Supply Chain Risk Management (SCRM): A Simplified Alternative for Implementing SCRM for Small and Medium Enterprises

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Abstract—Recent changes in supply chains, especially globalization and collaboration, have created new risks for enterprises of all sizes. A variety of complex frameworks, often based on enterprise risk management strategies have been presented under the heading of Supply Chain Risk Management (SCRM). The literature on promotes the benefits of a robust SCRM strategy; however, implementing SCRM is difficult and resource demanding for Large Enterprises (LEs), and essentially out of reach for Small & Medium Enterprises (SMEs). This research debunks the idea that SCRM is necessary for all enterprises and instead proposes a simple and effective Vendor Selection Template (VST). Empirical testing and a survey of supply chain practitioners provide a measure of validation to the VST. The resulting VST is a valuable contribution because is easy to use, provides practical results, and is sufficiently flexible to be universally applied to SMEs.

Keywords—Multiple Regression Analysis, Supply Chain Management, Risk Assessment, Vendor Selection.

I. INTRODUCTION

GLOBALIZATION has changed the way that many firms interact with their supply chains. Firms are not only competing based on their own strengths, but on the strengths of their supply chains [1]. The shift in strategy and increased reliance on outside firms has created contemporary risks that, until recently, most firms were not aware existed [2]. Therefore, most enterprises focus little attention on supply chain risk and do little to manage it. Small and Medium Enterprises (SMEs), despite their differences in size and resources, face similar risks to Large Enterprises (LEs) within their supply chains. SMEs do not have the resources to manage risks on every level and must therefore apply their efforts effectively and efficiently.

Despite the multitude of research studies conducted both on SCRM and on SMEs, the question of how an SME with limited resources can effectively identify and mitigate risk within its supply chain has not been adequately answered. Juttner and Ziegenbein reiterate "there is a lack of techniques and measures which meet the specific SCRM requirement of small to medium businesses" [3]. SMEs already tend to be less concerned with methods that support the management of supply chains [4], and as such addressing these complex issues are not their primary concern.

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Furthermore, according to a survey of SMEs by Huin, Luong, and Abhary [5], CEOs of SMEs tend to be heavily involved in all operational and supply chain decisions [6].

Carson and Audrey expand on this with their explanation that CEOs of SMEs make most decisions independently and in response to current situations resulting in seemingly random decision-making processes [7]. The informal and personal basis for managing may hinder SMEs' adoption of SCRM even once the contemporary risks are recognized and understood.

The intent of this research is to simplify the art of SCRM and present it in a package that is of practical use for a typical SME. As illustrated by Juttner and Ziegenbein [3] and by Coronado and Coronado [28]; SMEs cannot exert significant influence over their supply chains. The activity where an SME has the greatest influence over its supply chain is in the vendor selection. This, therefore, is the best area to focus its SCRM efforts. The literature review provides a breadth of information relating to direct and indirect factors that influence SCRM. The review highlights the facts that SMEs are limited in their ability to manage supply chain risks due to a lack of resources and influence predicated by their size.

The next section develops a theoretical background based on the relevant literature. Following the theoretical background is the contribution of the research - the Vendor Selection Template (VST). A statistical data analysis follows the template. The research paper concludes with discussion, conclusion of the significance of the contribution of the research and a suggestion for future research.

II. THEORETICAL BACKGROUND

SCRM for SMEs has proven to be a difficult task because the existing SCRM approaches do not match the requirements of SMEs [3]. Juttner and Ziegenbein [3] proposed that a traditional three-phase approach incorporating risk identification, risk assessment, and risk mitigation would be an effective strategy for SMEs. While they have outlined the details of their proposed strategy, they have not address the fact that SMEs simply do not have the resources to execute an identification, assessment, and mitigation strategy. This correlates with other research conclusions that "SMEs do not manage risk adequately" [8]. Finch [8] expands on his observation that "SMEs increase their own exposure to risk by becoming partners in a supply chain and few [have] made an assessment of the risks involved or had a strategy in place for managing risks. "The conclusion reached by Finch, however,

is not universally accepted. Ellengaard [9] observed that SMEs approach to SCRM shares the same flaws as those of the LEs; that is, their risk management is not proactive. Regardless of whether SMEs are using similar approaches as LEs or different, the consensus is that there is a lack of techniques to aid them in their efforts [3].

A considerable number of research studies have recently been conducted on SCRM, including ones by [10]-[14]. Each research study gave different views on how supply chain risks could be managed. Attempts to build the understanding of the challenges that are unique for SMEs have recently been a topic of research [4]. The research on varied related topics has given insight into several relevant issues and challenges facing SCRM. The consolidated topic of SCRM for SMEs is not well represented in literature. In general, research of supply chain management does not address issues that are peculiar to SMEs [6]; however, there is sufficient literature on the individual topics components.

A. Enterprise Risk Management

Enterprise Risk Management was historically limited to buying insurance to protect against catastrophic loss. Risk management eventually evolved into a broader view of managing financial risks, and in the past few decades "all kinds of tools and techniques for risk management have emerged" [15]. The breadth of research of the topic is rapidly expanding and some organizations' standards are gaining wide acceptance. The International Standards Organization (ISO) published ISO 31000 in 2009; it provides a framework for risk management with an emphasis on tailoring the ISO standard to suit the organization [16]. COSO also has a published risk management template that provides an integrated framework of internal controls. COSO's framework, endorsed by the U.S. Securities and Exchange Commission [17], identifies several risk components that need to be managed. Monahan, an academic researcher specializing in risk management, proposes "Strategic Objectives at Risk (SOAR)" as a simple approach to risk management [18]. The academic contribution demonstrates that the topic is relevant in academia as well as in industry.

However, in spite of the variety of frameworks available, and despite evidence that "companies that have embraced strategic risk management are among the most successful" [15], SMEs simply do not have the resources to implement an overarching risk management framework.

B. Supply Chain Risk Management

SCRM lies under the umbrella of ERM with specific focus on supply chain activities. There have been a multitude of SCRM templates offered [12], but contrary to satisfying the goal of simplifying the topic, the vast selection has made it more difficult. Tummala and Schoenherr [19] observed, "there is a lack of conceptual frameworks and empirical findings to provide clear meaning and normative guidance". The frameworks have attempted to account for the uncertainties by incorporating statistical analysis and simulation into the models. Some of the models use a computerized mathematical technique known as Monte Carlo simulation [20], while others apply 'fuzzy logic' in an effort to account for the uncertainties [12]. Research has found that fuzzy logic is effective for improving decision making when selecting vendors [21]. The variety of strategies for vendor and product selection have prompted other researches to develop risk assessment tools to measure, predict, and mitigate the risks associated with the selection strategies[12].

Despite the efforts to advance the art of SCRM, there are gaps in the research including lack of definition, inconsistent process, and a shortage of empirical research [13]. However, the gaps may be reduced or eliminated through closer involvement with industry and increased conceptual work. These findings support a strategy of including empirical research in the development of SCRM solutions.

In contrast to the theories that a well-devised model can be used to mitigate risk, Blos Wee, and Yang [10] concluded that "given the range of potential risks, it is not possible to devise a single solution". They narrowed their research in SCRM in an attempt to assess the origin of supply chain risk. In their assessment, globalization has caused an increase in external competition and subsequently caused an increase in the number of potential suppliers; this increase is a key contributor to supply chain risk. Furthermore, they posed a framework for identifying risk drivers base on financial, strategic, natural, and operations categories. Their framework is based on the theory that increased external competition increases risk.

Tang and Tomlin [14] presented a conflicting theory; they posit that supply chain risks can be mitigated through the flexibility that is gained by engaging multiple suppliers. Richie and Brindley [22] reached a similar conclusion. Before SCRM became an important topic, they predicted that internet access would create global opportunities for SMEs that would be beneficial. The conflicting theories have been carefully researched and together they support the theory that globalization and outsourcing adds both benefits and risks to the organization [23].

Despite the different opinions expressed in literature concerning what generates or increases risk, and whether complex models are able to predict risks, there is a consensus that the risks must by recognized and understood as a prerequisite to successfully mitigating them. It stands that as globalization began to impact business strategies, most firms were unaware of the uncertainties that were arising in their supply chains [2]. SMEs are experiencing the effects of globalization in a similar, albeit reduced way, as experienced by large enterprises [22].

The theoretical background concludes with the following hypotheses:

Hypothesis #1: Objective decision-making tools are suitable to LEs, while subjective methods are preferred by SMEs. Most important decisions within an SME are made by the CEO / Owner and are based more on intuition and experience, and less on quantitative information. CEOs / Owners of SMEs would likely not have a high interest level in adopting a systematic risk analysis tool.

Hypothesis #2: An organization's willingness to adopt a complex SCRM strategy is directly related to its size. SMEs have limited resources and therefore less inclined to adopt a formalized risk management tool unless it is applicable to many types of supply chain decisions, easy to use, and produces useful results.

These two hypotheses are tested in this research with the development and application of a Vendor Selection Template (VST). The VST enables an SME to affect SCRM at the point where it has the most influence – vendor selection.

III. VENDOR SELECTION TEMPLATE (VST)

Supply chain decision makers have traditionally focused on three basic criteria: price, schedule, and delivery [24]. Expanding on the traditional purchasing decision strategy, to incorporate criteria that are subjective in nature but never the less still influence the outcome of the decision, can be organized through the application of a PEST analysis. A PEST Analysis is a "framework of macro-environmental factors" [25] that organizes criteria under Political, Economic, Social and Technological categories. The PEST framework makes it is possible to expand the traditional purchasing criteria with political and social risk drivers. The expanded decision model is presented here as the VST. One of the most significant features of the VST is that it incorporates SCRM into vendor selection with little additional effort beyond that which is already being expended during normal daily operational activity. There are several prerequisites for successfully implementing a VST in an SME; the intended VST must satisfy the following criteria:

- Simple to use and applicable to most supply chain decisions,
- Include financial criteria and risk drivers in the analysis,
- Produce clear and useful results,
- Complement the existing decision making strategies, and
- Flexible enough to allow a significant level of subjective input.

To use the VST, as illustrated in Fig. 1, the user enters the alternatives as column headings and adds the monetary factors below that. The monetary factors are summed in the "base price" row at the bottom. The user then rates the alternatives against the political and social criteria. The VST automatically calculates the "value of attributes" through a simple formula that multiplies the average attribute value against a portion of the base price. This, in turn produces an "adjusted cost." The dual results – base price and adjusted cost – allow the decision makers to consider both purely financial value (base price) and overall expected cost to the organization.

The VST also displays the risk level for each alternative; this is determined by the average of the attributes. Note that for calculating the risk ratings, the economic criteria are omitted. This prevents an unusually low price from overshadowing other criteria information that would indicate a high level of risk. If the organization selects a product that has a medium or high risk level, they will know that some degree of risk mitigation may be necessary.

The VST not only aids the decision makers in quantifying all of the relevant information, but it also provides an illustrative tool that can be used for presenting the decision to other members of the organization. When making future decisions of a similar nature, the users will be able to review the previous decisions.

Brand / Factory		A	B	C	D	E
Vendor		a	b	c	d	e
Inputs:	Input type	Vendor Assessment	Vendor Assessment	Vendor Assessment	Vendor Assessment	Vendor Assessment
Costs						
Base price		$23,400	$22,220	$23,207	$22,412	$18,985
Shipping	Currency	$0	$0	$0	$0	$0
Startup		$0	$0	$0	$0	$0
Discounts		($702)	$0	$0	$0	$0
Supplier Info	Libert Scale:					
Past performance	1 = bad	5	3	3	3	3
Trust & Ethics	2 = below avereage	5	2	3	3	3
Product Info	3 = neutral					
Compliance to spec	4 = above average	5	5	4	5	2
Reputation	5 = Good	5	4	3	2	3
Extra features/benefits		3	3	3	3	3
Base price		**$22,698**	**$22,220**	**$23,207**	**$22,412**	**$18,985**
Value of attributes		$9,360	$2,222	$1,160	$1,121	-$949
Adjusted cost		**$13,338**	**$19,998**	**$22,047**	**$21,291**	**$19,934**
Risk Level		**Low**	**Low**	**Low**	**Low**	**Med**

Fig. 1 Vendor Selection Template

The VST is a significant contribution. As stated in the hypothesis section above, a VST must satisfy several criteria as a prerequisite for its success. To use the VST, the user simply enters a few details on cost, supplier information, and product information for each of the alternatives. This satisfies the first two criteria: simple to use, and inclusion of financial and risk-driver criteria. The results that the VST produces, base price, adjusted cost, and risk level satisfy the other criteria. The results are clear and useful, and they use a common language that complements the existing decision making strategies. Last, the VST is flexible in allowing subjective input of the political and social attributes. Therefore, the VST satisfies the five criteria for a successful SCRM tool. Interested people can adopt the template for their own use by through the following steps:

1) Select appropriate cost inputs. For the research, base price, shipping, startup, and discounts were used. Depending on the industry, other costs such as commissions, import fees, maintenance fees, or other costs may be more appropriate. The selection of these variables will quantify the total cost and be universally applicable to common supply chain decisions made in that industry.

2) Select appropriate qualitative variable. These variables will allow the decision makers to assess attributes that will potentially influence the overall cost and success of the decision. As with the cost variables, these will be universally applicable and limited in number to maintain simplicity.

3) The "value of attributes" is a monetary expression of subjective inputs. This is accomplished by first converting the "1 to 5" Likert scale to "-2 to 2". The converted number is then multiplied by 5% of the sum of the costs. If the attribute was rated as a "1" or "2", the resultant value will be negative. The sum of the calculated values are then presented as the "Value of attributes"

4) The "Risk Ranking" is based on the inverse sum of the subjective attributes. A value of less than 0.07 is "Low", between 0.07 and 0.1 is "Med", and above 0.1 is "High".

Note: The calculations in the VST are done in the background. This helps to focus discussions on the supply chain decision and not on the how the results are produced.

IV. DATA ANALYSIS

An online survey was conducted via Qualtric's research & data collection website [26]. The analysis of the survey data was based on a total sample of 153. While this is certainly not an exhaustive survey, it supports a sufficient level of construct validity when augmented with the results of the empirical testing. The purpose of the analysis is to describe the meaning, relationships, and impacts among the questions rather than forecast or estimate them; we consider that size of the sample is appropriate. An initial observation of the survey results indicates that LEs are more engaged than SMEs in formally applying SCRM (see Fig. 2).
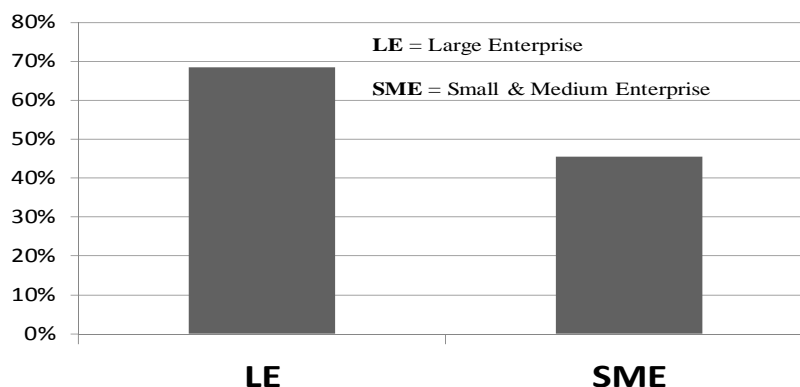
Fig. 2 Firms formally using SCRM

The initial observation, however, requires an in-depth analysis to determine whether there is a systematic cause and effect relationship between the application of SCRM tools and the formal adoption of SCRM. The following analysis attempts to validate whether this cause and effect relationship exists.

Categorization of the variables was necessary due to some variables, such as *"Q2 – What type of organization is it?"* are categorical variables. Conducting statistical analysis on categorical variables would return inaccurate responses, so these variables were converted to dummy variables prior to analysis to properly represent the nature of their possible answers. For other variables, such as *"Q5 – Does your organization use an established, formal raking system to evaluate product / vendor alternatives?"* the use of dummy variables has not been necessary due to they are ordinal variables, and the possible answers have a clear and natural order. After downloading, refining, and categorizing the data, there were 153 complete observations to analyze.

Once all the data was prepared, we started an iterative process to select the best model. The backward elimination, multi-criteria iteration process consisted principally to identify observations and variables that need to be removed due to they

are outliers and are not significant variables, the technique is useful in understanding causes within a set of data [27].

In order to have an initial idea about the relationships of the questions, we decided to perform a regression analysis to compare the variables. The first statistical analysis revealed that Q7 has the highest correlation to the other variable and offers the best fit of statistical analysis; this can be seen with the "R Square" and "Adjusted R Square" values in Table I.

TABLE I
ANALYSIS OF QUESTIONS

Regression Statistic	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Multiple R	.407	.082	.282	.282	.727	.744	.816	.642
R Square	.166	.007	.080	.079	.529	.553	.665	.413
Adjustable R Square	.125	-.041	.035	.035	.506	.532	**.649**	.384
Standard Error	.792	1.676	1.656	1.166	.926	.791	.784	.390
Observations	153	153	153	153	153	153	153	153

The above analysis has shown that Q7 is the question with the highest correlation with the rest of the questions. From this, we decide to perform a complete analysis for this scenario. During the backward elimination analysis of Q7, 25 observations have been eliminated as well as variables Q2, Q3, and Q4. For the elimination of observations and variables, the analysis of standard residuals and the test for individual significance of variables have been applied. After 26 iterations, we found the following model (Table II). The equation of the model is:

$$Q7 = -0.2 + 0.134 Q1 + 0.150 Q5 + 0.691 Q6 + 0.407 Q8.$$

TABLE II
Q7 AS DEPENDENT VARIABLE

	Coefficients	Std. Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-.200	.161	-1.236	.219	-.519	.120
Q1	.134	.050	2.709	.008	.036	.232
Q5	.150	.048	3.106	.002	.054	.245
Q6	.691	.054	12.880	.000	.585	.798
Q8	.407	.099	4.106	.000	.211	.603
Standard Residuals	Min =	-1.940		Max =	1.977	

We can conclude that the variable *"Q6 - Does your product / vendor selection template include an assessment of potential risks?"* with a coefficient of 0.691, is highly influential on Q7. We interpret this to mean that a method for assessing potential risks when selecting vendor alternatives is a critical step in SCRM; this activity can be accomplished by implementing a tool such as the VST proposed here.

A second analysis of the data attempts to identify variables that lead to or explain why firms use a formal rating system to evaluate alternative suppliers, question 5 *("Q5 – Does your organization use an established, formal ranking system to evaluate product / vendor alternatives?"*). The analysis may explain different factors that would lead a firm to utilize the VST proposed in the research. A backward elimination, multi-criteria analysis with Q5 set as the dependent variable (Y) is summarized in Table III.

TABLE III
Q5 AS DEPENDENT VARIABLE

	Coefficients	Std. Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	.478	.101	4.754	.000	.279	.677
DQ26	.292	.148	2.011	.047	.005	.592
DQ31	-.510	.103	-4.978	.000	-.713	-.307
Q7	.923	.029	31.790	.000	.866	.981
Standard Residuals	Min =	-1.949		Max =	1.984	

From Table I, it is possible to see that certain types of organizations (DQ26 = public/government/NGO), roles within the organization (DQ31 = Engineer/Technical) and related risk analysis activities (Q7 = assign a predicted risk level for new products / vendors) are all contributing variables to formally ranking new suppliers. Two interesting observations emerged from the analysis: (i) size of organization, small, medium, or large, were not significant answers; and (ii) observations from senior management and owners were also not significant.

As expected from the analysis, Q7 has the highest impact on Q5. To obtain the previous model, the analysis of standard residuals and the test for individual significance of variables have been applied at a confidence level of 95%. All of the P-values for the independent variables are significant; they are less than 0.05 (or 5%), which is the level of significance.

The observations from Table III give proof to our first hypothesis. CEOs and owners of SMEs make decisions mainly

through intuition and experience. Their interest level in formal tools for SCRM is low.

V. DISCUSSION AND RECOMMENDATION

Empirical testing of the VST was conducted on site with a manufacturing SME using real-world supply chain decisions. The management group at the test site consisted of the President/CEO, Operations Manager, and Engineering Manager. The VST was applied to three actual supply chain decisions and the results produced closely matched the managers' intuitive instinct. The group commented that the VST appears to be an effective tool for documenting the decision for future follow-up and reference. The ability to impart subjective attributes into the decision criteria satisfied the desire to include intuition and experience in the process; rather than changing the way decisions are made, it simply changes the way the decision results are communicated and recorded.

The empirical testing revealed consistency between the hypotheses, the literature, and the events that were occurring in the daily operations. The management of SMEs make supply chain decisions based on a variety of inputs, or sometimes using intuition with no apparent inputs at all. While the CEO at the test site showed interest and support for the VST, she did not actively engage in testing the tool or analyzing its results. This also correlates with the second observation in Table III above; that the opinions of managers and owners of firms did not reveal any statistical significance concerning using formal risk mitigation tools.

The results of the statistical analysis of the survey must be weighed according to the expected construct validity of the variables. This is questionable since the results do not closely match the literature. For example, LEs have several advantages over SMEs for mitigating supply chain risks. They were earlier to recognize the risks and better ability to expend resources to mitigate them. Size of enterprise should therefore be highly correlated with the application of risk management tools and strategies. In fact, there is very little correlation between the size of the organization and its approach to SCRM, although overall LEs are more engaged in SCRM.

SMEs, with their limited resources and limited ability to influence their supply chain partners will only gain advantage from SCRM efforts if they are simple, efficient, and effective. Vendor selection is an activity that is already part of the daily operating activities of any SME and it is the point when the SME exerts its maximum level of influence. This makes the vendor selection activity the ideal place and time for SMEs to begin SCRM.

This research has demonstrated that a tool for helping to manage SCRM can be beneficial for SMEs provided it is easy to use and produces results in a language that is easily understood. The simplicity of the VST and its use of common business terms for inputs and outputs make it very easy to adopt without expending new resources. The statistical analysis has demonstrated that the tool is an important step in implementing SCRM. Adopting the VST would be beneficial

for SMEs who recognize risk within their supply chains and understand that efforts to manage those risks are meaningful.

We can conclude from the research that SMEs are not simply small versions of LEs and that an extensive SCRM strategy is not appropriate for them. Several challenges prevent SMEs from adoption the SCRM tool even where positive reception and statistical analysis strongly advocate its use. The literature and statistical analysis performed agree that SMEs are led by people who prefer making decisions based on personal intuition and experience; a formal SCRM strategy is not suitable for SMEs. Rather, a simple to use tool, such as the VST developed herein is both beneficial and appropriate.

Further research is necessary to explore the theory that SMEs can, and possibly will, adopt additional tools and strategies relating to SCRM provided that the tools and strategies are simple to use, effective, and coordinate well with existing activities. A review of the general goals of SCRM and comparison to typical SME activities should reveal further opportunities.

VI. CONCLUSION

This research investigates the existing state of the art of SCRM and explores the reasons that SMEs have generally not adopted it. SMEs, when they do recognize the potential risk, are generally either not able or not willing to engage in an extensive SCRM effort. The development of a simple and effective VST is a significant contribution because it allows SMEs to apply an effective SCRM approach without expending additional efforts. The key to the VST's effectiveness is that it is executed at the point in a supply chain relationship where the SME has its maximum level of influence – the point of vendor selection. The VST can be easily adopted by any organization by following the simple steps outlined in this paper.

APPENDIX A: SURVEY QUESTIONS

Q1: What is the size of your organization?
- Small (<50 people)
- Medium (50 to 500 people)
- Large (>500 people)

Q2: What type of organization is it?
- Manufacturing
- Transportation & Logistics
- Educational
- Service Industry
- Other

Q3: What is your position in the organization?
- Engineer / Technical
- Manager
- Supply Chain Specialist
- Administrative

Q4: What is your typical contribution when selecting a new product or vendor?
- Technical input / specifier
- Source potential suppliers

- Approval / final decision
- All of the above

Q5: Does your organization use an established, formal ranking system to evaluate product / vendor alternatives?

- Never
- Rarely
- Sometimes
- Often
- All of the time

Q6: Does your product / vendor selection template include an assessment of potential risks?

- Never
- Rarely
- Sometimes
- Often
- All of the time

Q7: Does your organization use a formal system for monitoring and following up on risk with existing supplier contracts?

- Never
- Rarely
- Sometimes
- Often
- All of the time

Q8: Does your organization formally address supply chain risk management?

- Yes
- No

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