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Assessing Improvement Opportunities and Risks of Supply Chain Transformation Projects

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1. Introduction

Planning and control systems have deeply evolved in recent years in order to cope with the needs of manufacturing firms. It is possible to identify a route of evolution that begins with the introduction of MRP systems (Orlicky, 1975) and, passing through the management of capacity and materials constraints, moves towards contemporary APS (Advanced Planning & Scheduling) and SCM (Supply Chain Management) solutions.

New functions, such as ATP (Available to Promise) or CTP (Capable to Promise), are nowadays considered necessary conditions for order planning and quoting. On the other hand, the offer of planning systems has reached a high level of performance with APS, where huge sets of objectives and constraints are standardised in libraries so that manufacturing systems can be modelled in detail.

APS/SCM systems represent the most relevant innovation in the world of manufacturing since the introduction of MRP systems in the Seventies (Turbide, 1998). In fact they marry the potentialities of modern processing systems with the most sophisticated heuristic / optimising / AI-based techniques developed by operations research.

Although most of the benefits provided by APS/SCM systems are generally quite apparent to operations managers which have to manage complex logistics system, a fair evaluation of these benefits should be provided by APS/SCM Vendors in order to prove that the huge amount of investment connected to the acquisition, implementation and maintenance of APS/SCM is paid back. In particular, the evaluation process could be divided into two different phases: the first one concerns the quantification of the expected improvement, while the latter focuses on the risks which could turn out in lower-than-expected returns. It is worth here specifying that the term "risk" could be intended not only to address negative cases (actual benefits lower than expected) but even positive cases (actual benefits higher than expected); moreover, when evaluating the project risk, intangible benefits (and drawbacks), such as the organisational impact of the IT project, should be considered.

This work describes the achievements of a research project, carried out at Politecnico di Milano, whose objective is to develop a new methodology, SNOpAck (Supply Network

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Opportunity Assessment Package), for the value assessment of APS/SCM system application in a supply chain.

The chapter is arranged as follows. Section 2 presents a brief literature review of value assessment approaches. Section 3 introduces a new methodology, which focuses on the value assessment of APS/SCM information systems. Section 4 presents a case study focused on the first 3 steps of the methodology (namely, 1. Preliminary analysis, 2. Analysis of operations and business processes and of Key Performance Indicators and 3. Evaluation of the APS/SCM solution). Section 5 reports some concluding remarks and suggests future research paths.

2. Theoretical framework

In recent years many studies have been focused on the evaluation of the possible benefits and costs related to the implementation of an information system into a company. Section 2.1 presents a survey of the most interesting contributions dealing with the value assessment of information system (IS) projects, whereas section 2.2 focuses on the project carried out at Politecnico di Milano, by highlighting its main features and goals.

2.1 Methodologies for the value assessment of IS projects

In the last three decades IS implementation has been one of the most important issues for the management of almost all kinds of companies. Several empirical studies have shown that organisations are not at all comfortable in the evaluation of IS investments (Willcocks & Lester, 1993). A large number of methodologies and techniques has been therefore proposed to help in the evaluation of IS investments. Different researchers could identify (Renkema & Berghout, 1997) over 65 methods supporting the evaluation of IS investments. Actually too many methods exist, "roughly one per consultant" (Farbey & Finkelstein, 2000), but most of them are not published from consultancy firms because of the possible loss of competitive advantage.

Several survey papers have shown that most methods of information system evaluation used in the practice, both ex-ante and ex-post, are variants of consolidated techniques and ways of thinking, which can be traced back to the following classification proposed by the works of Farbey *et al.* (1993) and Farbey & Finkelstein (2000): *i.* quantitative and comparative methods (or "objective" methods), provide a quantification of costs and benefits in economic terms, so allowing to compare the costs and benefits of different information systems; such methods usually rely on conventional accounting methods; *ii.* qualitative and exploratory methods (or "subjective" methods) emphasise the importance of understanding the opportunities as well as the threats which the change may bring to some stakeholders, with the aim of obtaining an agreement on the objectives through a process of exploration and mutual learning.

The classification framework proposed by Farbey *et al.* (1993) and Farbey & Finkelstein (2000) is reported in Tables 1 and 2.

Notice that, in spite of the wide availability of value assessment approaches, most companies apply simple accounting techniques, belonging to the cluster of quantitative and comparative methods: Ballantine & Stray (1999) carried out a survey showing that the most

used methods for the evaluation of IS projects in companies are still ROI and Cost-Benefit Analysis methods.

Finally, it is worth highlighting that researches validating evaluation methods are hardly available and that general prescriptions about the use of which method in which circumstances can not be given (Renkema & Berghout, 1997).

2.2 Value assessment of APS / SCM projects

When dealing with the introduction of information systems for Supply Chain Management in a company, the topic of identifying and analysing the extent of change and of the expected benefits (value assessment) is a key issue and no universally accepted methodology can be found in literature, although the task of evaluating the benefits appear simpler in this case, since the benefits are restricted to Operations.

The proposed methodology supports both industrial users during the process of "ex-ante" evaluation of the opportunity to implement an APS/SCM solution and consulting firms during the process of definition of the features to which address a possible choice of a specific information system solution. The main goals driving its development are completeness, objectiveness and possibility of a partial automation. It has resulted an analytical methodology that, recalling the classification by Farbey *et al.* (1993) and Farbey & Finkelstein (2000) (see Table 1), can be classified in the group of "cost-benefit analysis" methodologies although it has some distinguishing features that will be deeply presented in the following section.

3. THE SNOpAck methodology

At Politecnico di Milano a research project was carried out with the aim of developing an original value and risk assessment methodology, called SNOpAck (Supply Network Opportunity Assessment Package), for evaluating APS/SCM implementation projects. When dealing with an implementation project in a specific company, the methodology aims at answering to the following three main questions:

i.   which information requirements should be addressed in order to improve company's operations?
ii. which benefits would arise by fairly covering such requirements?
iii. which is the **Value** (in terms of quantifiable benefits and costs) related to a specific APS/SCM solution?

An overview of the steps of the SNOpAck methodology is presented in Figure 1; each step will be described in the following sections; further details are reported in Fahmy Salama (2002).

Method	Detail	Process management	Data
Cost/ revenue analysis	Very high	Accounting and costing staff	Cost accounting and work-study method
Return on investment (ROI)	High	Calculation by professionals; tangible costs and benefits aggregated as cash flows	Tangible; direct; object
Cost-benefit analysis	High	Bottom up; carried out by experts; money values for decision makers by incorporating surrogate measures	Cost and benefit elements expressed in standard money valu form; pseudo-objectiv
Return on management (ROM)	Low	Calculation by professionals; manipulates accounting figures to produce a residue – value added by management	Accounting totals (e. total revenue, total labour cost)
Boundary values and spending ratios	Low; aggregate	Top-down; senior stakeholders involved; calculation by professionals	Ratios of aggregated numbers (e.g. IT exper per employee)
IE, information economics	Usually very high	Many stakeholders involved; detailed analysis required	Ranking and rating objectives, both tangib and intangible

Table 1 – Quantitative and comparative methods (Source: adapted from Farbey et al. (1993) and Fa

Method	Detail	Process management	Data	
MOMC, multi-objective, multi-criteria	Any level	Top-down; consensus seeking; all stakeholders involved; best choice is computed	Priorities are stated by stakeholders; subjective evaluations of intangibles	th p
Value analysis	Any level; generally detailed	Iterative; senior to middle management involved; variables identified by means of Delphi method	Indirect; subjective evaluations of intangibles; utility scores	E: fo in
Critical success factors	Short list of factors	Senior management define CSFs	Interview or self-expression; Quick but consuming senior management time	
Experimental methods	From detailed to abstract	Management scientists working with stakeholders	Exploratory; uncertainty reduction	

Table 2 – Qualitative and exploratory methods (Source: adapted from Farbey et al. (1993) and Farbe
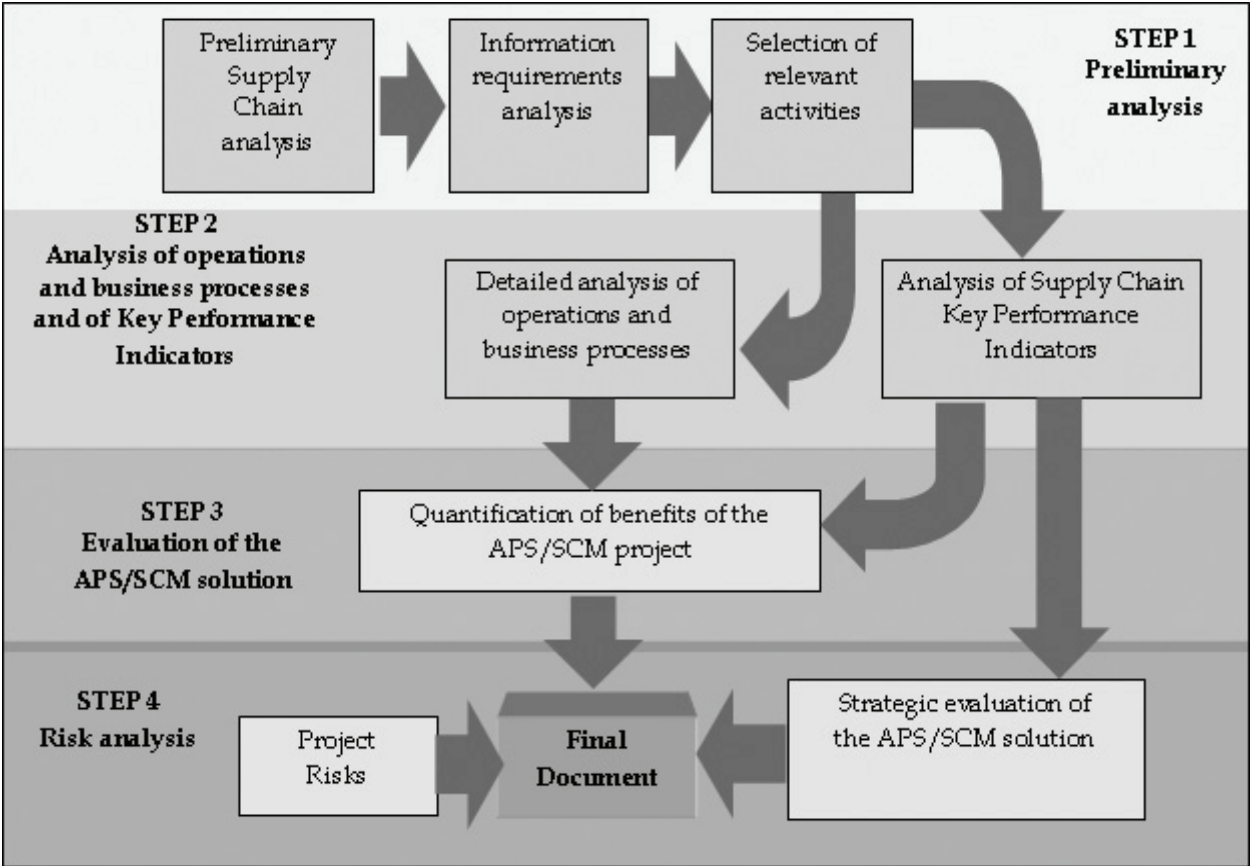
Figure 1. Structure of the SNOpAck methodology

3.1 Step 1: preliminary analysis

In the first phase, after a preliminary analysis of the organisation, an information requirements analysis is carried out. Through a structured questionnaire, a weight is associated to each information requirement, so to classify each of them in a range from "irrelevant" to "highly relevant". In order to counterbalance the subjectivity of the company's interviewee, the weights are corrected by identifying the supply chain typology that best suits the observed company. In particular, adapting the work of Fisher (1997), three main typologies have been identified, as depicted in Table 3: "efficient" supply chains for "functional" products, "quick" (or agile) supply chains for "innovative" products and "flexible" supply chains for "complex" products. The observed company can present a mixture of the above stated typologies; once the specific supply chain typology is identified, the weights are corrected by taking into account the typical pattern of information requirements which characterise that supply chain typology.

Once the information requirements analysis has been carried out, the most relevant requirements are selected by referring to a threshold value of the weights. For each of them, a set of activities supported by APS/SCM systems and fulfilling the information requirements are defined: these activities are "relevant", in that their execution has a considerable impact on supply chain performance.

3.2 Step 2: Analysis of operations, business processes and Key Performance Indicators

The aim of this phase is the identification of company's performances improvement due to the implementation of the APS/SCM system. In order to carry out this step, a set of Key Performance Indicators (KPIs) has been identified and, later on, an "activities-performances relationships matrix" and a structured approach for KPI improvement evaluation have been developed.

As far as the KPIs are concerned, the performances considered in this methodology to evaluate the impact of APS/SCM solutions on organisations are based on a survey of the dashboards employed to measure the effectiveness and efficiency of logistic-production systems found out in literature, e.g. the metrics proposed by Bowersox & Closs (1996), Stadtler & Kilger (2000) and in the SCOR model (Supply Chain Council, 2003). The resulting KPIs can be classified in three main groups:

i. effectiveness performances, which address performances actually perceived by customers (e.g. on-time deliveries, delivery lead time);
ii. efficiency performances, which address performances not directly perceived by the customers (e.g. stock levels, work in process, resources saturation);
iii. automation performances, which address the improvement in efficiency due to the automatic execution of formerly manual activities (e.g. order entry, order release).

Moreover, by observing that in many cases a performance improvement leads to an indirect improvement of other performances, a cause-effect relationships network linking the KPIs has been developed. An example of relationships network is provided in Figure 2.
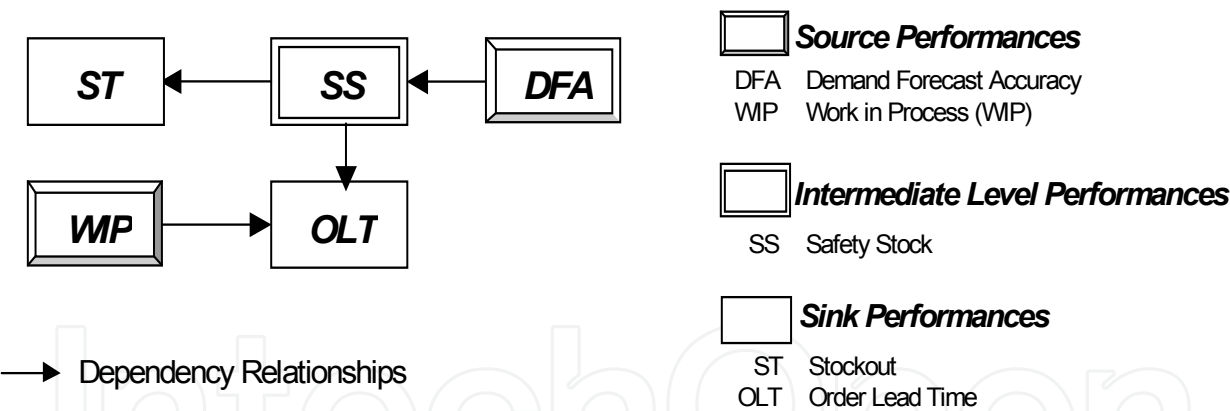

Figure 2. Example of relationships network.

For any of the activities identified in the previous step, the "activities-performances relationships matrix" supports the identification of KPIs affected by a streamlining of the activity itself, thus allowing a rapid definition of the "relevant" KPIs for the analysis and assessment of benefits. Figure 3 depicts the process of identifying the critical KPIs starting from the weighted information requirements.

	SC typology		
	Efficient	Quick	Flexible
Products features			
BOM complexity	Low	Low	High
Lifecycle duration	> 2 years	3 months – 1 year	> 2 years
Contribution margin	1 % – 15 %	> 50 %	> 10 %
Product variety (variants per category)	Low (10-50)	High (>300)	High (>300)
Average forecasting accuracy (error)	<10 %	> 40 %	-
Average stock-out level	1 % - 3 %	> 10 %	-
Average discount at lifecycle end (as percentage of the price)	0 %	10 % - 30 %	-
SC features			
Main goal	Cost efficiency	Demand is satisfied efficiently, by minimising stock-out, discounted selling and stock obsolescence	Timeliness in demand fulfilment
Manufacturing focus	Keeping high the manufacturing equipment utilisation rate	Keeping some excess of manufacturing capacity	Maximising operative flexibility
Lead-time focus	Light reduction strategy	Aggressive reduction strategy with big investments	Aggressive reduction strategy by means of big investments
Integration level	High both with upstream and downstream partners	High both with upstream and downstream partners	High with upstream partners
Vendor selection approach	Selected by cost and quality	Selected by speed, flexibility, quality	Selected by speed, flexibility, quality
Inventory strategy	Keeping a high rotation rate and minimising inventory along the SC	Minimising inventory though avoiding stock-out in new products launch phase	-

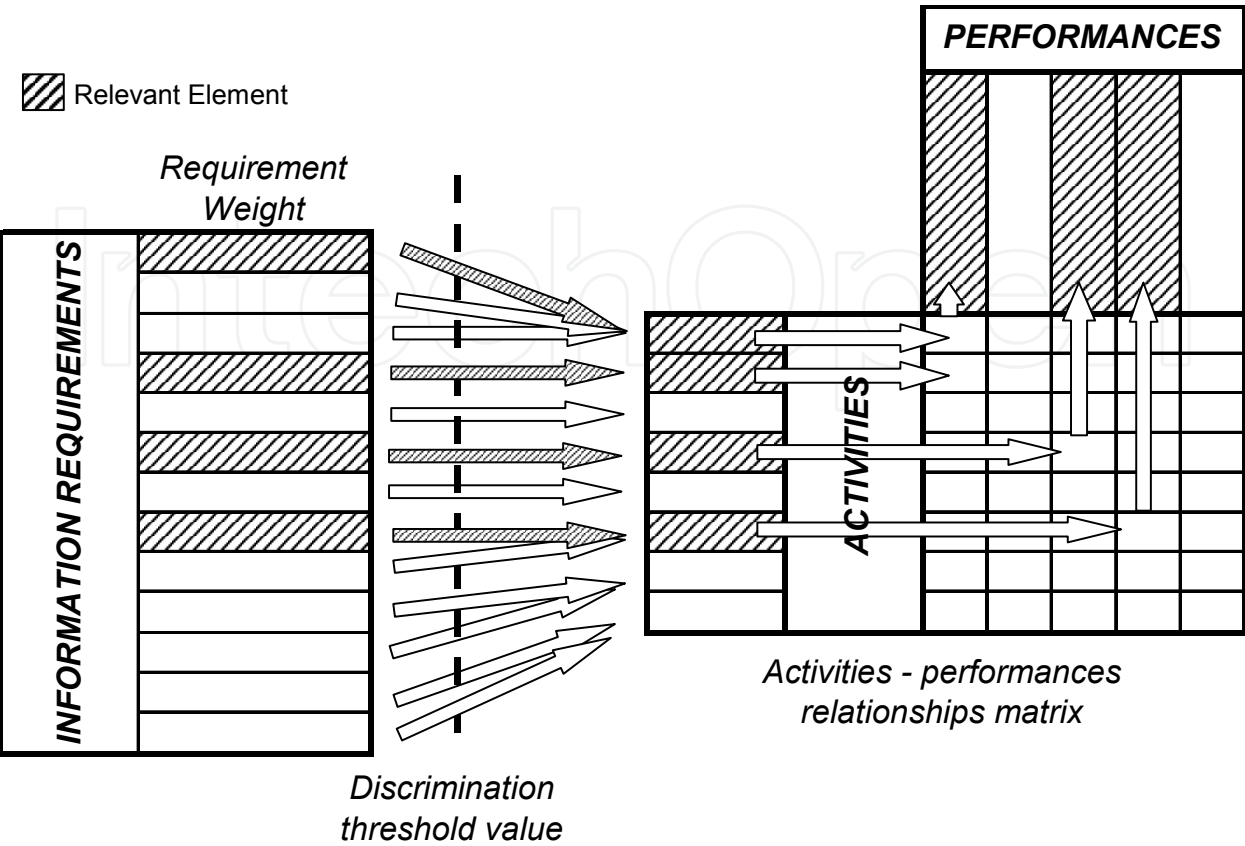Table 3 –Supply Chains typologies (Source: adapted from Fisher (1997)).

Figure 3. Tool for rapid selection of relevant activities and performances.

Finally, the structured approach for KPI improvement evaluation supports the assessment of KPIs improvement by considering the following elements:

i.   the actual widening of KPI value improvement ("performance gap");
ii.   which factors determine the performance gap ("cause factors", e.g. supplier delays, unreliable production plan), if the gap exists.

When applying the structured approach, a company's manager is to support the identification of the previous elements. Then, for each KPI, an analysis is carried out (jointly with the company's manager) with a twofold aim:

i.   a weight of influence on the performance gap is assessed for each cause factor and for each influencing performance (recall Figure 2); the weights sum is 100%;
ii.   the percentage reduction of each cause factor due to the adequate support of the "relevant" activities is esteemed

The overall percentage reduction of the performance gap is then calculated as a composition of the cause factor reductions and of the cause performance improvements (cause performance improvements have been previously calculated by means of the same structured approach). Figure 4 depicts the structured approach as a whole.

When it is possible, besides the performance gap analysis, quantitative analysis methods can be applied to determine the performance improvement (e.g. resource saturation).
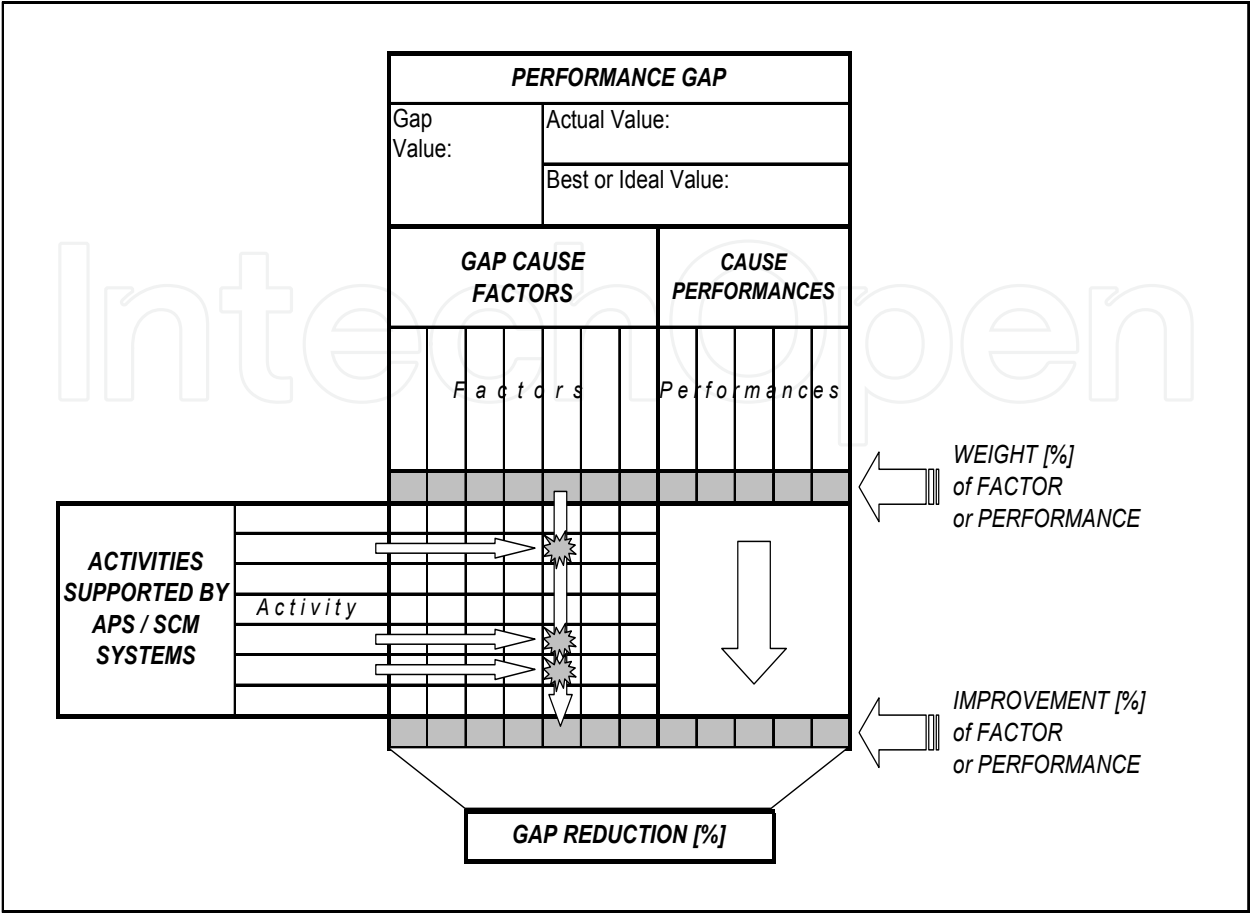
Figure 4. Performance gap analysis.

3.3 Step 3: Evaluation of the APS/SCM solution

In the third step, the final assessment of the introduction of an APS/SCM solution is carried out, by quantifying the APS/SCM benefits (Figure 5). A performance improvement usually implies a measurable economic gain in the short term, due to an improvement of supply chain efficiency or effectiveness or to a cost reduction for the automatic execution of former manual activities.

Besides the short-term quantitative benefits, possible intangible benefits may arise from the implementation of an APS/SCM system. For instance, these benefits may be related to an improvement of the competitive advantage (e.g. an improvement in customer order timeliness has an impact on customer service level), or to the organisational impact of the system (e.g. an APS/SCM project usually implies a redesign of tasks and roles or even a change management). Although it is hard to define the economic gain for the improvement of intangible performances, it is important to check their improvement with the overall business strategy for the supply chain management, when considering the opportunity of implementing an APS/SCM information system solution. This topic is the object of the following section.

Figure 5. Benefits evaluation.

3.4 Step 4: Risk analysis

Once the expected tangible benefits related to the implementation of an APS/SCM solution have been evaluated, a further analysis is carried out, taking into consideration risk and intangible aspects; the analysis methodology has been developed on the basis of cognitive psychology (Kahnemann *et al.*, 1982). In particular, the aim of the analysis is threefold:

i. to determine the probability associated to each possible project outcome;
ii. to estimate the transient duration before the benefits are gained;
iii. to complement the quantitative analysis with a comprehensive set of qualitative considerations (the so called *strategic issues*).

An interesting side result of the proposed risk analysis is the evaluation of manager's own risk attitude, which helps in comparing different APS/SCM projects whose outcomes present different discrete distributions. Moreover, the risk analysis determines a ranking of the project risks, according to their impact on project results; this information is extremely important since it supports a focused monitoring of the risk factors which may threaten the project's success.

A case study presenting in detail the functioning of the Risk analysis is presented in Brun *et al*. (2006).

4. Rigamari case study

This section presents an in-depth case study of application of the SNOpAck methodology to a mechanical company, Rigamari (albeit being a real company, the company name has been disguised). Once analysed the defects (in terms both of inefficiencies and ineffectiveness) of

Rigamari supply chain planning process, SNOpAck methodology allowed to assess the value of the implementation of a APS system for supporting gas turbine production. After a detailed description of the company and, mainly, of the difficulties its supply chain suffered, this section reports the application of SNOpAck methodology.

4.1 Company presentation

When it was established, in 1842, Rigamari was a small Italian entrepreneurial metal alloy foundry, which entered in the mechanical production in the first few years of 20th century. In 1994 the company was acquired by an US-based multinational company. The core business of the company concerns the production of compressors, gas and steam turbines for oil and chemical plants, pumps and compression facilities, gas valves and gauges, petrol pumps, control systems for looms. Production activities take place in one of the 7 Italian plants of Rigamari among which, the most prominent are those based in Florence and in Borgo Ricco.

Borgo Ricco plant encompasses overall 80,000 square meters: 65,000 m² dedicated to machine and assembly operations of 3 different product lines: blades for steam and gas turbines, gas gauges and fuel pumps. Overall, 130 workers are employed in the production of blades for gas and steam turbines: in the last 2 years turnover for this product line has more than doubled, reaching 56 Million Euro. Once completed, blades are sent to the main Florence plant, where they are then assembled, in order to build the final machine. Besides, within the Florence plant are located the company offices (sales, R&D, etc.). Within Borgo Ricco plant, *gas turbines* accounts for the 80% of blades production, while *steam turbines* production (and, on turn, production of blades for steam turbines) accounts for the remaining 20% of orders. The case study will focus on *gas turbine* production.

A *gas turbine* employs two different kinds of blades: one for the compression stage and another for the turbine stage – in the latter stage, blades are hit by exhaust gas with an extremely high energy content. Both blades for the compression stage and the turbine stage are standardized, then different turbines normally adopts blades with the same characteristics.

Blades for gas turbines are obtained by machining operations on a die-cast piece produced by an external supplier. Work-cycle encompasses rectification, thermal treatments (realized by sub-suppliers) and a plethora of severe quality controls and checks (both during or after operations).

Components of a gas turbines are divided into two groups: *i.* "critical" components, having a long production (or supply) lead time, are manufactured (or supplied) on the basis of forecasts; *ii.* "non-critical" components are made to order. About the 100% of components realized within the Borgo Ricco plant are classified as critical.

The short term planning of blades production activities are derived from the mid-term planning of gas turbines, directly managed by Florence headquarter. The chief commercial manager is in charge of deploying a sales budget, based on historical data and forecasts. The Master Production Schedule is based on the sales budget and spans over a 12-month period. Once the MPS has been determined at Florence, the headquarter communicates to Borgo Ricco components requirements according to MPS and an additional set of forecasts spanning over the time period not covered by the MPS.

Technically, the workload at Borgo Ricco is managed according to *advanced order* logic: that is, components are manufactured before the actual purchase order is issued by a customer.

Theoretically speaking, the period covered by the MPS would be long enough to cover the information requirements at Borgo Ricco, since the overall lead time at Borgo Ricco is 10 months, on average. Nonetheless, requirements issued by Florence plant are not definitive: Commercial Officers in Florence revise sales budget every month (and components delivery dates are changed accordingly). As it could easily be guessed, this is a bit of a problem for Borgo Ricco planners, especially when delivery dates are anticipated. In such situations, production activities are rescheduled manually, since planners do not have any information tool supporting urgent order scheduling (such as a "capable-to-promise" tool).

The die-cast for the turbine section blades are ordered by Florence; as a consequence, after receiving the requirement for a set of blades, Borgo Ricco plant should also receive the die-casts.

As for the compression section, raw materials are ordered by Borgo Ricco: the production manager checks the availability of raw materials, and then communicates the net requirements to the purchasing department. Raw materials suppliers are divided in two groups according to the kind of supply relationship with Rigamari: *i. transactional relationship*, that is an arm's length relationship wherein each purchase is considered as one of a series of independent deals, and delivery conditions and purchase price are re-negotiated at every single deal; *ii. long-term agreements*, in this case an agreement is signed up between the two parts, so that on the one hand Rigamari undertakes to purchase a certain volume for the next 12 months, on the other hand the supplier undertakes to deliver goods within reduced supply lead times.

Borgo Ricco plant operates with "zero inventory": machining operations can start only after the arrival of raw materials for gas turbines blades. Unfortunately, delivery timeliness is by far smaller than 100%. Nevertheless, due to the "zero inventory" objective, the make-to-order logic theoretically eliminates obsolete stock; moreover the inventory levels of consumables and spare parts is not relevant.

Each production line is basically dedicated to the production of a specific kind of blade. Production planning and control is carried out by the planning office, encompassing 6 workers, along with the shop-floor responsible. In particular, the shop-floor manager is in charge of short term production scheduling, taking a series of decisions based on past experience, aimed at maximizing resource utilization (mainly by minimizing set-up times; in fact the direct variable cost of scheduled resources has a small impact upon overall variable cost of the end product). Such scheduling activities are supported by a spreadsheet with manual data-entry.

Urgent orders, mainly due to last-minute modification in product's technical specifications decided in Florence, account for a 60% of total orders and invalidate schedule effectiveness.

The issuing of warning signals (such as in the case of the break-down of machines, urgent orders, etc.) is carried out in an informal way and it is not automated, since the shop floor and planning office are close to one another. When interviewed, planners stressed the lack of a more 'active' management of such exception signals: they would welcome, for instance, the possibility to simulate alternative scenarios in order to briskly identify the best possible course of action.

On average, overtime accounts for one hour per day per worker on the shop floor; this is anyway not enough, and Borgo Ricco must often rely on production capacity of sub-suppliers (even though the Borgo Ricco plant has the technological capability to carry out the work) to carry out the required workload. As stated by the planning department manager "I'd rather hire another 20 guys; still, without those folks, there is yet another way to meet Florence requirements: to set-up an adequate information system". Both the amount of investments and hired personnel at Rigamari must abide the strict regulations determined by the holding company board.

Quality control activities are also manually planned and predictive maintenance is not considered relevant. Quality control stations are considered as a part of the production system and do not have particular planning criticality. Product quality is regarded as a Critical Success Factor at Rigamari. That's the reason why new products are always 100% tested, while sampling acceptation is only carried out in case of products with a significant reliability history. Such an effort in terms of quality control is necessary, due to the high costs of external failures (a broken blade would mean stopping the turbine and, in turn, a very high hourly loss for Rigamari customer). In the last few years, quality levels (mainly measured by the level of external failures quality costs) reached by Borgo Ricco have steadily been more than satisfactory and there is no intention to spend any additional effort to improve the planning of quality control activities.

Some of the phases of the blades production cycle (as, for instance, thermal treatments) are executed by sub-suppliers. The information exchange between Rigamari and sub-suppliers (in particular in terms of visibility on production advancement at the sub-suppliers premises) takes place on a completely informal base. The same holds true for the suppliers: visibility on supplier processes is particularly limited when the purchase order for rough pieces is issued by Florence.

Suppliers and sub-suppliers expediting and production advancement control are carried out by 4 employees at the Borgo Ricco plant plus an additional (external) person, by means of telephone or fax reminders. An increased visibility over external production would therefore be very welcome.

Once production is terminated, finished blades are immediately sent to Florence plant. Basically, Rigamari outsources most of its transportation activities to third-party carriers. The portion of transports managed internally (i.e. with Rigamari's own fleet) is not critical at all, since there is only one single destination (from Borgo Ricco to Florence, and back) and departures are scheduled on a daily basis; besides, transportation costs are not so significant and truckloads are always 100% full.

Supply Chain performance is controlled directly by Florence officers; in particular, after the delivery of a machine to the end customer, several logistics KPIs are calculated on an *ex-post* basis.

4.2 An overview of Borgo Ricco plant problems

In the last 6 months, production levels have more than doubled (they have started working on a 24/7 basis - 3 daily shifts, 7 days per week) and sub-suppliers workload has increased accordingly, accounting for 50% of the overall production. In this situation, Borgo Ricco situation has become unbearable.

One of the major problems of Borgo Ricco production planning and control system is related to timeliness and punctuality of raw materials delivery for both turbine and compression sections. Raw materials suppliers are large steel manufacturers, having great negotiation strength; by basing their production on long production campaigns, they often change their supply lead times with very short notice (being such a small customer, Rigamari cannot argue about that).

Moreover, for compression section blades, there is also the need to closely control the external production capacity, with special regards to the first few production phases.

Performance of turbine section blades production is affected by the late delivery of rough pieces from Florence, often later than the planned completion date of finished blades. Another problem is low production capacity of suppliers in charge of executing either complex or highly specialized processes: planning such suppliers production on the basis of reliable forecasts would very important to Rigamari.

Production planning is also disturbed by frequent requests from Florence to accelerate deliveries. Such requests are driven by the quarterly financial goals declared to stakeholders: not to run the risk to under-perform, managers at Florence headquarter strive to anticipate end-of-quarter deliveries in order to remain on target.

Since there is no possibility to protect the production systems against exogenous variations and disturbance with safety stock (as stated before, the holding company requires to work with "zero inventory"), the only source of flexibility is sub-suppliers production capacity (which, as a matter of fact, is systematically used by Rigamari). In order to rely on such source of flexibility, Borgo Ricco has to take into account both sub-suppliers' lead times and production capacity constraints. Each month, Rigamari issues an order for generic production capacity (without specifying the exact use) – it is a sort of "advanced booking" of production capacity. In order to book the right amount of production capacity, at the right time, Rigamari has to forecast correctly production requirements (over a one-month time period) and at the same time to time-phase requirements and available capacity in order to utilize booked capacity in the best possible way (i.e. both in an efficient and effective way).

4. 3 SNOpAck methodology application

The preliminary analysis of the company was carried out by means of informal interview with plant manager and production manager, and was focused on the evaluation of an APS/SCM tool for improving Borgo Ricco performances in gas turbine production. The operations of Florence headquarters were considered as out of scope. The main output of the first step of the methodology was the list of relevant information requirements, which follows:

- **Simulation of production activities**: typical of highly flexible manufacturing systems; it allows to evaluate the impact of different schedules in term of machines workload and material availability;
- **Integration with suppliers:** in terms of both *visibility to suppliers* (it allows to suppliers all along the supply chain to align their planning processes to final customer demand and, in particular, to align capacity with demand as soon as demand changes show up, thus avoiding the typical delay and bullwhip effects) and *visibility on suppliers* (it allows

to evaluate in advance the effects of several purchase alternatives and to communicate reliable delivery dates to the end customer)

- **Sub-suppliers planning and control**: typical of companies heavily relying on sub-suppliers, it gives visibility on third-party production activities (quality control, production advancement, etc.).
- **Alert management**: it allows to have real-time information on exceptions, bottlenecks, capacity constraints violation, thus allowing to promptly adjust plans accordingly.
- **Integration with customers**: mainly in terms of visibility to customers (Florence), allowing to increase service level offered to customers, in terms of reliable and frequently updated (if necessary) delivery dates, immediate order confirmations, possibility to make variations in the order conditions based on actual production advancement, etc.
- **Available to Promise/Capable to Promise (ATP/CTP)**: it allows to communicate to the customer reliable delivery dates based on available materials (raw materials and components, assemblies and sub-assemblies, finished products) and available production capacity. This requirement is most relevant in case of complex Bill of Materials, with many levels and long production cycles – especially with assembly operations requiring the co-ordination of several independent production flows.

On the basis of the list of information requirements, a set of relevant activities to be supported by APS/SCM was determined. They are: production programming, suppliers and sub-suppliers integration and planning, alert management, integration with customers and stock management, order promising (ATP/CTP).

Once the activities were determined, we moved on to step 2, with the aim of quantifying the improvement of KPIs due to APS/SCM implementation. This step was successfully carried out by referring to the activities/performances relationship matrix, which allowed to identify the set of relevant Borgo Ricco KPIs which can be improved thanks to the APS/SCM system, and by referring to the relationship network tool (see Figure 2) it was possible to determine the KPI which are expected to improve due to some improvement in upstream (first-tier) KPIs. The resulting relevant performances were: timeliness, on-time delivery, resources saturation, work in process (WIP). Once the relevant KPIs were identified, the improvement of each of them was quantified by means of structured approach for KPI improvement evaluation (see Figure 4) or analytically. Some examples are reported in the following.

Resource saturation reduction

7 rectification machines operating on 3 daily shifts for about 300 days per year:

- Total time = 50,400 hours/year
- Scraps = 330 hours/year
- Break-downs = 500 hours/year
- Problems due to Operators = 1,600 hours/year
- Set-ups = 7,500 hours/year

By simulating alternative schedules with lower overall set-up time due to better sequencing of similar jobs, it was possible to estimate that the improvement of planning activities could bring to a reduction of set-up times of about 30% → 2,250 hours per year (4.5% of total time).
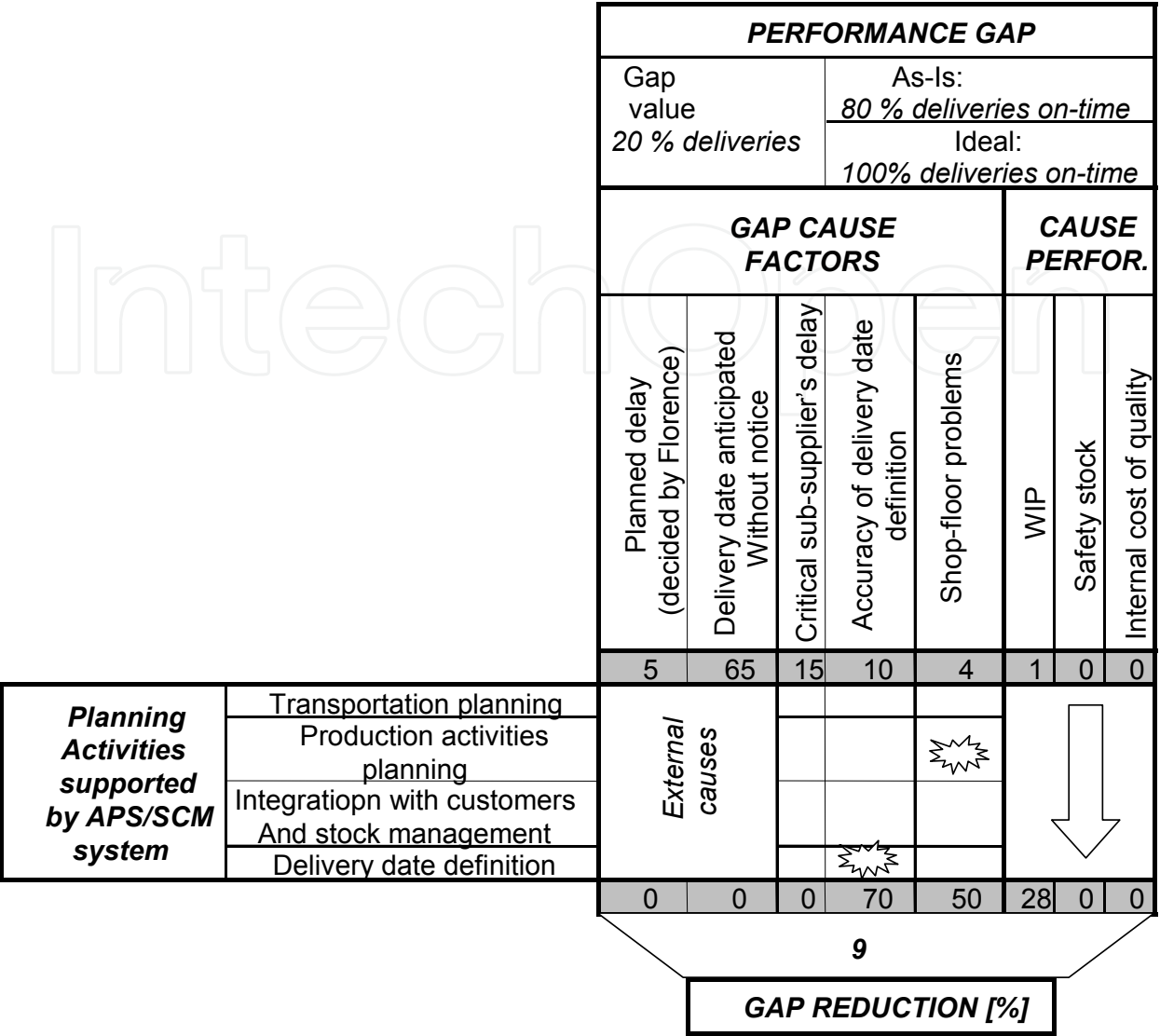
PERFORMANCE GAP							
Gap value 20 % deliveries	As-Is: *80 % deliveries on-time*						
	Ideal: *100% deliveries on-time*						
	GAP CAUSE FACTORS					CAUSE PERFOR.	
	Planned delay (decided by Florence)	Delivery date anticipated Without notice	Critical sub-supplier's delay	Accuracy of delivery date definition	Shop-floor problems	WIP	Safety stock	Internal cost of quality
	5	65	15	10	4	1	0	0

Planning Activities supported by APS/SCM system	Transportation planning	*External causes*					
	Production activities planning				💥	
	Integratiopn with customers And stock management					
	Delivery date definition				💥		
		0	0	0	70	50	28	0	0

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GAP REDUCTION [%]

Figure 4.

The estimated improvement are here summarised:
- timeliness: from 8 month to 7.5 month;
- on-time delivery: from 80% on time delivery to 82% on-time delivery;
- resources saturation: 4.5% of total time freed up for further production activities;
- work in process (WIP): from 220 sets of blades sets to 205 sets of blades.

During step 3, the improvements of timeliness and on-time delivery have not been quantified: their improvement positively impact on the company image of fast and reliable deliveries. On the contrary, the improvements of resource saturation and WIP have been quantified as follows:
- Resource saturation:
  - o Set-up reduction would free up production capacity (2,250 hours/year)
  - o Average productivity of rectification machines: 10 pcs/hour
  - o Direct variable costs for rectification process: 1.40 €/piece

     o   Sub-supplier cost: 10 €/piece

     o   Annual savings: 193,500 €

- WIP:
  - o   WIP reduction: 14 sets of blades (1 set = about 80 blades)
  - o   Direct variable costs: 850 €/unit
  - o   Average completion degree: 50 %
  - o   Opportunity cost of capital: 10 % per year
  - o   Annual savings on inventory holding costs: 47,600 €

Then, after transient time, an overall annual saving of about 250,000 € is expected.

As for the costs of the APS/SCM system, they were provided by the IT vendor which had just finished to successfully implement its APS/SCM system in Florence plant. The APS/SCM system fully satisfied the information requirements identified for Borgo Ricco, then that vendor appeared a good candidate for APS/SCM implementation in Borgo Ricco.

According to the last step of SNOpAck methodology, the strategic evaluation of the APS/SCM solution was carried out. The main elements of the analysis are reported in the following:

- the improvement of on-time delivery and of timeliness strongly contribute to the improvement of the image of Borgo Ricco and of the company as a whole;
- the APS/SCM system frees up time of planner employees which can be diverted into improving planning decisions (being more efficient allows to be more effective);
- project risks have been determined (data availability and correctness (g.i.g.o. rule); top management commitment; employees training) and strong attention should be devoted to them throughout the project otherwise they could undermine APS/SCM implementation success;
- the transient time to have the new APS solution up and running was estimated to last about one year; moreover, given the variability associated with some of the figures included in the saving estimation, benefits in the following years were protectively set to just 80% of the expected 250,000 €/year foretold by the procedure in Step 3.

The cash flows have then been recalculated considering the outcome of the risk analysis, and considering an overly cautious discount rate of 20%/year (worst case). As a result, the pay-back time for the implementation of the new APS/SCM system is estimated to be as short as 10 months.

5. Conclusions and future developments

Over the last 5 years, the model has been applied to more than a dozen manufacturing and service organizations belonging to different sectors. The cases were useful to identify strengths and weaknesses of the methodology. The objectives of completeness and objectivity are reached and many of the hypotheses of relations between management activities and KPIs were confirmed.

Yet, the methodology in its present form shown a major limitation, in that the analysis considers as given (and, therefore, deterministic) the characteristics of the APS/SCM solution.

The output of the methodology is basically the result of a data collection and a data elaboration phase. While the calculation procedure is really accurate, more could be done regarding input acquisition. The interviewed managers happened to have difficulties in imagining the effect of an APS/SCM system on the way their company works: a possible extension of the methodology includes the development of a set of visual or numerical examples which will provided to the interviewees during the analysis.

Future research paths also include an extension of the methodology specifically developed to analyse the operations and the supply chain of service companies.

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Supply Chain

Edited by Vedran Kordic

Traditionally supply chain management has meant factories, assembly lines, warehouses, transportation vehicles, and time sheets. Modern supply chain management is a highly complex, multidimensional problem set with virtually endless number of variables for optimization. An Internet enabled supply chain may have just-in-time delivery, precise inventory visibility, and up-to-the-minute distribution-tracking capabilities. Technology advances have enabled supply chains to become strategic weapons that can help avoid disasters, lower costs, and make money. From internal enterprise processes to external business transactions with suppliers, transporters, channels and end-users marks the wide range of challenges researchers have to handle. The aim of this book is at revealing and illustrating this diversity in terms of scientific and theoretical fundamentals, prevailing concepts as well as current practical applications.

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