ICIC Express Letters
Part B: Applications
Volume **9**, Number **3**, March **2018**

ICIC International ©2018 ISSN 2185-2766
pp. **225–231**

ENHANCING EFFICACY OF SUPPLIER CONSOLIDATION THROUGH INTEGRATING DEDICATED MANUFACTURING LINES

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Received September 2017; accepted December 2017

Abstract. *In these days, many companies are outsourcing to satisfy various customer needs and to survive in rapidly changing market environment. For this reason, companies are focusing supply based competitive strategies. They have to manage supply chain efficiently for reducing complexity. Supplier consolidation is one of worthwhile supply chain management strategies. Consolidating supplier has simultaneously enhanced the purchasing power and improved the product's quality. In order to consolidate suppliers, the supplier should produce a variety of products that the buyer requires. If they produce them in dedicated lines for each product, no additional efficiency is expected for consolidation. In this regard, this study presents the framework for a supplier to construct an integrated manufacturing line that produces multiple products. The effectiveness of the integrated manufacturing line is demonstrated by comparison with dedicated lines. A vehicle component manufacturer's welding process line is depicted as a case example.*
Keywords: Supplier consolidation, Integrated manufacturing lines, Production capacity

1. **Introduction.** In these days, increasing competition and a variety of demands cause to increase complexity in product development and production. In other words, companies invariably buy too many things from too many different suppliers. In this environment, many companies are focusing supply chain based strategy to achieve competitive advantage [1]. Companies spend a high portion of their sales revenue on purchasing raw materials and component parts. In the manufacturing industry, purchasing process takes about 50 to 60% of the total manufacturing cost [2]. In this regard, original equipment manufacturers (OEMs) want to reduce the purchasing price from suppliers, thereby saving the total costs [3].

Consolidating supplier is one of worthwhile supply chain management strategies that choose the best suppliers which can trust, and minimize the number of suppliers. Supplier consolidation can simultaneously enhance the purchasing power and improve the product quality [2]. Meanwhile, a remaining supplier's production capacity should be large enough to accommodate enlarged purchasing requirement from the OEM. They are also required to produce higher variety components to substitute other suppliers. Suppliers usually expand these capacity and variety requirements by building more lines, which are dedicated to produce specific components, respectively. Additional capital investment charged for this expansion damages efficacy of the supplier consolidation strategy.

In order to resolve this trouble, this study suggests integrating dedicated manufacturing lines, and presents a framework for this integration. As shown at the left side of Figure 1, dedicated lines can produce only pre-assigned components, which are denoted by MBR 1 and MBR 2 (abbreviation of a cross member component in a vehicle, which is our case example in this study). The squares denote manufacturing resources like facilities and workers. Line integration means building a single versatile line that produces different

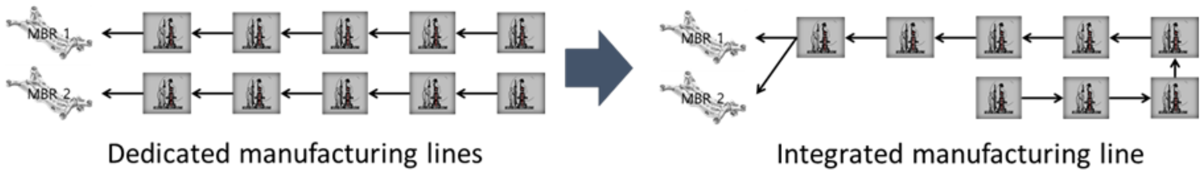

Figure 1. Integrating dedicated production lines

components, as depicted at the right side of Figure 1. This line should also produce as much as the dedicated lines do, in other words, maintain capacity of dual lines.

The proposed framework contributes to building an integrated manufacturing line at the same capacity of dedicated lines while minimizing additional resources. In order to maintain the capacity, an integrated line requires much more resources than a single dedicated line. Nevertheless, the increase can be minimized, as depicted by fewer resource squares for an integrated line in Figure 1, by systematic task decomposition and resource allocation, which will be presented later. The final step of the framework is to evaluate whether a resulting integrated line consumes less resource than dedicated lines. The evaluation needs an average production perspective considering capacity loss, which will also be described in the following sections.

2. **Literature Review.** Consolidating suppliers have benefits to manage supply chain. First, firms can reduce the complexity of supply chain management. Supplier consolidation strategy is studied with the questions of how to choose suppliers. Purchasing firms are concerned about number of suppliers. Firms try to compare with multiple suppliers and single suppliers on which selection is more effective to managing supply chain [1,6]. Firms set criteria that select suppliers in multi-objectives, e.g., quality, net price, geographic location [7] and then choose multiple suppliers or single suppliers. The decision that chooses suppliers can reduce the complexity in supply chain. Second, firms can reduce purchased costs. The purchased costs include price, shipping and so on [5]. Firms could achieve economies of scale by increasing the order size to a key supplier [5,8]. This can have the effect of allowing suppliers to invest in improving their production capacity to generate their profits. As a result, the company can provide at a lower price [8].

For achieving this benefit, previous researches mention supplier development program and long-term relationship with suppliers [8-10]. The firms have to make supplier development program that purchase high quality product and low cost from supplier. However, those researches, did not mention how to improve and maintain capacity of suppliers as much as it is required. In this article, we suggest the framework which increases the production capacity and utilization by integrating the dedicated lines.

From the perspective of the supplier who receives the consolidated procurement request, their product variety is greatly increased as well as production volume. Hu et al. [11] comprehensively review assembly line design and operation issues for producing a great variety of products. According to their classification, a line design problem consists of configuration, line balancing and delay differentiation topics. As noted by Koren et al. [12], different configurations for a variety of products have a significantly negative impact on both cost and quality. Since identical (or similar) configuration is a necessary condition for line integration, we also assume this condition. Many of previous studies have focused on the balancing problem since different products may have different working time for tasks. Matanachai and Yano [13] define an objective of maximizing workload stability in a mixed-model line balancing problem and propose a heuristic solution method. Some following studies [14,15] proposed an optimization method of adaptively assigning tasks to workstations to minimize overall overload of workstations producing mixed models. Meanwhile, AlGeddawy and ElMaraghy [16] proposed a model to construct a layout of mixed-model assembly lines to delay differentiated workstations and synchronize production rates of different models. While these previous studies focus on flexibility of a line configuration and stable workload between different products, this study questions how to boost capacity of a single line and its efficacy.

3. **Manufacturing Line Integration Framework.** An integrated manufacturing line should expand production capacity as much as multiple dedicated manufacturing lines may achieve. The basic idea of the framework is reducing takt time by splitting task on a single station to multiple substations. Takt time is the desired time between units of production output. This is determined by the time of bottleneck stations and, consequently, the production capacity of the line.

In order to illustrate our framework, we took an example of a welding process line of a vehicle component, which is called a cross member that supports weight of a vehicle between wheels. The framework assumes that dedicated lines are already set. And also, the integrated line configures a serial structure. In order to increase the production capacity, such a manufacturing line configuration is composed of substations which are using the same workbench. This configuration can remove part loading and set up time to share common workbench.

Step 1. Analysis of a dedicated manufacturing process

In this step, we analyze the dedicated manufacturing line process which has planned to produce a representative model. In order to proceed with this process, the entire line should be considered by stations individually. This analysis identifies the facilities, workers and production capacity of a whole manufacturing line. For obtaining information of production capacity, we have to find the bottleneck stations. The bottleneck station constrains the production capacity of entire line because the production capacity is less than demand and requires a long processing time called *takt time*. The reason for identifying the bottleneck station is to determine the takt time to increase production capacity in the manufacturing line integration.

These process characteristics of our case example are presented in Table 1. The manufacturing line consists of 20 welding stations (number from #1 to #20) with production capacity of 180,000 units per year – 4,050 hours. There exist three bottleneck stations that take 81 seconds to complete their tasks, which is takt time of the line. The cycle time that the total time from the beginning to the end of production is 640 seconds. The line facilities consist of 21 sets of arc robots and 4 sets of handling robots. An arc robot performs welding tasks and a handling robot carries an intermediate output between the tasks. Five workers work at 10 stations, by each worker taking charge of two stations, to load the components on the welding fixtures.

Table 1. A case example

Bottleneck stations	#2, #10, #16 (working time: 81secs)
Process takt time/cycle time	81secs (capacity: 180,000 units/year)/640secs
Facilities	Arc robot 21 sets/Handling robot 4 sets
Worker	5 Workers (#1, #3, #5, #6, #7, #8, #9, #11, #13, #15)

Step 2. Task decomposition

This step decomposes tasks of each station so as to increase production capacity of the whole line as much as we target. In our case example, a single dedicated line produces 180,000 units per year, and we want to substitute four dedicated lines with one integrated line with quadrupled capacity. Then the takt time should be no longer than 20 seconds.

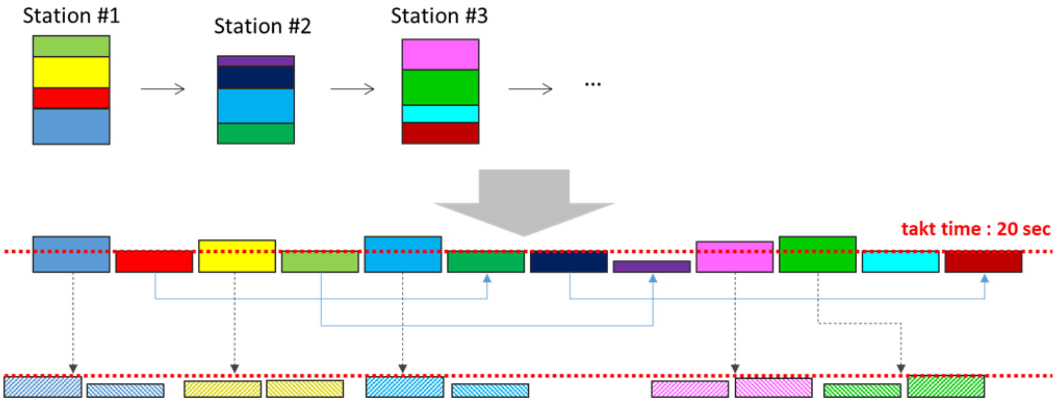

FIGURE 2. Task decomposition and re-decomposition

In order to achieve this takt time, every station should complete its tasks within 20 seconds by taking fewer tasks than the dedicated line. For example, if a station takes multiple tasks (colored boxes), as shown at the top row of Figure 2, first decompose them into unit tasks so as not to exceed the target working time, as shown at the middle row of Figure 2. They will be reassigned to individual stations preserving their precedence requirements in the next step. Much more stations are required to assign the decomposed tasks.

Some of the unit tasks may exceed the target working time even for completing them alone. Such task should be re-decomposed into smaller tasks, as shown at the bottom row of Figure 2. In our case example, tasks are classified into part loading, setting up, welding and extracting. While other tasks are hard to split, welding tasks can be further decomposed into narrower welding tasks. We split a long welding field into smaller lengths and made them unit welding tasks. Since welding is performed 7mm per second, maximum welding length is constrained by 98mm (= 7mm × 14secs) considering 6 seconds of set-up time.

Step 3. Task reassignment and resource allocation

In this step, tasks that decomposed in step 2 are assigned in a station by constraints between tasks. In assigning tasks, it is necessary to be able to perform all tasks simultaneously in one work station to minimize the number of stations. In case of conflicting between task constraints, the work station should be separated. We divide tasks based on three main constraints between tasks: 1) extracting finished sub components, 2) change the equipment or operator (e.g., fixture turns), 3) impossible working distance.

After the task assignment step is over, allocate facilities and workers for each station. When allocating resources, they place long-operating-time tasks first. If the task assigned to resource exceeds the takt time, additional resources should be deployed. Also, a resource can take on multiple tasks. However, the sum of the multiple tasks operating time which is assigned to resource cannot exceed the takt time. In other word, the operation time of resources should not exceed the takt time.

Figure 3 shows a part of a task and resource allocation table in our case example. For this station #9, part loading task is solely processed by a worker resource, LA0901. All welding machine resources take 6 seconds of set-up time, and process welding tasks as much as they can do in remaining 14 seconds. The bar charts show processing times. For example, machine MA0901 can process only task #9-1 that takes 14 seconds. If more tasks are allocated, the machine has to violate the takt time of 20 seconds. Meanwhile, machine MA0902 can process four tasks #9-2, #9-3, #9-8 and #9-9 that take 12 seconds in total. In this way, the minimum number of resources are assigned to complete the tasks.

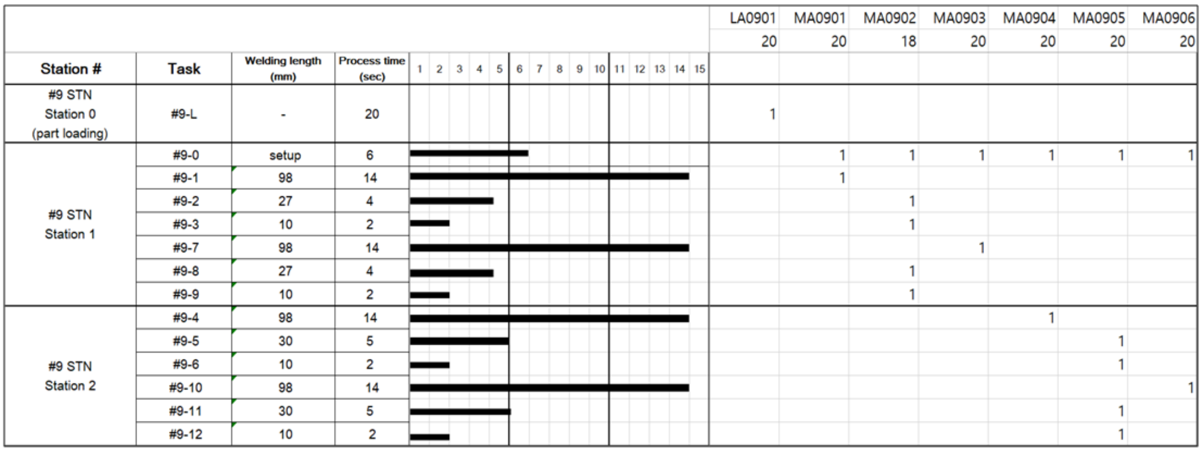

FIGURE 3. Resource allocation example

TABLE 2. Evaluation of performances

Performance dimensions	4 dedicated manufacturing lines	Integrated manufacturing line	5 dedicated manufacturing lines
Process capacity (Takt time)	720,000 units/year (Each line: 80secs Average: 20secs)	720,000 units/year (20secs)	900,000 units/year (Each line: 80secs Average: 16secs)
Production amount	460,800 units/year (Utilization 64%)	576,000 units/year (Utilization 80%)	576,000 units/year (Utilization 64%)
Resource-facilities	Arc robot 84 sets Handling robot 16 sets	Arc robot 94 sets Handling robot 5 sets	Arc robot 105 sets Handling robot 20 sets
Resource-workers	20 workers (5 workers each line)	9 workers	25 workers (5 workers each line)

Step 4. Evaluation of line integration

This step is for evaluating efficacy of an integrated line by comparing its major performance dimensions like capacity and resource usage with dedicated lines. This evaluation step may largely vary case by case, and we illustrate our case example here with Table 2.

Remember that our case example targeted to quadruple the capacity of a single dedicated line. The performance is compared with four dedicated lines as a same capacity alternative and five dedicated lines as a higher capacity alternative. The required resource for dedicated lines is computed by multiple of single-line resource, where resource for integrated line is derived from result of the previous resource-allocation step. The integrated line requires a little more facility resource (more arc robots and fewer handling robots) and less worker resource than the same-capacity dedicated lines. In this regard, line integration seems not such a superior alternative to improve efficacy of supplier consolidation. Additional effort to product different components in a single line could erode the slight advantage.

Meanwhile, in a perspective of actual production amount, it is far better than dedicated lines. Production amount is actually variable according to demand fluctuation. The supplier may lose some demand when its short-term capacity is less than the total demand. Assume that a dedicated line equips 50% more capacity than expected demand for certainly meeting demand. Then total overall utilization of dedicated lines is only 64%. An integrated line, however, can pool demand fluctuation between different products. It does not lose peak demand for a certain product because it can produce the product more by reducing production of other products. Assuming that standard deviation of demand for an individual product is about 25% of its expected demand, by the pooling effect, an integrated line can meet demand at the same level of certainty with only 25% more capacity of expected demand. Then, utilization is increased to 80%. In the case example of Table 2, an integrated line of 720,000-unit-per-year capacity can actually produce 560,000 units per year, which is equivalent to actual production amount of five dedicated lines. Therefore, the integrated line requires far less facility and work resource than the dedicated lines.

4. **Conclusions.** Consolidating suppliers is a proven strategy to obtain strength in a complex business environment. OEM firms can achieve the purchasing power by dealing with fewer suppliers. This can possibly minimize the cost of the supply chain by lowering the purchase price. Also, in term of product quality, it is possible to provide certain high-quality products through the use of proven supplier.

This study presents the framework for how to integrate supplier's manufacturing lines. The framework consists of four steps. First, analyze the existing dedicated manufacturing line to obtain data (e.g., resources, cycle time, production utilization rate, production amount). Then, in order to increase the production, shorten the takt time, decomposition and reconfigure the tasks, and allocate resources to each workstation. This has demonstrated the effect of efficiency when operating integrated manufacturing line pool each dedicated manufacturing lines' demand, resources. Figure 4 shows the benefit of purchasing cost reduction when operating integrated line under the production amount increased. When operating dedicated lines, if amount of production increases, it has to build another manufacturing line. Consequently, the total cost will increase linearly. On the other hand, when operating integrated line, it could be covered increased amount of production without additional manufacturing lines. Even as the quantity increases, the utilization of integrated line increases, and the total cost increases concavely. This could serve as a basis for negotiations to reduce the purchasing cost.

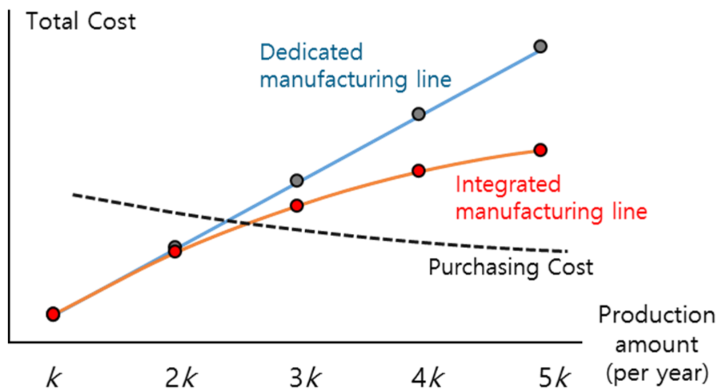

FIGURE 4. Reducing purchasing cost

A future topic may be to find out how suppliers will participate in the OEM's product design process to build these integrated manufacturing lines. OEM needs to find the link between the constraints and the design parameters that affect the supplier's manufacturing line during the product design process from the concurrent engineering point of view. To realize this, the information about the manufacturing line's constraints is sharing among the OEM and supplier should be done and the overall design of the product family should be decided based on this relation.

Acknowledgment. This work was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2017R1D1A1B03032176).

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