Procurement Risk Minimization and Optimal Supply Management Strategy Identification in Industries with Highly Perishable Products

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Abstract: In the constant changing environment, competition grows at a never seen rate. To win in a such hard context, any manufacturing industry needs operational excellence, that can be achieved avoiding production wastes, reducing economic and time losses. In those industries, which are characterized by high perishability and short shelf life of raw materials, semi-finished and finished products, the entire supply chain should be optimally right-sized, avoiding to keep huge amount of stocks, that could turn easily in wastes. In particular, this imposes finding new solutions to face raw materials procurement risks. This paper aims at identifying the best sourcing strategy, in order to fulfill finished products customers' demand, decreasing all typical inbound supply chain risks, such as supply lead time variability, raw materials price oscillations, low quality supplies, delivery failures etc. After a quick review of procurement management approaches, available in literature, this work standardizes a well-defined set of sourcing strategies. Then, an evaluation model has been developed, considering stockout probability, cost and shortage risk aspects. Given a specific scenario, characterized by certain levels of decisions influencing criteria, taken into account, the model will give in output the best procurement strategy to be applied, in order to minimize Total Stockout probability, Total cost and total Risk. The real step forward, made by this research work, is in terms of recollecting in one only model lots of influencing criteria, due to Suppliers' and Raw materials' characteristics, evaluating them all togheter, because so far, literature has only considered separately small subsets of them. On the long run, a firm will be able to correctly face any kind of scenario. This system is appliable in companies, characterized by the abovementioned features, especially in SMEs because of their limited size and economical-financial power.

Keywords: Operational Excellence, Raw materials procurement risks, Warehouse management, Quality management, Supply strategies.

1.Introduction

Today's Supply chains are becoming not only more efficient but also riskier due to numerous chain links that are subjected to breakdowns, disruptions or disasters. So, a supply failure is identified as one of the top supply chain risks (Zeng, et al., 2005). Although many studies, focused on business risks in various contexts, have been presented in literature, research effort on risks associated with sourcing strategy and supply market has been limited, especially from a quantitative point of view (Zeng, et al., 2005). Researchers attempt to mitigate negative impacts of supplies failures by applying sourcing strategies such as local versus global sourcing, single versus dual/multiple-sourcing (PrasannaVenkatesan & Kumanan, 2012), but considering a limited base of decision criteria: supplier reliability and purchasing cost. This paper aims at fulfilling, at least partially, this literature lack, in particular increasing considered criteria to evaluate risks of any unpredictable operations interruptions caused by a supplier's unavailability to satisfy buyer firms's demand.

A Sourcing strategy, in Supply chain management, involves suppliers selection, procurement contracts design, product design collaboration, materials procurement and suppliers' performance evaluation (Chopra & Meindl, 2005), for each purchased items family (Agboyi, et al., 2015). A purchased items family is a set of items to be purchased, with similar characteristics (e.g. production technology, economic value, etc) and with the same positioning in Kraljic's Matrix. The importance of sourcing strategies is due to their impacts on buyer firm's internal operations. Sourcing dictates the beginning of actual production runs, since availability of purchased raw materials and components are essential for production (Zeng, 2000). In addition, raw materials' quality has a direct impact on final product's quality, independently by production processes' yield. Suppliers and sourcing strategies selections are critical activities for a company, a wrong choice could be enough to upset the company's financial and operational positions (Agboyi, et al., 2015). Since a typical manufacturing firm spends 55% of earned revenues on materials purchasing (Leenders & Fearon, 1998), disruptions due to supply inadequacies could have a major impact on companies profitability (Burke, et al., 2007). Indeed, in the last decade, many industries have changed supplier selection processes, abandoning the lowest bidder supplier selection methodology, replacing it with multicriteria approaches to select the optimal supplier base (number of suppliers a firm does business with). So, procurement activities have acquired a key strategic role over the time, evolving in Strategic Sourcing and aiming at reducing supply costs, increasing supply efficiency.

In recent years, supply chain risks are growing significantly, however companies do not manage supply risks appropriately (Kotula, et al., 2018). They focus only on suppliers' financial structure and suppliers' bankruptcies, limiting the considered supply risks, while they should also consider some other ones, including macro risks, demand risks and transportation risks (Ho, et al., 2015). This is even more valid for Perishable Product Supply Chains, where it is impossible to mitigate supply failures risks increasing safety stocks. There is a general understanding: design and management of perishable product supply chains are complicated by specific products' characteristics, such as deteriorating product quality (Rijpkema, et al., 2014). Complexities of these supply chain structures are due to strong inter-dependencies between the chain's nodes: a risk, generated in a point of the chain, will be transferred to the others rapidly (Wang, et al., 2017). Therefore, these cases require higher modelling efforts than other supply chains. These efforts aim to satisfy logistic goals (such as purchasing cost and delivery service requirements), ensuring that products will be delivered with the right quality at the right place and time (van der Vorst, et al., 2009). Perishability deteriorates materials over the time and this means that since inventories enter a warehouse, their quantity will be depleted not only by customer demand but also by items deterioration (Fauza, et al., 2015). So, with items' deteriorating property, not all inputs could reach final customers as finished products. If a product's input quality is lower than the acceptable level, the item will be removed from production process, resulting wastage (Ren, et al., 2013). In these contexts, an overstock in raw materials will imply an extra cost, for sure. This leads to a basic assumption in this paper: purchasing quantity has to be as lower as possible, fulfilling customer demand but avoiding any kind of economic or technical advantages, that would increase the purchasing lot sizing. Perishability related wastes reduction and customers' demand fulfillment are the main objetives of inventory control in perishables (Kouki, et al., 2018). Frequently ordering small batches, the stockout risk increases indeed, in this case, dual and multiple sourcing are the most used sourcing strategies (Keramydas, et al., 2015). These strategies should be used to minimize stockout risks, reducing average inventories at the minimum.

This paper takes for granted perishability, that is an underlying assumption in model proposal. The proposed model focuses on the most suitable sourcing strategy evaluation, basing on suppliers' and raw materials' characteristics as: supplier lead time, quality level, material cost and so on. Most part of these factors has been collected by a literary review, the other ones have been introduced as new but useful criteria to have more accurate evaluations. In the following sections, starting from a literary review of existing approaches for sourcing strategy selection, it will be introduced a model, that allows to choose the best sourcing strategy, in perishable products supply chains, given a specific Scenario. Then, the model has been applied to an Italian SME belonging to Fresh Food Industry, testing efficiency and effectiveness of the proposed approach.

2.Literary Review

Literature attempts to mitigate negative impact of supply failures by applying strategies such as local versus global sourcing, single versus dual/multiple-sourcing and performance-based supply contracts (PrasannaVenkatesan & Kumanan, 2012). Except for the Global sourcing strategy, that has a too long supply lead time to be applied in a Perishable Product Supply chain, the most used sourcing strategies will be evaluated later in this work. Frequently used sourcing strategies are: negotiating with several suppliers in competition (multiple sourcing) and developing long-term partnerships with one or few suppliers (single/dual sourcing) (Berger & Zeng, 2006).

(Smeltzer & Siferd, 1998) have highlighted that when an organization reduces its supplier base, it relies on fewer suppliers for critical material, increasing risk of supply interruptions. Eventhough, developing partership with specialized suppliers will increase quality and assembly easiness in finished products. (Karpak, et al., 1999) presented a goal programming approach for supplier selection and order allocation, that aims at minimizing product acquisition costs and maximizing product quality and delivery reliability. (Zsidisin, et al., 2000) defined a mathematical model determining the optimal number of suppliers in presence of risks. (Zeng, et al., 2005) identified two strategies to reduce supplier risks. The first one is to deversify suppliers, keeping multiple sources available for key products or services, which helps not only to prevent stockouts but also to promote competitions between suppliers. The other one is keeping a network of backup suppliers, activable in case of emergency. (Ding, et al., 2006) proposed a Genetic Algorithm for suppliers selection and orders allocation with the aim of minimizing cost and maximizing demand fill rate. (Berger & Zeng, 2006) proposed a decision-tree approach that helps a buyer firm to determine the optimal size of its supply base in presence of risk, related to any unpredictable interruption, caused by all suppliers being unaivalable to satisfy the firm's demand. (Ting & Cho, 2008) proposed a two-step decision-making procedure: an Analytic Hierarchy Process (AHP) for selecting a firm's candidate suppliers and a model to optimally allocate order quantities within them. (Che & Wang, 2008) proposed an Algorithm for suppliers selection and orders allocation with the aim of minimizing total supply costs (purchase, transportation and assembly cost), purchase and assembly time, maximizing delivered parts' quality. (Stock, et al., 2010) have identified causes and effects of supply disruptions, pointing out how suorcing strategies, that consider costs and supplier delivery reliability, need attention. (PrasannaVenkatesan & Kumanan, 2012) proposed an hybrid optimization and simulation approach to design supply chain sourcing strategy. The authors developed a multi-objective binary particle swarm algorithm, that aims at minimizing total costs, maximizing supplier delivery reliability in non-perishable supply chains. (Dotoli & Falagario, 2012) proposed a three-step methodology for optimal suppliers selection in a multiple sourcing context. The proposed technique firstly divides suppliers into efficient and not efficient ones, secondly ranks all efficient suppliers and lastly computes order quantities for each of them. (Fang, et al., 2016) introduced an approximate dynamic programming algorithm (ADP) to evaluate sourcing strategies' performance, in terms of incurred total cost. (Kouki, et al., 2018) emphasized dual sourcing's benefits, in contexts of perishable inventory systems with random lifetimes. The authors showed as dual sourcing remains more cost-effective than single sourcing with an emergency supplier. (Kotula, et al., 2018) analyzed which are critical risk factors that shall be managed by a company, pointing out suppliers' creditworthiness, continuity, quality and material's price. (Dong, et al., 2021) have identified two strategies for an OEM, considering fixed ordering cost and reliability investment costs. The OEM should prefer Single sourcing in case of high fixed ordering costs and Dual sourcing with high reliability investment costs.

Analyzing these works, it is evident how references are mainly focused on dealing with emergencies, in terms of delivery failures risk, and not on finding strategies to optimally manage all kind of suppliers. (Kotula, et al., 2018) confirmed that risk management in supply chains is continuing to receive significant attention in the existing literature, instead research on risk aspects, related to strategic sourcing across various industries, even in a multinational perspective, is scant. So, the literary focus is on mitigating supply risks impacts and not on mitigating supply risks occurrences. All previous approaches are improvable: they are limited to evaluate a small set of criteria, while sourcing strategy design is a multi-objective optimization problem, that involves a trade-off between minimizing total supply cost and risk and maximizing suppliers' deliveries reliability. Despite last references make a step forward in terms of completeness of analyzed factors, this paper proposes a model that overcomes all previous ones, in terms of considered influencing factors to detect which is the best strategy for procurement management, in any kind of scenario. Indeed, this paper aims at introducing a new model that suggests the best sourcing strategy, considering a bigger and more exhaustive set of criteria, partially recollected from literature, and partially added as new ones.

3.Sourcing Strategies Analysis

The proposed model evaluates which is the optimal sourcing strategy in any scenario. The characteristics of a specific scenario, in combination with a specific sourcing strategy, will give in output a certain stockout probability, a certain cost and a certain risk level. Before introducing the model, the three considered sourcing strategies have to be detailed. But why is sourcing strategy detailing extremely important? These strategies deeply influence scenarios evaluation, in terms of total stockout probability, total cost and total risk. Each of them mitigates one or more influencing factors, mitigating the total result. Indeed, Strategic Sourcing is a risk mitigation strategy by definition (Zhao, et al., 2016). In particular, the stockout probability, due to suppliers' and raw materials' characteristics, of a scenario will be mitigated by the chosen sourcing strategy. In literature, the most used and detailed sourcing strategies are: Single sourcing, Dual sourcing, Multiple sourcing, Contingent Sourcing (Fang, et al., 2016), Network sourcing and Global sourcing (Zeng, 2000). We have considered Single, Dual and Multiple Sourcing strategies, accompanied by the Acceptance Sampling, an adding option to the three main strategies.

Single Sourcing Strategy - This strategy implies to have one only supplier, with whom, a buyer firm, has developed a partnership. Single sourcing involves the idea of reducing number of suppliers a firm does business with, in order to create and sustain excellent relationships with them. Many successful firms use long-term partnerships to achieve high quality and low cost components (Berger & Zeng, 2006). The strategy's advantages are in terms of improving quality, improving supply stability, ensuring flexibility in demand changes reaction, reducing costs for both buyer and vendor. The selected supplier, with learning economies, may reach extremely high quality levels and extremely low production and delivery costs. The strategy's disadvantages are in terms of high delivery failure risk and of absence of bargaining control power on supplier (Zeng, 2000). Delivery time and cost are set by suppliers, without any possibility of negotiation for the buyer firm, which has a too low bargaining power. In conclusion, this strategy has a high cost (because the supplier has no competitors and the competition would lower raw material supply costs) and a high risk level (a delivery failure coincides, for sure, with a stockout). Since supply risk derives mainly from uncertainty affecting suppliers' manufacturing processes, the only way to reduce it, with Single sourcing, is to select a single supplier that has sustained effort in process reliability improvement (Dong, et al., 2021).

Dual Sourcing Strategy – Since Single Sourcing is extremely risky, a better solution could be having two or three qualified sources. Managing a small supplier base still allows close buyer-seller relationships. Alternatively to dual sourcing strategy, that implies regular orders to both suppliers, a firm could limit its strategy to a contingent sourcing, with a main supplier and a backup one, used only in case of emergency. However, unless having a backup supplier with a very short (zero) lead time, it is preferable to use a dual sourcing strategy (Zhao, et al., 2016). Dual Sourcing implies to have two suppliers in competition, with whom a buyer firm has developed partnerships. Parallelizing two suppliers reduces total supply failure risks and total costs (thanks to the competition between them), maintaining at the same time Single Sourcing advantages.

Multiple Sourcing Strategy – This strategy implies to have more suppliers in an intense competition. It has an effective mitigation effect on risk of delivery failures, in time of shortages due to failure at supplier's plant, on lowest price and shipping costs (Zeng, 2000). Consequences of the strategy may include a large base of suppliers to deal with and very short duration contracts, with longer negotiations and with a lower flexibility of buyer firms in responding to final customer demand changes (Zeng, 2000).

Acceptance sampling – Forcing a supplier to check quality of entire batches substituting all scraps, in case of batch rejections at acceptance sampling, increases total supply costs but decreases quality losses. This can be considered as a secondary strategy, that can be added to the three main ones in cases of high quality losses.

In conclusion, a strategies comparison can be done. Single sourcing is preferred to Multiple sourcing because of increasing buyer-vendor relationships, easing delivery planning, decreasing investment in inventory, handling costs decreasing to manage one only supplier. Moreover, product quality improves, thanks to supplier's developed expertise in customized solutions for the partner buyer firm. The Single sourcing disadvantages are high switching costs, that justify sustaining uncompetitive performance and costs. Moreover, limiting the supplier base, delivery failure risk and firm dependence from suppliers increase (Berger & Zeng, 2006). To face these threats, firms frequently adopt a dual sourcing strategy, that introducing competition between the two suppliers, imposes them constant performance improvement and cost reduction. (Faes & Matthyssens, 2009). A multiple sourcing strategy shall be used in case of strategic items purchasing, in case of high supply failure risk, generally in mature stage industry, where supplies reliability is more important than high quality and low costs. The existing literature commonly highlights as dual or multiple sourcing, in contrast with single sourcing, can be leveraged to mitigate single sourcing strategy associated risks, due to a competition increasing (Qi, et al., 2015).

4. Model Proposal

The proposed model, starting from a set of inputs, provides in output an evaluation of the three considered sourcing strategies, in terms of stockout probability, total costs and total risk of buyer firms operation interruptions (in terms of severity and occurrence). This model can be considered a decision support tool, that eases strategic decisions of optimal sourcing strategy in any specific scenario.

First step of the model is to understand orders quantities and frequency of a firm. The items' perishability acts here: the higher perishability level is, the lower order quantity is and the higher order frequency is. A firm may compute minimum order quantities as the ratio between Finished Product Demand and Production Quality Rate. Where: Finished Product Demand is referred to customer demand in a specific time bucket (e.g. Day, week, month) and Production Quality Rate is the yield, that increases raw materials quantities needed to fulfill finished products demand.

Actual order quantities are firm's choice: the greater they are, the lower stockout probability is and the higher safety stock are. However, being in a perishable products supply chain safety stocks have to be as lower as possible and so, actual order quantities have to be as nearer as possible to the minimum ones.

Since having identified needed raw materials and their suppliers' market, a firm has to analyze and evaluate all suppliers' market and raw materials' characteristics, then inserted as model's inputs. Where suppliers' market of a firm means the set of available suppliers to fulfill requirements of a firm.

Spread out in literature, it has been proposed a huge set of supplier's characteristics but a very limited set of raw materials' ones, to be taking into account in strategic sourcing. Firstly, we have recollected all existing criteria, then we have added other important unconsidered factors.

(Ting & Cho, 2008) proposed a long list of parameters as sourcing strategy designing factors: Raw material cost and transportation costs, Raw material quality in terms of Defect and scrap ratio, Raw material batch rejection ratio, Delivery on time and delays, Delivery quantity shortages, Supplier response to change level, Lead time to order (Supplier's Production and Delivery time). (Mwikali & Kavale, 2012) added: supplier's technical capability to produce and sustain high performance standard in terms of time (Lead time variability) and quality. (PrasannaVenkatesan & Kumanan, 2012) added: Production capacity of supplier's plant in time buckets, production capacity of buyer's plant in time buckets, Raw material inventory holding costs and shortage costs (in case of delivery failures). (Qi, et al., 2015) individuated another influencing factor: competition level in supplier's market, and highlighted how supplier reliability plays a more important role than selling price. (Dong, et al., 2021) added: supply reliability level, finished product failure behavior (Finished Product Scrap Ratio), supplier's production capacity and supplier's learning effect. Additionally, we have considered: specialization level and business relevancy of purchased items, detailed below. In *table 1*, all decision criteria, considered in this paper to choose the optimal sourcing strategy, have been summed up.

SUPPLIER'S CHARACTERISTICS		RAW MATERIAL'S CHARACTERISTICS	
1 - Quality Loss	%	7 - Specialization	Low/Med/High
2 - Batch Rejection Ratio	%	8 - Business Relevancy	Low/Med/High
3 - Delivery Quantity Shortages	%	9 - Raw Material Cost	Low/Med/High
4 – Delivery Delays	%	10 - Raw Material Cost Variability	±%
5 - Total Lead time	Low/Med/High	11 - Transportation Cost	Low/Med/High
6 - Total Lead Time Variability	±%	12 - Stockholding Costs	Low/Med/High

Table 1 – Influencing criteria

A supplier's market is characterized by an average production quality loss (percentage of non-conformed items); an average percentage of batch refusal in the inbound quality control (percentage of delivery failures); an average percentage of quantity shortages and so, an average delivered lacking quantity respect the ordered one; a percentage of delivery delays; a total supply lead time (production + delivery) and its percentage variability. The total lead time of supply influences the flexibility of buyer firms in fulfilling unexpected customer demand changes, indeed the reaction time is longer. The longer lead time is the lower flexibility in reaction is, and so the higher stockout risk is.

A Raw Material is characterized by: a specialization level, tied to easiness in finding the raw material on suppliers' market, in case of delivery failure or shortages, the higher it is, the higher the stockout risk is; a business relevancy, tied to relative importance associated to the item by a buyer firm, and so it is proportional to the shortage cost (e.g. finished product unfulfilled demand cost, customers loss costs, and so on). The higher it is the higher stockout impact is, and so the higher stockout risk is; purchasing costs and their variability; transportation costs and a stockholding costs.

All considered decision factors can be grouped in three subset:

- Stockout Probability influencing Criteria: Quality Loss (i1), Batch Rejection Ratio (i2), Delivery Quantity Shortages (i3), Delivery delays (i4), Lead Time Variability (i6). Each of them contributes to total stockout probability computation with an inherent stockout probability level (x_i).
- Cost Criteria: Raw Material Cost (i9) and its variability (i10), Transportation Cost (i11) and stockholding cost (i12). Each of them contributes to total cost computation with an inherent cost level (c_i).
- Risk Criteria: Total Lead Time (i5), Specialization level (i7) and Business Relevancy (i8). Each of them contributes to total risk computation with an inherent risk level (r_i) of operations interruption due to delivery failures (in terms of severity and occurrence).

Each of the previous sourcing strategies (Single Sourcing (j1), Dual Sourcing (j2), Multiple Sourcing (j3)) and the acceptance sampling (j4) has mitigation effects on stockout probability factors (y_{ij}) and inherent values of cost (c_j) and risk (r_j).

Since we have inserted all scenario influencing factors and flagged the acceptance sampling presence or not, the model, applied to the specific case, gives in output a final evaluation for each strategy in terms of total stockout probability, total cost and risk.

Total stockout probability with the strategy j (TSP_j) is computed as:

$$TSP_j = \sum_{i\in(1,2,3,4,6)} x_i \cdot y_{i,j}$$

In case of Acceptance sampling presence, TSP becomes:

$$TSP_j = \sum_{i\in(1,2,3,4,6)} x_i \cdot y_{i,j} \cdot s_i$$

Where y_{ij} is the mitigation effect of strategy j on parameter i (with i belonging to subset of stockout probability influencing criteria), x_i is the stockout probability due to factor i and s_i is the mitigation effect of acceptance sampling on factor i. Total stockout probability is reduced keeping safety stock and so, from TSP, we have to subtract the term:

$$\frac{\text{ACTUAL ORDER}}{\text{MINIMUM ORDER}} - 1$$

With Actual Order ≥ Minimum Order, this term indicates the percentage of extra ordered quantity respect minimum one. Although the Actual Order Quantity is a choice, the high perishability level imposes that it has to be as lower as possible. Indeed, the extra ordered quantity percentage generally have a minimal reduction effect on TSP.

Total Cost with strategy j is computed as:

$$TC_j = c_j + c_9 \cdot (1 + c_{10}) + \sum_{i\in(11,12)} c_i$$

Total Risk with strategy j is computed as:

$$TSR_j = r_j + \sum_{i\in(5,7,8)} r_i$$

Having a complete evaluation of sourcing strategies in terms of stockout probability, total cost and risk level, the optimal one can be chosen. However, a company shall identify the optimal sourcing strategy, weighting model's output values basing on internal operations and economic-financial situation. For example, a company with high EBITDA should prefer lower risks with lower attention in costs, otherwise, in case of extremely low margins total costs should lead.

5.Case Study in Food Industry

In order to prove the proposed model effectiveness, we have applied it in an Italian SME, belonging to the Food Industry. This company produces four product families and we have selected two of them for the case study: PF1 and PF2. Both Product family are characterized by high perishability, with 2 days of finished product shelf life and 7-9 days of Raw materials' shelf life. The company works with weekly time bucket and so weekly average historical production data are detailed in *table 2*:

PRODUCTION REQUIREMENTS INPUTS		
	PF1	PF2
Average Finished Product Weekly Demand	400Kg	900Kg
Production Quality Rate	60%	78%
Minimum/Actual Order Quantity	667Kg	1154Kg

Table 2 – Production Requirements

Minimum order quantities and the Actual ones are the same because of a Zero Safety Stock strategy pursued by the company. This strategy is forced by the high materials' perishability. PF1 is characterized by high specialization level, high business relevancy, low cost, and it is purchased by suppliers with high quality but medium-low delivery reliability. PF2 is characterized by low specialization level, medium business relevancy, medium cost, and it is purchased by suppliers with low quality but high delivery reliability. We have evaluated all influencing criteria, assigning percentages or levels (high/med/low). In order to obtain a quantitative evaluation of the three sourcing strategies, assigned levels (high/med/low) have been transformed in numbers (3/2/1).

In *table 3,* analysis results of supplier's markets and raw materials have been summed up.

In *table 4* we have characterized each sourcing strategy in terms of mitigation effects on total stockout probability (y_{ij}) and in terms of cost (c_j) and risk (r_j).

All data derives from a Company procurement historical data series analysis, in terms of: stockout events, total procurement costs, supplier base compositions, acceptance sampling rejections and so on.

SUPPLIER'S CHARACTERISTICS	PF1	PF2	RAW MATERIAL'S CHARACTERISTICS	PF1	PF2
1 - Quality Loss	3%	15%	7 - Specialization	3	1
2 - Batch Rejection Ratio	1%	5%	8 - Business Relevancy	3	2
3 - Delivery Quantity Shortages	5%	2%	9 - Raw Material Cost	1	2
4 – Delivery Delays	6%	1%	10 - Raw Material Cost Variability	3%	5%
5 - Total Lead time	3	2	11 - Transportation Cost	1	1
6 - Total Lead Time Variability	4%	3%	12 - Stockholding Costs	2	1

Table 3 – Influencing Criteria Evaluation

SOURCING STRATEGY	$y_{1(j)}$	$y_{2(j)}$	$y_{3(j)}$	$y_{4(j)}$	$y_{6(j)}$	$c_{(j)}$	$r_{(j)}$
Single Sourcing	40%	80%	100%	100%	100%	3	3
Dual Sourcing	70%	90%	80%	80%	80%	2	2
Multiple Sourcing	100%	100%	20%	20%	20%	1	1
Acceptance Sampling	50%	50%	100%	100%	100%	1	1

Table 4 – Sourcing Strategies' mitigation effects, costs and risks

The Company has systematically applied an acceptance sampling on all raw materials, so both PF1 and PF2 exploit acceptance sampling advantages.

In *table 5,* the three sourcing strategies have been evaluated in terms of TSP, TC and TR.

FINAL EVALUATION	PF1			PF2		
	TSP	TC	TR	TSP	TC	TR
Single Sourcing	16%	8,03	12	11%	8,1	8
Dual Sourcing	14%	7,03	11	13%	7,1	7
Multiple Sourcing	5%	6,03	10	13%	6,1	6

Table 5 – Sourcing strategies' final evaluation

While for PF1 the choice falls univocally in Multiple Sourcing, having a lower stockout probability, cost and risk, for PF2 the choice is more complex: Single sourcing has a lower stockout probability but higher costs and risk, Dual/Multiple sourcing have higher stockout probabilities but lower costs and risks. The company, having an high EBITDA, chose Single sourcing, minimizing the stockout probability, ignoring the higher costs. In general, in cases similar to PF2, final choices are led by weights given by companies to sourcing strategy's total costs and shortage costs (incurred in case of stockout). The proposed model leaves to companies the trade-off between minimization of total stockout probability and minimization of total cost and total risk.

6. Conclusions

The proposed model aims at supporting decisions in terms of sourcing strategy choice in perishable product supply chains. These decisions have to be born from multicriterion analysis results, based on suppliers' market and raw material's decision criteria. The model considers lots of influecing criteria, partially already considered widely in literature and partially integrated as new ones. However, the real step forward made by this research work is in terms of recollecting all previous criteria in one only model, evaluating them all togheter, because so far, literature has only considered separately small subsets of criteria. For a specific case, given average supplier's market characteristics and given average raw materials' characteristics, the model evaluates all main used sourcing strategies (Single, Dual and Multiple Sourcing), in terms of Total Stockout Probability, Total cost and total Risk of shortages.

The case study application highlights how the model fully respects the proposal expectations. In particular, the evaluation of two different product families highlights how the model will suggest to apply: Single Sourcing, in cases of low average suppliers' quality level and high average suppliers' reliability (low lead time variability, high on-time delivery percentage and so on); Dual or Multiple Sourcing, in cases of high average quality level but low average delivey reliability. Moreover, the model shows as specialization level and business relevancy of raw materials impact on total shortage risk level, respectively in terms of occurrence and severity. In PF1, the higher specialization and business relevancy than PF2, lead to an higher average risk level (10-12) respect PF2 (6-8).

The case study's final evaluation highlights how a suourcing strategy choice can be difficult. In those cases in which the three model's outputs suggest the same sourcing strategy, the choice is easily detected, but in those cases in which cost and stockout probability indicates different choices, the optimal strategy is not univocally determined. For example, a company can decide to minimize the stockout probability at any cost, or to accept an higher stockout probability, minimizing the total cost. Choices depend on specific wheights, given by companies to each indicator. So, a further development of the model should be the integration of a weighted objective function, that, starting from the model's final evaluation and given company characteristics, will give in output the best sourcing strategy for a specific scenario and for a specific company. In order to do that, firstly it has to be defined which are describing factors of a company, setting ranges for each of them. These factors will define three weights, one for each output of the model: TSP, TC and TR. Then, the objective function can be easily obtained by multiplying the weights for the model's outputs. Each strategy will have a score, and the optimal one is which has the lowest score. An AHP metodology should be developed. In this way, the model's potentiality would be completely exploited and the final output will become the best sourcing strategy, given a specific scenario and a specific company.

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