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# UNDERSTANDING PERFORMANCE MEASUREMENT AND CONTROL IN THIRD PARTY LOGISTICS

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## Abstract

*Each individual planning process starts with clear objectives. These objectives specify the goals for the planning process, which is assigning tasks to resources at a certain point in time. Planning systems, whether manual or computerized, should utilize those objectives in their planning. In order to gain insight in the specific planning objectives for the Logistical Service Providers (LSPs) domain, we study the Key Performance Indicators (KPIs) related to this field. Typically, KPIs are used in a post-ante context: to evaluate the past performance of a company. We reason that KPIs could be utilized differently as well: if one knows what counts afterwards, it would be logical to anticipate this in the planning phase.*

*This paper thus focuses on the performance parameters and objectives that play a role in the logistical planning process. In order to gain insight in the factors that should play a role when designing a new software system for planning and control of LSP operations. In this paper we present an extensive literature survey we performed, and introduce a framework that is capable of capturing the dynamics of competing KPIs, while positioning them in the practical context of an LSP. We conclude with a first validation of the framework and a roadmap for our future work, with the design of a software agent-based planning system for (road-) logistics as an intended final result.*

*Keywords: Key Performance Indicators (KPI), Planning Systems, System Development, Multi Agent System (MAS), Logistics Service Providers (LSP), Third Party Logistics (3PL).*

# 1 INTRODUCTION

Over the last decades information systems have increasingly been applied to the traditionally manual planning role in industries such as (road-) logistics. However in practice the human planner has still a considerable role, assigning individual tasks to resources at a certain point in time. In this paper we want to focus on the planning input, output and the transition from input to output for Logistic Service Providers (LSPs). In order to do this transition well, a planning system – albeit manual or computerized – should utilize the proper performance parameters and objectives to derive to an optimal planning. To gain insight in this area, we considered the Key Performance Indicators (KPI) literature. Typically, KPIs are used in a post-ante context: to evaluate the past performance of a company. We reason that KPIs could be utilized the other way around as well: if one knows what counts afterwards, it would be smart to anticipate this in the planning phase already. Understanding this leads to better designed information systems.

This paper aims at giving more insight on the key performance indicators in the area of logistics service provision. To fulfill this goal we perform a literature study and we propose a framework to cluster performance indicators. The organization of the paper is as follows. We first briefly describe the LSP industry and shortly introduce the KPI domain (section 2). Then, we undertake a literature review in the areas of supply chain management and logistics service providers (section 3). In section 4 we synthesize the literature and develop a framework for KPI utilization (including the perspectives of several stakeholders). A first validation is shown in section 5. Section 6 presents the intended application and end goal of this research – to develop an agent-based planning system for a logistics service provider. Other shorter-term future research directions and conclusions are given in section 7.

## 2 KPI'S AND THIRD PARTY LOGISTICS

The increasing importance on core competencies opened up many business opportunities for logistics service providers (Christopher, 1998). They act as intermediaries in a supply chain that enable the organized movement of goods from a point of origin to a point of destination (i.e. from shippers to consignees) (Lai *et al.*, 2004). Instead of merely focusing on transportation activities, third party logistics providers (3PL) are additionally coordinating logistical activities, integrated on an intra- or even inter-organizational level (Sink *et al.*, 1996; Vaidyanathan, 2005). Companies in a supply chain have to decide to be either cost-efficient or lead time driven and the provision of logistics services is affected by this choice as well (Fisher 1997). Logistics service providers are further trying to expand their activities outside their home country (Lemoine, Dagnaes 2003).

A logistics service provider can be successful only, if it acts based on reliable and complete information about the performance of the company as a whole and all its units. It is therefore surprising that such an activity is usually carried out in an ad-hoc manner. This is due to a number of reasons. First of all, the selection of performance indicators is not trivial. No single indicator can give a full picture on the performance – each one presents a partial view from a specific viewpoint and is therefore not enough to serve as basis for management decisions. Historically, companies concentrated on financial indicators. Nowadays it is widely recognized that non-financial and even non-numerical indicators can give valuable information as well (Brewer and Speh, 2000; Ittner and Larcker, 2003; Chan, 2003). Such indicators though are more difficult to measure and compare. Considering an allegedly full set of indicators could result in a huge amount of data which would require a lot of efforts and high costs both in acquiring and analyzing. A reasonable solution would be to select the set of the most important indicators having in mind the goals of the company. The analysis should be performed with extreme caution so that the resulting set of indicators covers every relevant point of view. It is not uncommon that the selected indicators turn out to be conflicting – improving one may worsen another (Kleijnen and Smits, 2003).

Performance indicators are to a large extent domain specific. Our research focuses on the area of third-party logistics. But even within this area no unique subset of indicators can be selected. The choice is company specific and depends on the goals, state and orientation of the company. Therefore it is worthwhile to first concentrate efforts on providing aid in the selection process.

### **3 LITERATURE REVIEW**

Key Performance Indicators (KPI) are typically used in a post-ante context: to evaluate the past performance of a company, mostly through the analysis of aggregated data. Such metrics make it possible to compare performance with previous periods of measurement, industry standards or even individual competitors. Turning it upside down, we could reason that any logistical system should try to optimize and steer its decisions to the metrics it later shall be evaluated upon. Therefore, a clear insight in the aspects that drive logistical operations is useful. It can provide us with an answer to the question on what factors to optimize our planning. Besides the mentioned planning objectives, planning processes get complicated and constrained through a long list of restrictions, regarding issues such as: delivery, distribution time, driver, fleet, environmental, customer importance, etc.

KPIs could help to reduce decision complexity, especially at the operational planning level. This way, activities of control and execution can be distributed. By giving each element in the system the right KPIs, the system as a whole should behave in a certain desired way. KPIs allow the analysis of a system and comparison with a company's earlier performance, the rest of the industry, or other companies. Benchmarking can be an effective tool for improvement. Furthermore one should be aware that the perception of performance is relative: cost efficiency may be one of the important measures for an LSP, however, this might not be what the shippers and consignees desire – they would instead demand high quality and low price (Lai *et al.*, 2004).

In the literature we identified two major perspectives. First, there is a clear split between performance indicator related research that focuses on internal operations of an individual firm, versus literature that takes the supply chain perspective and seeks to optimize inter-organizational performance. For one exception we refer the reader to Gibson *et al.* (2002), which compared how shippers and carriers rank service. Second, we see a difference related to the use of performance indicators; they are either used at the strategic level, for performance evaluation, or at the highly operational level, for planning and control. In the next sections we review the different sources of literature.

#### **3.1 Supply chain performance**

Supply chain management is important to logistics service providers. Integrating operations with suppliers and customers generally results in a performance increase, for all stakeholders involved. Clearly it is important for logistics service providers to have the capability of analyzing its supply chain capabilities and steering its operations towards it. In the literature on logistical performance indicators we have identified a clear split between a chain-wide focus – incorporating the fact that several companies influence one another's performance, and are dependent upon each other – and a single company focus, incorporating just the factors one company can influence.

Supply chains can typically be categorized into either efficient or responsive supply chains (Fisher, 1997). Christopher and Towill (2002) make a similar distinction into lean and agile. Agility implies the ability of the supply chain to react quickly to change in market demand including dimensions such as product volume, variety or mix. Lean or efficiency oriented supply chains typically are producing and distributing products with predictable demand, which leaves relatively more time for planning and thereby allowing the supply chain to achieve greater levels of efficiency. Logistics service providers must be aligned with the supply chain they serve; measuring flexibility, efficiency and responsibility levels is a first step. Weber (2002) proposes a hierarchical model to assess supply chain agility. The Supply-Chain Operations Reference-model (SCOR) offers a model with standards to describe supply chains (SCOR - Supply Chain Council, 2003). Measurements which can be used to measure efficiency

or leanness of logistics service providers include fill rate of delivery plans, empty-to-loaded backhaul mile index, equipment utilization rates (hours), equipment utilization rates, vehicle maintenance costs. Metrics to measure responsiveness or agility include delivery performance to customer requested date, customs clearance time, export shipment processing time. Stewart identifies supply chain metrics along the four links of an integrated supply chain, similar to the SCOR model (Stewart, 1995): plan, source, make/assemble, and delivery. Planning can be measured by order lead-time, that is the time which elapses between the receipt of the customer's order and the delivery of the goods; it thus includes times for: order entry, order planning (design, communication, scheduling time), order sourcing, assembly and follow up, and finished goods delivery. Reliability and consistency of lead-time are also important characteristics. The customer order path is another important measure whereby the time spent in non-value adding activities can be identified, and suitable steps can be taken to eliminate them. Lai *et al.* (2004) pinpoint that the SCOR model has originally been developed with a focus on manufacturing processes. Therefore it might not be readily applicable for performance measurement in the context of service-based transport logistics.

A strong partnership emphasizes direct, long-term collaboration, encouraging mutual planning and problem solving efforts. Partnership evaluation criteria are (Gunasekaran *et al.*, 2001): level and degree of information sharing (Mason-Jones *et al.*, 1997), buyer-vendor cost saving initiatives (Thomas *et al.*, 1996), extent of mutual co-operation leading to improved quality (Graham *et al.*, 1994), entity and stage at which supplier is involved (Toni *et al.*, 1994) and extent of mutual assistance in problem solving efforts (Maloni *et al.*, 1997). However, Kemppainen *et al.* (2003) suggest, that it is neither feasible nor profitable to have strong collaboration with all supply chain partners. Logistics service providers should select key customers and focus on strengthening these relationships.

Another important point regarding supply chain management is the use of information systems (Sander *et al.*, 2002). Information systems support the integration of inter-organizational processes (Hammer 2001). For an LSP information systems revolve around four major players: the LSP's customer, the customer's clients, the customer's suppliers and alliances, and the LSP provider itself (Vaidyanathan, 2005). Ross (2002) shows that IT investment can have a positive impact on market performance as a result of better coordination in the value chain. However, putting such a high level of collaboration into practice is not easy. Both information quality and relationship commitment play an important role (Moberg *et al.*, 2002).

### **3.2 Performance management from an internal company perspective**

Whereas supply chain performance evaluation can take many identities as has been shown above, researchers agree more on internal measurement, cost calculation and performance evaluation methods. Company centered performance management focuses on the measurement and evaluation of decision making on company performance. Below we review several sources that listed such indicators.

In the 1990s Van Donselaar *et al.* (1998) performed a large-scale study in the transportation and distribution sector in the Netherlands. They focused on logistics performance from the provider's point of view – where they make a division between distribution and transportation. Their findings include the attractiveness of long trips for long-distance transportation (which might be influenced in the order-intake process). Furthermore they show that lower percentages of empty miles (of total miles driven) lead to better results, which pleads for minimization of miles driven empty. Finally, combining (international) shipments might be very beneficial, although it does consume more handling time.

UPS executive Peter Bromley (Bromley, 2001; Johnson, 2001) lists the big five Key Performance Indicators (KPI's) as important for UPS Logistics. Those are: On-time receiving, On-time shipping and delivery, Order accuracy, Inventory accuracy, Returns cycle time. Although (low) costs are important for UPS, the perfect customer experience (through a perfect service) seems to direct its business processes. We should be aware that this might be the case for companies active in parcel deliveries, but that regular logistical service providers are likely to be more cost driven.

Delivery performance can be measured by on-time delivery. This determines whether a perfect delivery has taken place or not, and it acts as a measure of customer service level. Stewart (1995) identifies the following as the measures of delivery performance: delivery-to-request rate, delivery to commit date, order fill lead-time and goods in transit. Quality and the way the information is exchanged determine the delivery performance to a large extent; possible performance indicators are: number of faultless invoices, flexibility of delivery systems to meet particular customer needs. Measurements to assess customer service and satisfaction are flexibility, customer query time, and post transaction measures of customer service. See (Fowkes et al. 2004) for a discussion on the reasons for delay and how reliability and predictability is valued in industry.

Mentzer *et al.* (1991) performed a study on performance evaluation in logistics. They identified a list of performance measures in five sub-areas of logistics: transportation, warehousing, inventory control, order processing and logistics administration. They further differentiate between areas of measurement: Labour measures (Loading, Driving, General labor), Cost measures, Equipment measures, Energy and Transit time measures. The list is rather detailed, and can be a useful basis for evaluate a logistical (planning) system.

Closely related to performance management, are modern accounting methods, such as Activity Based Costing (ABC) (Pirttila *et al.*, 1995; Themido *et al.*, 2001). ABC differs from traditional cost accounting by tracing costs to products according to the activities performed on them. Traditional approaches allocate direct and indirect costs on a proportionate basis using volume-based cost drivers such as direct labor costs, machine hours, or material dollars. Volume-based cost drivers will distort costs whenever products consume resources in disproportionate amounts. ABC has gained acceptance within manufacturing as an effective technique assigning product costs; however, most companies have not yet extended ABC to logistics operations. In theory, the application of ABC within an LSP would make it possible to trace costs to specific orders, customers, supply channels, or certain logistical activities. Surprisingly, we found only little research is done in this specific area.

### **3.3 Planning levels**

A company is usually divided into the levels strategic, tactical and operational. Gunasekaran *et al.* (2001) assigned metrics to the appropriate management level. However focusing on logistics service providers gives the opportunity to classify more specifically. Van Donselaar *et al.* (1998) distinguish between segments, which are marked by the different services that are offered to customers. Operational performance on the segment level was defined as the turnover per segment in proportion to the relevant costs in the segment. The relevant costs on segment level were variable costs (fuel, tires, maintenance, etc.), direct costs (depreciation, insurance, leasing, etc.) and the wages of the drivers in the segment. The score to measure the operational performance level at company level is derived from the segment performance metrics.

Lohman *et al.* (2004) perceive performance measurement systems as process control systems – with two separate levels: the operational level, and a tactical/strategic level. At the operational level, a comparison of input and output values with predefined goals takes place. If there is a discrepancy between the actual value of the PI and the desired goal, knowledge about the behavior of the organization is used to find an appropriate action, e.g. modifying the process. At the tactical or strategic level the control loop is used to evaluate the operational level, by changing goals if necessary. With these two control loops, a performance measurement system extracts the right process information and provides goal information needed to evaluate performance (comparison) as well as goals (evaluation).

### **3.4 The less easy measurable (or measuring the un-measurable)**

It is compelling to note that we have hardly seen concrete literature that pays attention to other factors than the easy-to-measure numbers as shown above, factors such as: cost, time, faults, IT utilization. Environmental factors, customer perceptions, employee happiness, et cetera are hardly covered in

logistical performance indicator literature. We found only two examples of papers focused on quantitative as well as qualitative performance measurements, namely Chow *et al.* (1994) and Chan (2003). The first is of a general nature, whereas the latter focuses on the electronics industry. Interestingly, both authors do not make a link with the ‘*balanced scorecard*’. We think however, that the balanced scorecard – which has become a well recognized management instrument in industry over the last years – might help in providing useful results.

The balanced scorecard is a framework that measures a company’s performance in an integrated manner. It provides a formalized mechanism to achieve a balance between non-financial and financial results across short-term and long-term horizons and is based on the notion that companies have to aim at a true integration of marketing, production, purchasing, sales and logistics (Brewer *et al.*, 2000). The balanced scorecard distinguishes four main perspectives (Kaplan *et al.*, 1992): customer, internal, financial, and innovation and learning. The focus on only four areas forces managers to concentrate on the most critical measures.

In order to use the concept of the balanced scorecard to its full potential each company must create its own version of it. The customer perspective deals with how the company performs from an external standpoint. On a general level, the customer of the logistics service provider is the supply chain. Knemeyer *et al.* (2003) examined the perspective of a logistics service provider’s customer. If the customer perceives that the logistic service provider focuses on the interaction between the companies and is concerned with winning and keeping the customer, the relationship can be strengthened. Stank *et al.* (2003) conducted a survey, which addressed a logistics service provider’s performance and how it related to market, customer satisfaction and loyalty. The model distinguishes between three different kinds of performances: relational performance, operational performance and cost performance. Kleijnen *et al.* (2003) propose the use of the balanced scorecard in order to deal with multiple performance metrics in SCM.

The internal business perspective translates the customer perspective into what the company must do in order to meet its customer’s expectations. Continuous change is required. For a logistics service providers these innovations can mean to change business strategies such as a change from short to long distance transport, adding additional activities, new countries, new modes of transport, new communication systems such as RFID or WebServices (Chapman, *et al.* 2003, Lemoine *et al.*, 2003). Financial performance indicators measure whether the company’s strategy, implementation, and execution are contributing to bottom-line improvement. Typically financial goals have to do with profitability, growth, and shareholder value.

## 4 KPI FRAMEWORK

The literature overview presented in the previous section supports the view that a new framework for performance indicators can be beneficial in the area of third party logistics. Previous research only concentrates on the point of view of the logistics service provider. We choose a more general approach and consider different points of view (both internal and external) on the company’s performance. Figure 1 presents our framework. We first focus on the higher level of the classification of performance indicators. On the horizontal axes we separate the different viewpoints corresponding to the parties involved. The **internal** point of view is represented by the two parties within the company – *management* and *employees*. The **external** point of view shows the perspective of the *customer* and the *society* (stakeholders), where in society we include parties such as government, various non-governmental organizations, and population not involved as customers or employees of the company. The motivation for including four different points of view comes from the fact that in many cases they will be conflicting and, in order to achieve a balance, the management should be aware of the needs and desires of all parties involved.

A number of examples can be given to support our approach. Consider for example the prices for the logistics services the company offers. Increasing the price will bring more profit which is desirable for the company. The customer, however prefers low prices. The society on the other hand is clearly not

so concerned with prices alone but more with the economic climate as a whole, e.g. how to increase the competition, fight the monopoly (which might be the factor leading to higher prices), reducing CO<sub>2</sub> emissions, etc. Employees are in general not so concerned with the prices but with their work conditions. Another example would be labour efficiency. Management is interested in maximum utilization of labour which, without applying restrictions, will lead to overexploitation. This naturally comes in conflict with the point of view of the employees. The customer however is not directly concerned with the internal affairs of the company but with the output (on-time delivery, flexibility, information on demand, etc.). The society might be concerned with cases of overexploitation on a large scale which might lead to, for example, legal issues or drastic increase in road accidents, strikes disrupting the traffic or health insurance issues.

The vertical axes in the framework divides the performance indicators in long-term and short-term. This distinction has been previously used in other research (e.g. Gunasekaran *et al*, 2001) and is accepted as a meaningful division that decision makers find applicable. The definitions we used are:

- **Long term** – Some performance indicators, e.g. profit revenues, can be measured best over longer time periods (more than a month). In theory, all reasonable indicators can be measured over longer periods of time.
- **Short term** – It depends on organizational strategy and measurements costs, what indicators the organization decides to measure in the short term. For example, an organization aiming at maximizing its total number of driven kilometers may want to report on this measurement on a daily basis. As measurement costs are also concerned, over time it may be possible that indicators are moved from long to short term measurement as measurements costs decrease. This is recently the case where the incorporation of IT systems and sensor technology (such as RFID) enables measurement of many indicators on short term basis.

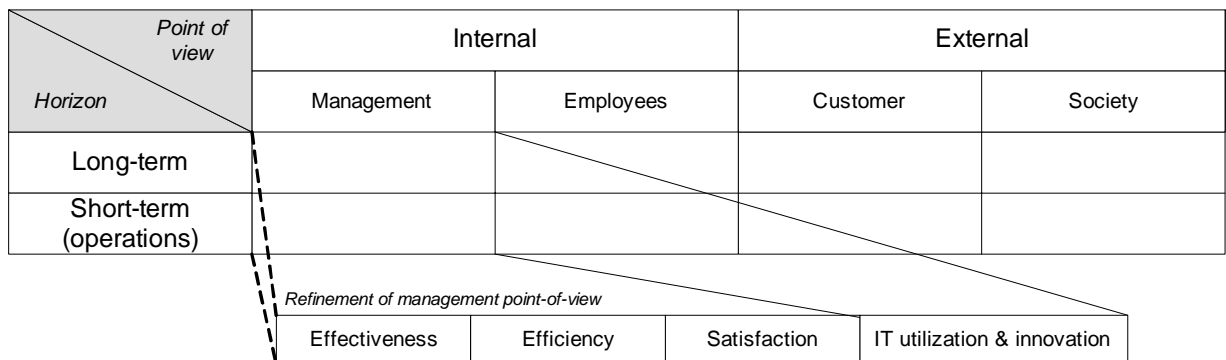


Figure 1. High-level framework to cluster KPI's relevant for LSPs

The classification discussed so far is very general. It incorporates all relevant points of view but does not provide structure within these viewpoints. We extended it in this direction. We concentrate on the management point of view and formulate further splitting of the performance indicators in four categories (see the lower part of Figure 1). The reason for considering only the management point of view is that it is the one in which we are most interested and we expect it to accumulate a richer collection of indicators where further refinement is necessary.

We consider the following four categories: effectiveness, efficiency, satisfaction and IT/innovation. For these classifications, companies can either be interested in them in the long or short term. We elaborate more on each of these categories in the following paragraphs.

- **Effectiveness**– Effectiveness measures the capability of producing an intended result. It thus concerns the ‘outside’ of the organization – what results does the organization achieve? Or, more from an external viewpoint, how do customers perceive the performance of the organization? Examples of such indicators are on-time-delivery, number of customers and service provision.
- **Efficiency** – Efficiency is the measurement for producing results taking into account used resources. It thus refers to the ‘inside’ of the organization – how does the organization achieve its



results? We may also say that efficiency measures the ratio between input and output. Inherently, efficiency is concerned with organization and production costs.

- **Satisfaction** – Satisfaction represents the human factor in our model. All organizational achievements may be optimal regarding effectiveness and efficiency, the people in the organization should still be able to do their work to some degree of satisfaction. Therefore a very important factor, that constraints the performance optimization problem. Example satisfaction indicators are salaries, workable hours and holidays.
- **IT and innovation** – Besides managing the daily workings of the organization, the organization is concerned with its performance in the long run. As such, innovation and IT utilization are indispensable (essential?) factors for measuring this kind of performance. An organization that is working optimal now may not be the best tomorrow if it does not take its own circumstances into reconsideration constantly.

## 5 FRAMEWORK EVALUATION

In order to evaluate the framework developed we went through several steps. First we consulted an industry expert in order to cross-validate our model with feedback from industry. In the next step we visited the planning department of an LSP, to see whether we could actually find proof for the validity of our framework in their daily operations.

### 5.1 Expert interview

The interviewee prepared for the interview by reading the draft version of this article, i.e. the literature review, and the definition part of the framework. The interview lasted for one-and-a-half hours. The interviewer started with a short introduction. He explained in ten minutes what the purpose was of this interview, what has been done so far, and what future plans were. Furthermore he made clear why especially this interviewee was selected. Over the next seventy-five minutes, the interviewee gave his vision on performance measurement and performance indicators. His answers were guided by his over twenty years of industry experience in logistics and operations. To the end of the interview, the interviewer used five minutes to summarize the points discussed in the interview, which were then confirmed by the interviewee. The results of the interview are presented below.

In traditional Operations Research (OR), operations are often rated and optimized upon a small set of parameters only – sometimes as little as one single parameter. This results in non-optimal system behaviour. Consider the example of empty-kilometer minimization. This optimization often results in trucks standing still, waiting for a next order (preferably with a starting point equal to the place of waiting). Trucks do not anticipate on next orders in more fruitful regions than the one they are now, and often waiting-time costs money as well – the driver needs to be paid and the truck could have been utilized for other purposes (e.g. making money). Reviewing single optimization parameters can hardly be seen separate from other indicators, as the following indicates: Let us consider an LSP that has a truck driving around with only one small package – so, it uses only 5% of its carriage capacity – utilizing a very inefficient route, with lots of detours. It is however not driving around empty – so from an empty-kilometer perspective this truck operates very effective. Although we do realize that the truck could have carried more cargo, and the route it took could have been more efficient. However, we do not know yet whether the customer is actually paying for this trip – because if so, no LSP would mind to have a truck driving around via an inefficient route, with only little cargo as long as the customer is paying a good price for this specific trip.

Not all indicators do have a direct translation in costs, or financial measurements, but do translate in, for example, extra appreciation from the customer. An interesting example is Cehave – a Netherlands based company active in the agri-business. When delivering feed products to farmers, farmers prefer and value it to be the first farm on the delivery-roundtrip, since with each extra visit (between Cehave's plant, and the farmer's farm) the risk on animal diseases and infections rises. The paradox however is that, although farmers prefer the service of being the first customer, they are not willing to pay for this service.

Agility is more-and-more required for LSPs business operations. It is very important to have a flexible business infrastructure, capable of quickly reacting and adapting to changes in operations: new orders, re-routing of a truck, or handling changes in the environment (such as a traffic jam). Therefore quick react capabilities are of true importance; measuring these however is a complicated matter.

Planning systems targeted at such industries could well be build by using agent technology, and dynamic system [control] structures; utilizing measurement and reaction mechanisms to derive to smart decisions. [We] believe that smart local

decision making, making the right decisions at the right moment and right place are likely to result in well behaving planning systems. Feedback plays an important role in such systems. Performance measurement should not only look at the parameter as such, but also at the way those parameters change (and behave) over time – thus be aware of the first or second derivative of the function as well.

The framework as presented in this paper is very interesting. It is finally an attempt to have a complete scheme, looking beyond just financial indicators, and especially dedicated for the logistical industry. It measures more than solely costs, like it also captures perceptions (of management, customers, employees at different levels, et cetera). A very useful division is the split between the strategic, tactical, and operational time-domains. It might furthermore help in overcoming problems in supply chains that want to assess chain wide performance. However, some adjustments and generalizations might be needed.

Critical notes on the work include: a subdivision/refinement as we made for the classification of the management point-of-view should be made for all the categories as mentioned in the framework (see Figure 1), thus including employees, customer and society as well. Therewith the framework becomes three-dimensional. Be aware that optimal, does not mean the same to all companies. Optimal for one company, can be far from optimal for another company.

Interesting aspect of the presented work is that it could serve as a tool that makes performance indicators, and therewith system-control a discussable issue in an organization – which would be a real valuable tool to evaluate current systems, and to design future systems. The true advantage of this approach is that it could be relatively easy translated into an agent-based software system. With software agents monitoring and controlling single performance indicators, and steering upon these.

## 5.2 Industry evaluation

Industry visits with the planning team of the container unit of a Netherlands based medium sized LSP provided us with a first validation from industry itself. This LSP operates 40 trucks in its container business. The process is not entirely computerized yet. Planning is still a manual task performed daily by three full-time planners; they are partly supported by information and communication technology. They utilize a platform called CarrierWeb, which enables them to track and trace trucks and carriers – based on their GPS location – every single minute all throughout Europe. This platform also allows sending and receiving text based messages. The planning as such uses a computer application as well, but this is not more than a list of orders to execute; the order-to-truck-assignment is done by the planner (who then changes the status of an order in the system). The (manual) assigning is based on simple (unwritten) heuristic rules such as: if a new order is available at the place where the previous order ended, take this order - therefore reducing the amount of empty kilometres. The planners do utilize performance objectives from the other quadrants in our framework as well, such as the ‘happy’ employee perspective; one of the planners explained: “I never assign such [long distance] jobs to this driver. Simply because I know that I will be on the phone with him for half an hour then [before he agrees on executing this order]. Thus I assign such orders to other drivers...”. Furthermore, we found support for the use of external parameters such as *customer happiness* which is of true importance in the planning process and *company reputation*. The planners use several objectives and rules for their planning, many of which are not well defined and documented.

Although not yet having gone through a rigorous evaluation process with the LSP described, we believe that our findings support our hypothesis that performance indicators and objectives used in their daily planning can indeed be divided based on their point-of-view and plan-horizon. As a next step we plan to work with them in more detail and link our framework to their business process to define the indicators that play a role, and to work on the definition of a system design that could support the planners in their daily work.

## 6 TOWARDS AGENT-BASED PLANNING SOFTWARE

The greater goal of our research is to contribute to building an information system that will support and optimize the operations of logistics service providers. The domain area of logistics has specific characteristics that need to be taken into account in the design process. By nature, a logistics service provider is a highly complex, distributed system. It may consist of a large number of actors, many of which operate in a partially independent way. Optimizing the whole system involves optimizing the performance of each of these actors. Trying to achieve this in a highly centralized way is not always

realistic. The limitations of the currently used solutions include high complexity of the system and poor generality of the found solutions - they are only applicable to a specific situation.

Given the distributed nature of logistics service providers, a more suitable approach would be to represent the involved parties as agents operating within a multi-agent system (Wooldridge *et al.*, 1995). Such a system is adaptive by reacting to the changes in the environment (e.g., price changes influenced by the season, increase in the traffic congestions in a certain area, etc.) in a distributed way without always having to affect the whole system. The complexity on the level of a single agent is limited, but the whole system can generate optimal or nearly-optimal solutions to highly complex tasks by interaction and negotiation between the agents. Agents are autonomous entities such that, up to some degree, they are able to decide on their actions for themselves based on some given intentions and/or desires and acquired beliefs. In the LSP domain as elaborated in this paper, such intended actions are inherently related to the discussed performance indicators.

We are undertaking a case study in cooperation with the before mentioned LSP (Section 5.2) investigating the deployment of an agent-based information system based on the KPI framework that was introduced in Section 4. Concretely, we consider a multi-agent system (MAS) that has agents on different aggregation levels: 1) strategic agents (closely linked to long-term performance objectives/indicators) and 2) operational agents (for example, an agent that plans truck routes). Each strategic agent is assigned to a particular PI and considers it its task to monitor, analyse and/or optimize that indicator. The strategic agents, in cooperation with the operational agents, then provide insight into the company performance in terms of the defined PIs. Moreover, by giving the strategic agents increasingly more autonomy (e.g., optimisation of their indicators and interaction with other strategic agents), the system gets a steering rather than analysis function.

We employ a two-phase development trajectory. Firstly, we take the KPI framework presented here and (within the context of the case study) extend it with expressing *relations* between the indicators, e.g., conflicting, independent, conforming, and *requirements* on the indicators. We use a formal language developed by Popova and Treur (2005) to express these relationships and requirements. A requirement on an indicator may be to optimize it, e.g., maximize the customer satisfaction. Secondly, we define the strategic agents (being responsible for particular PIs) and the operational agents (performing given company tasks, like planning). These agents communicate to each other in a given (FIPA compliant) agent communication language to exchange information about their knowledge and goals. The information exchange between the strategic agents is particularly challenging: this is namely the negotiation about the involved PIs and thus relates the system directly to the strategic objectives of the company.

At the time of this writing, we are developing a prototype of the described agent-based information system. A system designed as such is flexible from a system design and maintenance perspective. Compared with systems developed utilizing different development methodologies, an agent system can start with little agents (solely controlling single tasks), to be later extended through the addition of extra agents to the system. We hypothesize that a MAS is a logical candidate for (inter-organizational) information systems, through its simple modelling by means of small independent objects – when compared to more traditional information systems developed.

## **7 DISCUSSION AND FUTURE DIRECTIONS**

This paper is likely to benefit the fields of logistics, information systems and distributed agent-based systems; since it links the business issues of performance measurement, and planning and control, with the design of (logistical) information systems. Our literature survey shows that separate studies have looked at performance measurement / evaluation for logistics. However, these studies have mainly been within a particular area or case and have focused on external and quantitative indicators. Our review has considered the areas of supply chains, internal company performance, planning and more qualitative (less measurable) indicators. Furthermore we touched upon several areas in our literature survey that turned out to be only researched to a little extend, such as the link between performance

indicators and planning systems, the link between Activity Based Costing and logistics, and the domain of the less easy measurable performance indicators.

For the near future, we consider possible further research directions within several areas. Firstly, a more extensive case study is necessary to evaluate the validity of the proposed model. We have currently preliminarily verified the workings of our model with a field expert and a first visit to an LSP, but consider the definition of practical case studies within companies essential for fine-grained evaluation. On the short term, we hope to receive more detailed feedback from experts to gain insights on how the ideas presented here apply in practice. Secondly, we consider necessary to obtain more insight into the relationships between the indicators. As the main aim of the research in this paper was to obtain insight in performance indicators, we found the indicators to be entangled in a web of relations, e.g., conflicting, independent, conforming. We think of our classification framework as a good departure point for investigating these relations as they often relate to the different categories as identified in the framework, ultimately resulting in an analysis model for key performance indicators. Thirdly, we pursue to develop a multi-agent system that supports logistics service providers. The framework presented here is a first step towards our long term aim to use performance indicators to steer logistical operations upon, complementing its function as an evaluation tool post-ante.

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