-time deliveries

			Late deliveries
			Wrong deliveries
	Service accuracy	Percentage of accurate services delivered to partner	
		Paperwork accuracy	
		Order-entry accuracy	
		Invoice accuracy	
		Payment accuracy	
		Forecast accuracy	
	Number of partner contact points		
	Partner perception of flexible response		
	Partner value ratio		

5.2 Conclusion

After the relevant performance indicators for the area of services have been identified, there is now the need for a clear structure of an according service PM system (SPMS). To be comprehensive and applicable, first goals for such an SPMS have to be identified.

6 Conclusions and goal definition for the SPMS

Based on literature research and industrial requirements key design features and goal definitions for an effective SPMS have been identified and are presented below.

Goal	Description / Goal property	Goal category	Goal type
Hierarchical approach	Whenever possible, the factors of the SPMS should be decomposed hierarchically into a practical level of detail.	technical	must
Mapping of causal chain / Interdependencies among the PIs	The SPMS shall illustrate connections between the PIs and are linked to each other.	technical	must
Deployment system	SPMS should translate the strategic objectives and deploy the revisited priorities into different levels of hierarchy using performance measures.	technical / strategic	nice to have
Integration of subjective and objective measures ("soft" and "hard" measures)	SPMS should content both subjective and objective performance metrics (e.g. subjective measures for customer satisfaction, perceived quality)	functional	must

Balanced view	Balanced view on performance considering both: different perspectives and time horizons (short- vs. long-term PIs, financial vs. non-financial)	functional	nice to have
Different perspectives: customer benefit, interaction view and internal view	The performance measures are focused on fulfilling both the intern needs of the service providers (internal view) and the external needs of the customers (customer perception, customer benefit) as well as on the interaction view between the customers and providers (service encounter interface).	functional	must
Multidimensional	Different aspects of performance must be included into the SPMS such as qualitative and quantitative performance attributes as well as technical and human interaction attributes (e.g. cost, quality, time, networking etc.).	functional	must
Different process levels, flow orientation	The SPMS should integrate all internal relationships of providers and customers with all functions, activities and processes along the supply chain (e.g. source, make, support).	functional	must
Adaptability / Modularity / Customisation	The SPMS should be adaptable to various company's requirements and to different service clusters by assignment specific PIs on the lower levels.	technical / strategic	must
Flexibility / Extensibility	The SPMS should be flexible and have a dynamic character that ensures agility and responsiveness of the system to the specific needs and environment of the company.	technical / strategic	must
Pre-configured standardized performance metrics	The SPMS should be pre-configurable to a certain extent on the upper levels (level 1 and level 2). A tool of generic standardized metrics provides selection support (that means SPMS helps in selecting the right metrics given a certain target within a specific environment).	technical / strategic	must
Integration with other firm systems	SPMS should be integrated within the other existing PMSs (e.g. BSC). Thus, the development of SPMS is not a "green field" approach.	technical / strategic	nice to have
Limited number of PIs	To create appropriate action it is necessary to use a limited number of performance measures. More measurement demands more analysis time and increases the risk of information overload – it becomes difficult to know which performance measures should be prioritised.	technical	must
Transparency	The SPMS should enable transparency between customers and service providers.	functional	nice to have

Accountability	The PIs contained in the SPMS shall be quantitative and if not, a common understanding of the assessment should be established.	functional	must
User-friendliness	The SPMS should be designed in a way that information is easily retrieved as well as easily understood by those whose performance is being evaluated.	functional	must
Combination of bottom-up and top-down approach	The SPMS should integrate top-down approach (based on the general literature review and best practices) and bottom-up approach (based on specific company's needs, surveys, interviews and workshops) that ensure practical applicability of the SPMS.	tactical / strategic	must
Completeness	The SPMS should take account of all the relevant performance factors in the environmental field.	tactical / strategic	must
Support strategic, tactical and operational objectives	The SPMS should support strategic, tactical and operational objectives of a company. The top level considers corporate issues on the basis of generic measures from the stakeholders whereas lower levels include objective and specific PIs provided by shop floor engineers and operators.	tactical / strategic	nice to have

In conclusion, for measuring the performance of industrial services, a balanced, multi-criteria and hierarchical SPMS is considered to be effective, which considers both the customer's benefit and interaction view between customers and service providers as well as internal efficiency of the service providers. It should be flexible and dynamic, ensure the adaptability and applicability of the system to the real environment and specific company's needs.

From the application and usage point of view, the SPMS should be technology and user-friendly and easily facilitated by training the relevant personnel.

Bibliography

T. Altiok and R. Ranjan; Multi-Stage, Pull-Type Production/Inventory Systems, IIE Transactions, Vol. 27, 1995.

B.C. Arntzen, G.G. Brown, T.P. Harrison, and L.L. Trafton; Global Supply Chain Management at Digital Equipment Corporation, INTERFACES, Vol. 25, 1995.

R.C. Barker; Value Chain Development: An Account of Some Implementation Problems, International Journal of Operations and Production Management, Vol. 16 No. 10, 1996.

B.M. Beamon; Performance Measures in Supply Chain Management, Proceedings of the 1996 Conference on Agile and Intelligent Manufacturing Systems, Rensselaer Polytechnic Institute, Troy, New York, 1996.

B.M. Beamon; Supply chain design and analysis: models and methods; International Journal of Production Economics, Vol. 55, 1998.

B.M. Beamon; Measuring supply chain performance; International Journal of Operations and Production Management, Vol. 19, No. 3, 1999.

P.C. Brewer, T.W. Speh; Using the Balanced Scorecard to measure supply chain performance; Journal of Business Logistics, Vol. 21, No. 1, 2000.

P.C. Brewer, T.W. Speh; Adapting the Balanced Scorecard to supply chain management; Supply Chain Management Review, 2001.

A. Bytheway; Information in the Supply Chain: Measuring Supply Chain Performance, Cranfield School of Management Working Paper Series SWP1\95, March 1995.

A. Bytheway; A Review of Current Logistics Practice, Cranfield School of Management Working Paper Series SWP10\95, March 1995.

R.C. Camp; Benchmarking--The Search for Industry Best Practices that Lead to Superior Performance, ASQS Quality Press, Milwaukee, WI 1989.

S. Cavalieri, P. Valckenaers, U. Bititci, R. Bandinelli, K. Mendibil; Performance measurement systems in manufacturing: state of the art and future trends; Proceedings of the International IMS Forum 2004.

CE-NET consortium (Concurrent Enterprising Consortium) website: http://www.ce-net.org/

CGI Group Inc.; Supply chain management performance assessment: CGI's proven approach to measuring supply chain success; White paper, 2004.

F.T.S. Chan; Performance measurement in a supply chain; International Journal of Advanced Manufacturing Technology, Vol. 21, 2003.

F.T.S. Chan, H.J. Qi; Feasibility of performance measurement system for supply chain: a process-based approach and measures; Integrated Manufacturing Systems, Vol. 14, No. 3, 2003.

F.T.S. Chan, H.J. Qi, H.K. Chan, H.C.W. Lau, R.W.L. Ip; A conceptual model of performance measurement for supply chains; Integrated Manufacturing Systems, Vol. 41, No. 7, 2003.

M. Christopher; Logistics and Supply Chain Management, Richard D. Irwin, Inc., Financial Times, New York, NY 1994.

D.P. Christy and J.R. Grout; Safeguarding Supply Chain Relationships, International Journal of Production Economics, Vol. 36, 1994.

M.A. Cohen and H.L. Lee; Strategic Analysis of Integrated Production-Distribution Systems: Models and Methods, Operations Research, Vol. 36 No. 2, 1988.

M.A. Cohen and H.L. Lee; Resource Deployment Analysis of Global Manufacturing and Distribution Networks, Journal of Manufacturing and Operations Management, Vol. 2, 1989.

M.A. Cohen and S. Moon; Impact of Production Scale Economies, Manufacturing Complexity, and Transportation Costs on Supply Chain Facility Networks, Journal of Manufacturing and Operations Management, Vol. 3, 1990.

R.L. Cook and R.A. Rogowski; Applying JIT Principles to Continuous Process Manufacturing Supply Chains; Production and Inventory Management Journal, First Quarter, 1996.

L.M. Corbett; Delivery Windows - A New View on Improving Manufacturing Flexibility and On-Time Delivery Performance, Production and Inventory Management Journal, Vol. 33 No. 3, 1992.

K. Cravens, N. Piercy, D. Cravens; Assessing the performance of strategic alliances: matching metrics to strategies; European Management Journal, Vol. 18, no. 5, 2000.

T. Davis; Effective Supply Chain Management, Sloan Management Review, 1993.

S.K. Das; The Measurement of Flexibility in Manufacturing Systems, International Journal of Flexible Manufacturing Systems, Vol. 8, 1996.

D.E. Dreyer; Performance measurement: a practitioner's perspective; Supply Chain Management Review, 2000.

H. Duin, A. Saffarpour, M. Oliveira; PRIME simulation model; Presentation of the PRIME project (http://www.alfamicro.pt/prime/project/consortium.htm), 2006.

P. Folan, J. Browne; A review of performance measurement: towards performance management; Computers in Industry, Vol. 56, 2005.

A. Gunasekaran, C. Patel, R.E. McGaughey; A framework for supply chain performance measurement; International Journal of Production Economics, Vol. 87, 2004.

A. Gunasekaran, H.J. Williams, R.E. McGaughey, Performance measurement and costing system in new enterprise; Technovation, Vol. 25, 2005.

Y.P. Gupta and S. Goyal; Flexibility of Manufacturing Systems: Concepts and Measurements, European Journal of Operational Research, Vol. 43 No. 2, 1989.

K. Ishii, K. Takahashi and R. Muramatsu; Integrated Production, Inventory and Distribution Systems; International Journal of Production Research, Vol. 26 No. 3, 1998.

J.B. Johnson and S. Randolph; Brief: Making Alliances Work Using a Computer-Based Management System to Integrate the Supply Chain", Journal of Petroleum Technology, Vol.47 No 6, 1995.

J.P.C. Kleijnen, M.T. Smits; Performance metrics in supply chain manage management; Journal of the Operational Research Society, Vol. 54, 2003.

R. Lamming; Squaring Lean Supply with Supply Chain Management, International Journal of Operations and Production Management, Vol. 16 No. 2, 1996.

L. Lapide; True measures of supply chain performance; Supply Chain Management Review, 2000.

H.L. Lee and C. Billington; Managing Supply Chain Inventory: Pitfalls and Opportunities, Sloan Management Review, Vol. 33, 1992.

H.L. Lee and C. Billington; Material Management in Decentralized Supply Chains, Operations Research, Vol. 41 No. 5, 1993.

H.L. Lee and E. Feitzinger; Product Configuration and Postponement for Supply Chain Efficiency, Institute of Industrial Engineers, Fourth Industrial Engineering Research Conference Proceedings, 1995.

C. Lohman, L. Fortuin, M. Wouters; Designing a performance measurement system: a case study; European Journal of Operational Research, Vol. 156, 2004.

J. Hamilton; Service Value Networks: value, performance and strategy for the services industry; Journal of Systems Science and Systems Engineering, Vol. 13, No. 4, 2004.

B.H. Maskell; Performance Measurement for World Class Manufacturing, Productivity Press, Portland, Oregon 1991.

A. Neely, M. Gregory and K. Platts; Performance Measurement System Design, International Journal of Operations and Production Management, Vol. 15 No. 4, 1995.

S.J. New; A Framework for Analysing Supply Chain Improvement, International Journal of Operations and Production Management, Vol. 16 No. 4, 1996.

D.D. Newhart, K.L. Stott and F.J. Vasko; Consolidating Product Sizes to Minimize Inventory Levels for a Multi-Stage Production and Distribution Systems; Journal of the Operational Research Society, Vol. 44 No. 7, 1993.

A.D. Nicoll; Integrating Logistics Strategies, Annual International Conference Proceedings American Production and Inventory Control Society, 1994.

A. Otto, H. Kotzab; Does supply chain management really pay? Six perspectives to measure the performance of managing a supply chain; European Journal of Operational Research, Vol. 144, 2003.

C.H. Pan; An integrated framework to measure supply chain performance; PhD Thesis, 2005.

D.F. Pyke and M.A.Cohen; Performance Characteristics of Stochastic Integrated Production-Distribution Systems; European Journal of Operational Research, Vol 68 No. 1, 1993.

D.F. Pyke and M.A.Cohen; Multi-Product Integrated Production-Distribution Systems; European Journal of Operational Research, Vol. 74 No. 1, 1994.

J. Schmitz, K.W. Platts; Supplier logistics performance measurement: indications from a study in the automotive industry; International Journal of Production Economics, Vol. 89, 2004.

A. Sennheiser; Determinat based selection of benchmarking partners and logistics performance indicators; PhD Thesis ETH Zurich, 2004.

A.K. Sethi and S.P. Sethi; Flexibility in Manufacturing: A Survey, International Journal of Flexible Manufacturing Systems, Vol. 2 No. 4, 1990.

J.K. Shank and V. Govindarajan; Strategic Cost Management and the Value Chain, Journal of Cost Management for the Manufacturing Industry, Vol. 5 No. 4, 1992.

N. Slack; Flexibility as a Manufacturing Objective, International Journal of Operations and Production Management, Vol. 3 No. 3, 1993.

N. Slack; The Manufacturing Advantage, Mercury Books, London, 1991.

V. Stich, M. Weidemann, A. Sennheiser, K. Glaubitt, M. Schnetzler; Performance Measurement, included in L.M. Camarinha-Matos, H. Afsarmanesh, M. Ollus; Virtual Organizations, Systems and Practices; Springer, 2004.

D.R. Towill; Supply Chain Dynamics, International Journal of Computer Integrated Manufacturing, Vol. 4, 1991.

D.R. Towill, M.M. Naim and J. Wikner; Industrial Dynamics Simulation Models in the Design of Supply Chains, International Journal of Physical Distribution and Logistics Management, Vol. 22 No. 5, 1992.

S. Tzafestas and G. Kapsiotis; Coordinated Control of Manufacturing/Supply Chains Using Multi-Level Techniques; Computer Integrated Manufacturing Systems, Vol. 7 No. 3, 1994.

R.I. van Hoek; "Measuring the unmeasurable" – measuring and improving performance in the supply chain; Supply Chain Management, Vol. 3, No. 4, 1998.

V.T. Voudouris; Mathematical Programming Techniques to Debottleneck the Supply Chain of Fine Chemical Industries, Computers and Chemical Engineering, Vol. 20 Suppl. Pt. B, 1996.

N. Waters-Fuller; JIT Purchasing and Supply: A Review of the Literature, International Journal of Operations and Production Management, Vol. 15 No. 9, 1995.

J. Wikner, D.R. Towill and M.M. Naim; Smoothing Supply Chain Dynamics, International Journal of Production Economics, Vol. 22 No. 3, 1991.