Service Orchestration of SMEs in Emerging Economies

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***Abstract*—Small and medium enterprises contribute significantly to the industrial economy of emerging markets. They are adaptable to change and can play pivotal role in innovations. However, with small work force, inflexible infrastructure, limited capital, and myopic exposure to the overall supply chain, such enterprises face continuous hurdles for growing amidst globalization. In this paper, we propose *service orchestration* as a business model for inclusive growth of small and medium enterprises with the large international firms. We outline the strategic, tactical, and operational roles of the orchestrator, and the analytical and IT infrastructure required in various stages of orchestration.**

I. Introduction

There is no commonly agreed definition or abbreviation of *Small and Medium Enterprises* (SME). The commonly known SME is used by EU, World Bank, UN, and WTO. In the United States, *small and medium businesses* (SMB) is predominantly used. India uses the term *Micro and Small Enterprises* (MSE), whereas South Africa uses *Small, Medium, and Micro Enterprises* (SMME). The definition is also ambiguous as EU uses the parameters of employment, turnover, and asset size for defining SME [1], and India uses the parameters of investment in plant and machinery [2]. Irrespective of the abbreviations and definitions, it is widely accepted that such enterprises are pivotal to industrial economy of a country. In India, the sector accounts for 45% of the manufacturing output and 40% of the total export (in terms of value). Further, the sector employs 59.7 million personnel across 26.1 million enterprises [2]. In the EU, SMEs comprise approximately 99% of all firms and employ between them about 65 million people [3]. Globally SMEs account for 99% of business numbers and 40% to 50% of GDP. For the scope of this paper, we will use the commonly used abbreviation SME to denote the enterprises from countries with their respective definition.

SMEs significantly contribute to economy, poverty alleviation, employment, and availability of products and services at affordable costs [4]. In many sectors, SMEs are also considered responsible for driving innovation and competition. With less manpower and low capital investment, SMEs are known for fast decision making and are adaptable to change [5]. This flexibility in decision making and implementing organizational changes is archived by preferring simplicity and flexibility regarding their processes and organizational structures [6]. However, there are number of challenges faced by SMEs, unlike the large and multinational enterprises [4], [7], [8]:

1) Limited capital and finances.
2) Limited IT resources and technical manpower.
3) Lack of R&D.
4) Limited exposure to regulations, import-export policies, government incentives.
5) Inefficient supply relationships, shortage of supply, labor, and inputs.
6) Marketing problems of identifying potential customers.
7) Conventional business models that are not competitive for global markets.
8) Small independent organizations that are dependent on large corporations for business.
9) Myopic exposure to business processes in the entire supply chain.

The above challenges are more pronounced in emerging economies where the SMEs are fragmented and localized, with huge information asymmetry with respect to the global demand and requirements. Conventional strategies for alleviating the above gaps are workshops and conventions organized by governments and industries. Such meetings provide platforms for learnings and meeting potential business partners. In this paper, we propose the need of an *orchestrator*, who essentially overcomes the above challenges in terms of marketing, finance, collaborative networking, givernment connections, and supply demand matching. The orchestrator thus enables the inclusion of SMEs in global supply chains.

II. Service Orchestration

The orchestrator is a management literature metaphor to describe the role of a player who organizes and manages a set of activities in a network, by ensuring value-creation opportunities in the system and value appropriation mechanisms for each player [9]. Orchestration brings about and manages whole set of tangible and intangible elements starting from design to distribution, without the orchestrator being involved directly in any of the elements of the supply chain. Unlike outsourcing, orchestrators manage a network of contributors who have a stake in the outcome. Medion AG (Germany) orchestrates the entire value chain from the initial product to after-sales services of computers and peripherals for its retail customers

[10]. Li & Fung (Hong Kong) is a trading company that provides its clients with a *virtual company* for manufacturing apparels and toys [11], [12]. The clients, usually from US and Europe, approach Li & Fung with demand for a certain apparel. The company has a network of thousands of globally dispersed service providers. Based on the client requirements, service providers are chosen to provide each of the constituent activities, thus creating a virtual company. Li & Fung owns no factories or hard capacities and all the activities in the value creation, except for coordination, are performed by independent service providers.

We propose the need of orchestrators like Li & Fung, who can satisfy large and international orders by sourcing from service providers and SMEs. The SMEs in individual capacities do not have access and also capability to execute and deliver a composite service. Each of them have their specialities and expertise. The orchestrator firstly decomposes the service demanded into small, independent services. Appropriate service providers from SMEs are identified to deliver the constituent services which are coordinated and executed by the orchestrator. The possibility of such a complex service execution is largely motivated by Li & Fung. Li & Fung primarily operates as an agent, finding suppliers to manufacture items according to customers' specifications. The items include garments, toys, household items, sporting goods, handicrafts, and fashion accessories. The company is divided into several dozen independent divisions, each of which concentrates on orchestrating for one category of products and serves one or few customers. The company has a international sourcing network with thousands of suppliers in over dozens of countries. Different countries offer different combinations of manufacturing capabilities, quality standards, and cost. The international sourcing *network* is not a formally constituted entity but consists of two intangible assets: *relationships* with the service providers and *knowledge* of the manufacturing capabilities, special skills, business practices, and regulations pertaining to each country and each supplier. The knowledge also includes the hidden costs like tariffs, duties, taxes, quotas, customs declaration processes, security requirements, and interfacing with government authorities. Further, all these are frequently subject to change. Li & Fung's business depends on these assets which leverages the international differences in labor costs and manufacturing capabilities to provide products that closely match the customers' requirements with respect to price, quality, and delivery time.

The following example illustrates how a network of activities are orchestrated when a typical order is received at Li & Fung [13]. Consider an order for 10,000 garments from a European retailer. The yarn will be sourced from Korea, but woven and dyed in Taiwan. The zippers are ordered from China and because of labor conditions and quotas, the garments will be made in five factories in Thailand. Finally, the garments will be shipped from Thailand to Europe all arriving in identical condition, as if made in a single integrated factory. The total lead time is five weeks, since the order was placed. The business model of Li & Fung illustrates the definitive possibility of orchestration for SMEs in emerging economies. We show how an orchestrator like Li & Fung can overcome many of the challenges faced by SMEs, thus enabling inclusive growth of these small industries in the global markets.

The orchestration is also studied in the domain of logistics as *global trade orchestrator* – one who can orchestrate the many activities, dependencies, and relationships across a global logistics network [14]. Such players were called as *integrated knowledge-based logistics providers* in [15]. These new value players will dominate the supply chain, outsource non-core capabilities to contract manufacturers and third party logistics providers, and take control of the supply chain decision process. In the following section, we describe in detail the role of an orchestrator for SMEs and investigate the characteristics (in terms of capabilities and resources) required for orchestration.

III. Service Orchestration of SMEs

Figure 1 illustrates a service planning, execution and delivery by an orchestrator utilizing various services provided by SMEs. In the following, each of the steps shown in the figure are described in detail.

A. Service request

The customer or client comes up with a service request to the orchestrator. The customer need not have visibility into the service providers and the orchestrator is the single point of contact owning all responsibilities for the service delivery and the associated risks.

B. Unbundling the service

The service request is unbundled or disaggregated into smaller or atomic services. Unbundling of a complex service into a smaller constituent services is a necessary requirement for inclusive growth of SME players. The unbundling implicitly assumes modularity, with well defined interfaces between the interacting services. The granularity of disaggregation is limited by the underlying modularity in the constituent services. By disaggregating a complex service into smaller services, the orchestrator can leverage the specialization and expertise of appropriate SMEs in executing the respective smaller services. One can unbundle a service in many possible ways. With many smaller services, orchestrator is faced with increased challenges in coordination during execution. *The orchestrator thus requires profound domain knowledge of the underlying process of the service being unbundled.*

C. Service composition

The service composition problem is the selection of service providers from the network of SMEs for each of the constituent services. The orchestrator should have complete knowledge of the SMEs in the network, their capabilities and limitations, special skills, and business practices. The service providers should be chosen such the service request can be accomplished as per the customer's requirements. The orchestrator should have strong analytics and optimization

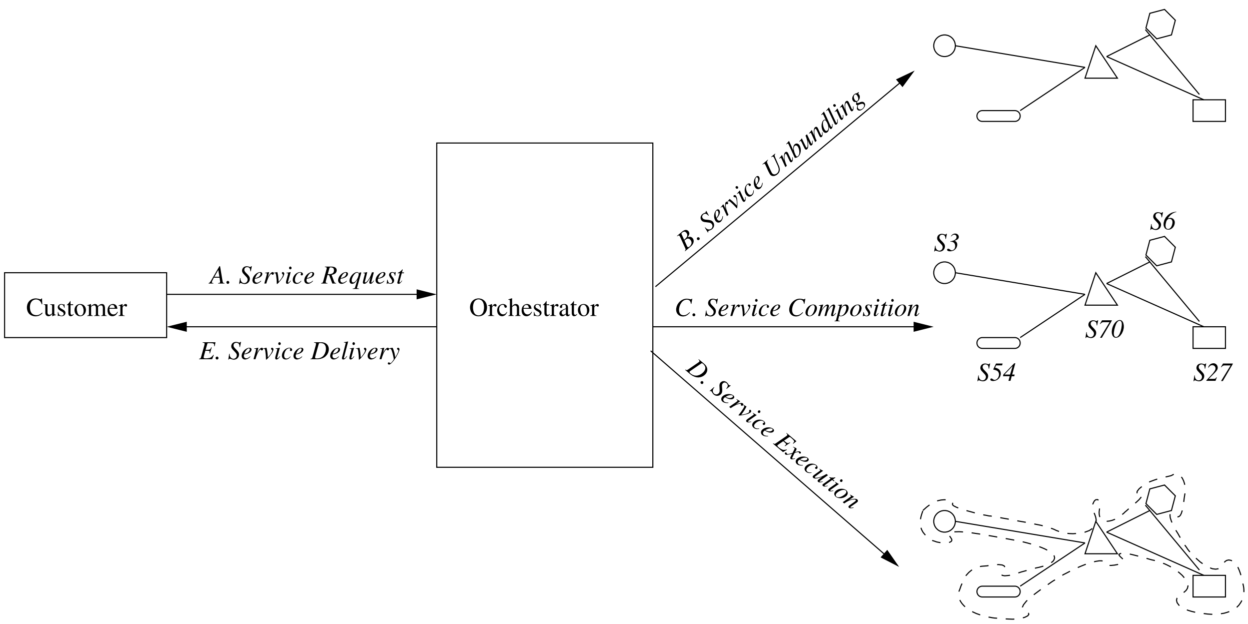

Fig. 1. SME Orchestration

capabilities for optimal service composition. The network of service providers so composed is a *loosely coupled* network [16]. A loosely coupled network span across multiple enterprises of varying domains and specialities. The processes will be defined in terms of *entities* (which SME will participate and what is its role?) and *milestone-driven deliverables* (what are the specific outcomes that must be delivered in what time frame?).

D. Service execution

The service composition is a planning stage, whereas in execution, the orchestrator coordinates each of the atomic services. By coordination, we mean that the orchestrator will *not* specify in detail the activities required for accomplishing the atomic service, but rather only focus on end result and interfaces. Thus the orchestrator needs no complete visibility into the SME's operations and data. Given the requirements, the SME can accomplish the service it its indigenous way using its legacy system. With selective visibility of the execution in progress, the orchestrator should be capable of handling online exceptions and risk management. The orchestrator should also have the required IT infrastructure and connecting technologies for real time response and risk mitigation.

E. Service delivery

The orchestrator delivers the required service as per the customer's demand and requirements. The customer has no knowledge of the internal workings of the orchestrator and the service is delivered as if executed by a single service provider.

The orchestration is a service-oriented activity, even if the deliverables in any of the steps above are tangible, manufactured products. From the execution perspective, it is also project based, where a service request is considered as a project. Each project is managed by a team which ensures that all the required constituent services are integrated, completed on time, and the entire service delivery has met quality specifications.

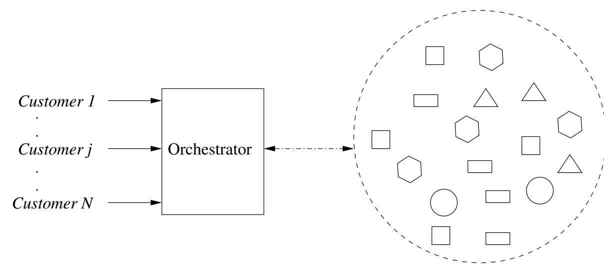

Fig. 2. Orchestrator with the SME network

IV. ECONOMICS OF ORCHESTRATION FOR SMEs

Figure 4 shows the orchestrator's perspective of relationships with the customers and a network of service providers or SMEs. For any business model to be practically implementable, the economics should provide positive incentive for each of the players. In our model, the three players are *customer*, *orchestrator*, and *SMEs*.

A. Customer

The customer needs a complex service to be delivered as per the requirements at the lowest cost possible. The orchestrator unbundles the complex service into atomic services. Unbundling is economically advantageous as the original complex service market have very few or no service providers. If there are only few service providers, then the pricing will not be favorable to the customer. However, the atomic service markets are generally competitive and each of them can be obtained with lower cost. Thus the complex service could be obtained economically, including the cost of coordination and profit margin of the orchestrator. The customer can also directly orchestrate this sourcing activity, if there is enough domain knowledge and orchestration capabilities. However, the service providers may not provide the competitive price to the customer that is given to the orchestrator. To the service provider, orchestrator is not a single potential business partner, but a source for various businesses.

B. Network of SMEs

The network consists of SMEs of varying domains and specialities. For example, if the orchestrator is in the domain of apparels, the SMEs belong to weaving and knitting, cut and sew operations, dyeing, packaging, and logistics providers. For each of the domain, there will be multiple SMEs. The network is not a formal entity constructed using negotiated and enforceable contracts, but rather a set of relationships. Without any prior agreements, the orchestrator can choose to engage an SME based on the requirements, SME's capabilities, and economic incentives. Thus, the orchestrator acts as a broker in obtaining business engagements for an SME. The participating SME may not be even aware of the original complex service request or the customer for whom it is being delivered. As mentioned above, to an SME, orchestrator is not a single potential business partner, but a source for various businesses. Further, an SME is not a unique service provider in its domain that belongs to the network of the orchestrator. With competitors around, the business transaction is priced competitively, but a competitive service delivery assures future businesses from the orchestrator. Without the orchestrator, the search costs too be high for an SME to find a large customer. Thus, the presence of the orchestrator provides tangible positive economic incentives and intangible future growth prospects by working on service requests of global standards.

C. Orchestrator

Form the above discussion, it is clear that orchestration is economically beneficial for both customers and SMEs. At the outset, the orchestrator provides brokerage service and hence a reasonable profit margin as a function of the total cost of the service is an obvious pricing model. Li & Fung uses this model of charging a fixed percentage over the total cost. As the apparel business is low margin, high volume activity, the above pricing is feasible. Depending on the nature of service and the presence of the other orchestrators, the pricing mechanism may vary.

V. Roles of the Orchestrator

In [16], seven roles of orchestrator are outlined. We categorize the roles of orchestrator for SMEs as *strategic*, *tactical*, and *operational*.

A. Strategic

- Recruit and develop participants into the SME network.
- Structure appropriate incentives for participants and increasing specialization over time.
- Cultivate a deep understanding of processes and practices to continually improve the quality.

The strategic roles are for long term decisions related to the development, maintenance, and continual upgradation of the network of SMEs. As noted earlier, an important asset to the orchestrator is the relationships with the SMEs. The network of SMEs needs to be restructured - *expanded*, *pruned*, *repositioned* - in response to the market conditions. There are strategic decision problems related to how much to invest in developing new SMEs, which SME should be upgraded with new technology, what tangible and intangible incentives to e provided to strengthen the relationship with SMEs, etc. Further, the orchestrator should develop a deep understanding of the processes and practices, in response to the ever changing customer needs, technologies, and business processes.

B. Tactical

- Define standards for communication and coordination.
- Develop and manage performance feedback loops to facilitate learning.

The tactical roles correspond to medium term activities. As shown in Figure 4, the orchestrator interacts with various customers and a large set of SMEs. The business processes are loosely coupled and well defined standards for communication and message passing are required for coordination. We discuss more about this in Section VII. Another tactical role is developing and managing performance feedback roles. Each customer order is a project-based activity and the performance in terms of lead time, coordination costs, quality, etc can be used in improving individual SME capabilities and also in composing better team of SMEs for a given project. For a customer, a set of service providers are assembled and coordinated to execute the project. The modeling of interactions between service providers of adjacent activities can provide useful information regarding the compatibility of the service providers. With better compatibility between the service providers, the orchestrators can gain with less coordination costs.

C. Operational

- For a customer demand, dynamically compose tailored business processes, involving multiple service providers.
- Execute the composed business processes, assuming ultimate responsibility for the end product.

The operational roles are managing customer orders. Two primary operational roles are *planning* and *execution*. The unbundling of service and service composition problem is the planning, whereas in execution, the service is being accomplished by coordinating with participating SMEs. We explore both of these roles in detail in the following sections.

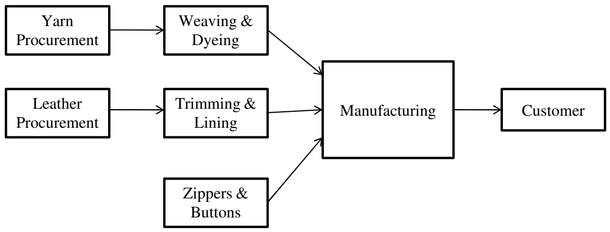

Fig. 3. Network of activities to be orchestrated

VI. Planning: Service Unbundling and Composition

The planning in orchestration comprises of stages B and C in Figure 1. The service unbundling stage disaggregates the complex service into a network of atomic services and the service composition stage is selection of service providers for each of the atomic services. In this section, we explain in detail the planning stage with an example adapted from [17]. The orchestrator considered in [17] is similar to Li & Fung, who orchestrates production of apparel for multinational corporations by leveraging the services of SMEs from emerging economies. In the following, we describe in detail how the orchestrator unbundles the production process and chooses the service providers using an optimization framework.

The orchestrator receives an order for a quantity $DEMAND$ of a certain product from customer C. The qualitative features and the delivery time are fixed and known. The orchestrator has to deliver the required quantity, with each unit adhering to the stated requirements, with minimal cost, and at the stipulated time. The orchestrator firstly disaggregates the entire manufacturing process into N individual indivisible activities. Figure 3 shows a typical set of activities for producing a apparel like jacket. The activities are not exactly the same as the *stages* or *echleons* or *tiers* in supply chains, which are usually categorized based on inventory requirements. The activity is here defined as a indivisible service that has the choice of being provided by different service providers. The resulting network is a directed tree with activities as nodes and the flow of materials directed from the leaves to the root. Each leaf activity depends on no other activity and the root activity, labeled as N, is the delivery of the finished product to the customer C.

The leaf activities are usually procurement of raw materials or sub-assemblies. Each of the intermediate activities require inputs from the immediate predecessors. The linear combination of the inputs plus the local additions creates one unit of output in an activity. For example, in a shirt production activity the inputs eight buttons, one pocket, one collar, two sleeves, and two brand labels stitched together results in one shirt. There is only one successor to each activity (except for root with none) and at least one predecessor for activity (except for leaves with none). Thus the network has information regarding the precedence in activities and the recipe for each activity.

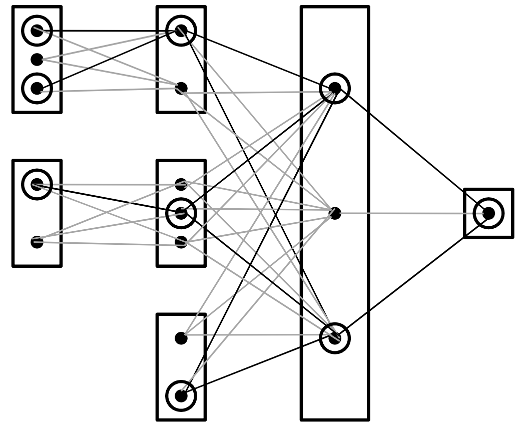

Fig. 4. Multi-layer network flow optimization

One can obtain the above network from the bill of materials. For a product like PC or toys, the network could be complex with more activities and many different ways of combining them.

Each activity has the option of being single sourced or multi-sourced. For multi-sourcing, the orchestrator can restrict the number of service providers. Each activity also has a time duration, within which it has to be completed. The time requirements are mandatory constraints with no option for different service providers accomplishing the same activity on different cycle times. The directed edge from an activity to its successor also depicts the transportation of goods. We assume that there are no alternate choices of service providers for transporting for brevity. Based on the time constraints, the shipping mode between any two service providers of adjacent activities will be known and hence the cost of transportation can be added appropriately.

With the above network, the orchestrator shortlists appropriate service providers for each activity from its network of SMEs based on the knowledge about their capabilities. They are chosen such that they closely match the customer's requirements in terms of quality and price. The individual activity requirements are then communicated to the respective shortlisted service providers for invitation of bids. A bid for an activity from the service provider consists of the price that he will charge for accomplishing the activity and supply quantity range (applicable for multi-sourcing activities). As lead time is a mandatory constraint, there is no negotiation in that dimension. The quality issues have to be dealt with by the orchestrator by making quality checks during the process. This is one of the features that distinguishes the orchestrator from a B2B matching agent from electronic marketplaces that can merely match the service providers. Once the bids are obtained, the optimization problem faced by the orchestrator is to choose the service provider for each activity taking into account various constraints.

Figure 4 shows the respective multi-layer network flow optimization of the network of figure 3. Each activity has alternate choices of service providers shown as dark dots. A feasible solution (network) is shown with circles around dots and dark lines on the links. The cost of the network is the total cost of procuring the service at each activity, transporting between different activities, and coordinating the entire network. In [17], the above multi-layer network optimization problem is modeled as the following mixed integer program.

A. Indices and Index Sets

We use the following notation to express the model mathematically.

$i, j \in \mathcal{A}$	Activities, $\lvert\mathcal{A}\rvert = N$; Root is labeled N
p, l, m	Service providers
$(i,l) \in \mathcal{PA}_i$	Service providers for activity i
$c, n \in \mathcal{N}$	Nation groups
$(i,l) \in \mathcal{PN}_n$	Service providers belonging to nation group n
$\mathcal{FA}$	Set of activities with no inputs (leaves)
$\mathcal{IN}_i$, $(i \notin \mathcal{FA})$	Set of activities that provide direct inputs to i (predecessors)
$\hat{i}$	Activity that receives direct input from i (successor activity)

B. Data

Following are the available data to the orchestrator.

$[\underline{NSP}_i, \overline{NSP}_i]$	Range of admissible number of service providers for activity i
$PCOST_{il}$	Unit cost of providing activity i by service provider $(i,l) \in \mathcal{PA}_i$ (received as bid)
$[\underline{SUP}_{il}, \overline{SUP}_{il}]$	Range of units of activity i available from (i,l) (received as bid)
$CCOST_{il}$	Cost accrued to the orchestrator for coordinating with (i,l): quality checks, development, and training
$TCOST_{iljm}$ $(i \in \mathcal{IN}_j)$	Unit cost of moving from (i,l) to (j,m), including transportation cost and duty
$ICOST_{iljm}$ $(i \in \mathcal{IN}_j)$	Cost accrued to the orchestrator for coordinating the transfer of goods from (i,l) to (j,m): customs handling, security clearance, interfacing with regulatory bodies
$DUTYD_{cn}$	Unit duty drawback for importing from nation group c and exporting to nation group n in different condition. For brevity, we assume all possible combinations.
$DEMAND$	Number of units demanded by the customer. The number of units required for activity is converted appropriately to produce one unit of the required product. Hence, the demand for each activity is $DEMAND$.
$QUOTA_n$	Available quota (units of the required product) for importing from nation group n. The quota is imposed on nation group which is the *origin* of the product, where it undergoes major transformation. We assume that this happens at activities that is the predecessor of activity N.

C. Decision Variables

x_{il}	$\in \{0,1\}$, Binary variable to select service provider (i,l) for activity i
y_{iljm}	≥ 0, Units transferred from (i,l) to (j,m) $(i \in \mathcal{IN}_j)$
z_{iljm}	$\in \{0,1\}$, Binary variable to decide whether $y_{ijlm} > 0$
d_{jlcn}	≥ 0, Units provided by $(j,l) \in \mathcal{PA}_j$ that can avail duty drawback for importing from nation group c and exporting to nation group n

D. Constraints

1) Sourcing: Constrain the number of service providers for each activity. For single sourcing at i, $\underline{NSP}_i = \overline{NSP}_i = 1$.

$$\underline{NSP}_i \leq \sum_{(i,l)\in\mathcal{PA}_i} x_{il} \leq \overline{NSP}_i,\ \forall i \in \mathcal{A}\setminus\{N\} \tag{1}$$

2) Supply and demand:

$$y_{il\hat{i}m} \leq BigM z_{il\hat{i}m}, \quad \forall i \in \mathcal{A}\setminus\{N\},\ (i,l)\in\mathcal{PA}_i,\ (\hat{i},m)\in\mathcal{PA}_{\hat{i}} \tag{2}$$

$$\underline{SUP}_{il}x_{il} \leq \sum_{(\hat{i},m)\in\mathcal{PA}_{\hat{i}}} y_{il\hat{i}m} \leq \overline{SUP}_{il}x_{il}, \quad \forall (i,l)\in\mathcal{PA}_i,\ \forall i \in \mathcal{A}\setminus\{N\} \tag{3}$$

$$\sum_{(i,l)\in\mathcal{PA}_i}\ \sum_{(\hat{i},m)\in\mathcal{PA}_{\hat{i}}} y_{il\hat{i}m} = DEMAND,\ \forall i \notin \mathcal{FA} \tag{4}$$

3) Flow constraint for service provider:

$$\sum_{i\in\mathcal{IN}_j}\ \sum_{(i,l)\in\mathcal{PA}_i} y_{iljm} = \lvert\mathcal{IN}_j\rvert \sum_{(\hat{j},p)\in\mathcal{PA}_{\hat{j}}} y_{jm\hat{j}p}, \quad \forall j \notin \mathcal{FA}\cup\{N\} \tag{5}$$

4) Duty drawbacks: The duty drawback that is considered here is exporting the good in different condition. This also includes re-exporting to the nation group after value addition. The $DUTYD_{cn}$ appropriately captures per unit drawback for the above scenarios. For every service provider, we model the duty drawback variables as flows on a transportation problem. The sources are the nation groups from where the inputs are imported and the destinations are the nation groups where the goods are exported with value addition. The supply capacity for the sources and the demand at the destinations are appropriately calculated from the flow variables $\{y\}$.

$$\sum_{n} d_{jmcn} \leq \sum_{i\in\mathcal{IN}_j}\ \sum_{(i,l)\in\mathcal{PN}_c\cap\mathcal{PA}_i} y_{iljm}, \quad \forall j \notin \mathcal{FA}\cup\{N\}, \forall c \in \mathcal{N} \tag{6}$$

$$\sum_{c} d_{jmcn} \leq \sum_{(\hat{j},p)\in\mathcal{PN}_n\cap\mathcal{PA}_{\hat{j}}} y_{jm\hat{j}p}, \quad \forall j \notin \mathcal{FA}\cup\{N\}, \forall n \in \mathcal{N} \tag{7}$$

5) Import quotas:

$$\sum_{i\in\mathcal{IN}_N}\ \sum_{(i,l)\in\mathcal{PA}_i\cap\mathcal{PN}_n} y_{ilNC} \leq QUOTA_n,\ \forall n \in \mathcal{N} \tag{8}$$

E. Objective

The objective is to minimize the overall cost of orchestration, including coordinating costs and variable production and shipping costs.

$$\begin{aligned}\min & \sum_{i\in\mathcal{A}\setminus\{N\}} \sum_{(i,l)\in\mathcal{PA}_i} CCOST_{il}x_{il} \\ & + \sum_{i\in\mathcal{A}\setminus\{N\}} \sum_{(i,l)\in\mathcal{PA}_i} PCOST_{il} \sum_{(\hat{\imath},m)\in\mathcal{PA}_{\hat{\imath}}} y_{il\hat{\imath}m} \\ & + \sum_{i\in\mathcal{A}\setminus\{N\}} \sum_{(i,l)\in\mathcal{PA}_i} \sum_{(\hat{\imath},m)\in\mathcal{PA}_{\hat{\imath}}} TCOST_{il\hat{\imath}m}y_{il\hat{\imath}m} \\ & + \sum_{i\in\mathcal{A}\setminus\{N\}} \sum_{(i,l)\in\mathcal{PA}_i} \sum_{(\hat{\imath},m)\in\mathcal{PA}_{\hat{\imath}}} ICOST_{il\hat{\imath}m}z_{il\hat{\imath}m} \\ & - \sum_{c\in\mathcal{N}} \sum_{n\in\mathcal{N}} DUTYD_{cn} \sum_{j\in\mathcal{A}\setminus\{N\}} \sum_{(j,m)\in\mathcal{PA}_j} d_{jmcn} \end{aligned} \quad (9)$$

VII. Execution: Coordination and Service Delivery

Execution comprises of stages *D* and *E* of orchestration in Figure 1. The orchestrator assumes ultimate responsibility for the service delivery and hence has to coordinate with various service providers so that the service is delivered as per the requirements stated by the customer. The orchestrator does not micro-manage the SMEs. Instead, appropriate milestones are identified for each of the service provider in the loosely coupled network. The interfaces between the stages in the service chain are clearly defined for the service providers to adhere to. The roles of the orchestrator for execution are:

- Identify check points, targets, deadlines, and interfaces for each of the activities in the service chain.
- Monitor at the higher level, whether the above are met.
- If there are exceptions, orchestrator should in real time handle the exception, so that the final service delivery is not affected.

The above roles require continuous and resilient connectivity of the service providers with the orchestrator. Such an IT infrastructure poses two major challenges:

- The SME network consists of various enterprises differing in IT capabilities, ranging from middle size ERP systems to simple EDI. Integrating these differing legacy systems is very costly, given the loosely coupled nature of business transactions.
- SMEs are inherently limited in IT infrastructure and is very expensive for their capital to invest in enhancing new IT capabilities.

The *service oriented architecture* (SOA) mitigates both the challenges. SOA is essentially a collection of *services*, that can communicate among each other for data passing, message passing, and coordinating some activity [18]. In the context of SOA, a *service* is a function that is well-defined and self-contained. Web services is the promising technology to implement web services. SOA provides loosely-integrated suite of services, which precisely meets the requirements of orchestration. In [19], orchestration of loosely coupled business processes is proposed as a governance technique for SOA. In our work, we propose essentially the opposite of using web services and SOA as the underlying IT infrastructure for orchestration.

SOA still suffers from a limitation in the orchestration context, as the business events may not follow predetermined patterns. A event can be defined as a significant change in state of a system. The business events include the check-points and milestones set in the various stages of the service chain and these inputs will be coming from different service providers. Given the dynamic nature of service composition and uncertainties arising due to SME performance, it is not feasible to design a SOA that follows predetermined sequence of events. Rather the orchestrator must be able to define the business processes dynamically such the process flows to be driven by asynchronous events. For example, if the zippers and buttons from Korea are delayed due to bad weather, then the manufacturing in Thailand has to be either re-scheduled or an alternate supplier for zippers need to be identified so that production is not delayed. To support such dynamics, *event-driven extension* of SOA, called as *Event-Driven Architecture* (EDA) should be used [18]. EDA basically handles production, detection, consumption of, and reaction to events. The SMEs and other service providers act as *event emitters* and the orchestrator is the *event consumer*. As soon as an event is presented, the orchestrator has the responsibility of providing the reaction. EDA facilitates responsiveness and is designed to handle asynchronous and uncertain environments which would ideally suit for orchestration of SMEs.

VIII. Final Notes

SMEs contribute significantly to industrial economy and with their fast decision making capabilities, they are adaptable to change. However, in emerging economies, SMEs face the challenges of accessing global markets with their limitations in information access, IT infrastructure, business practices, and knowledge of government regulations. In this paper, we proposed the business model of service orchestration for integrating SMEs into global supply chains. The orchestration is more knowledge-based than using hard capacities. The proposed model is motivated by the Hong Kong based trader Li & Fung that orchestrates in the apparel domain. We discussed in detail the various steps in service orchestration of SMEs and outlined the roles of the orchestrator. We showed in detail the planning and execution roles, which outlined the analytic and IT capabilities required for the orchestrator. As the orchestrator is primarily knowledge based, there are several decision theoretic, game theoretic, and computational problems to be solved. Following are few of the interesting research problems for further investigation.

1) Algorithm: The proposed mixed integer program can be solved using commercial optimization packages. Even if one expects few alternative service providers for each activity, the problem can become computationally demanding with too many interdependent decision variables. Some of the binary variables (especially from $\{z\}$) can become redundant for certain problem instances and also the duty drawback variables. However, the presence of such interrelationships can even render the sophisticated commercial packages clueless while using branch and bound algorithms. Exploiting the several known structures in the problem (like network flow and transportation) and developing branch and cut algorithms can tame the computational demands.

2) Lead times and transportation modes: We assumed for simplicity fixed lead times and fixed transportation modes. Allowing choices for transportation modes can possibly decrease cost. For example, a low cost service provider may have available capacity immediately which may require expedited shipping from the input activities and can trade-off the shipping cost with low production cost. The complexity of the problem, however, increases in the dimension of time factor and requires scheduling of activities in tandem with network flow.

3) Service provider disruption: One of the concerns is the disruption of a service provider during the execution. The orchestrator should be able to shift to another alternative with least cost and without disrupting the already established network of service providers. Stochastic programming tools can help in handling such uncertainties.

4) Developing new service providers: The proposed model chooses service providers based by minimizing coordination costs (one of the terms in the objective function). This discourages choosing new service providers as the coordination costs are high. However, for the orchestrator, it is required to develop and accommodate new service providers. The model should be able trade-off this qualitative feature with the quantitative coordination cost.

5) Combinatorial bidding: Coordination cost for a service provider is a fixed cost. The model assumed no common service provider across different activities. This can be included with certain inequalities. The interesting extension is to allow *combinatorial bidding* – where a service provider can bid for a combination of activities and possibly quote a reduced price for due to economies of scope. Combinatorial bidding has been successfully employed for many industrial procurements [20]. However, the computational demands on the optimization problem increases significantly and it is an interesting research problem.

6) Muliple products: The customer demand considered is this paper is for multiple units of a single product. If there is a demand for multiple products that share no common activities, then they can be treated as different customer orders. However, for multiple products that share certain common activities, merging them into a single network can achieve economies of scale, but with added complexity in design and optimization.

7) Developing competitors: The interactions between service providers can also lead to competition threat. One of the greatest risks in orchestration is the partner becoming a competitor. With the repeated interactions and good compatability, a strategically colluded subset of service providers can have the same end-to-end visibility as the orchestrator. If such a coalition decides to move up the value chain, then it is a potential competitor to the orchestrator.

8) Network restructuring: As noted earlier, an important asset to the orchestrator is the relationships with the service providers. The loosely coupled network of service providers needs to be restrucured - *expanded*, *pruned*, *repositioned* - in repsonse to the market conditions. There are interesting decision problems related to how much to invest in developing new service providers, which suppliers should be upgraded with new technology, etc.

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