Chapter

# Enhancing the Resilience of Sustainable Supplier Management through Combination with Lean and Audit

*Ping-Kuo Chen, Qiu-Rui He and Xiang Huang*

## Abstract

Industry 4.0 has positive effect on the enhancing of the resilience. However, if the resilience can be promoted by lean and auditing environment priority, after further combine with industry 4.0 environment, the resilience will become stronger. Even though, two research questions should be verified priority: How do manufacturers make good use of pull production and employee involvement under lean practices that can strengthen supplier management robustness and enhance the prevention ability of resilience? Why does the combination of lean practices with an audit mechanism strengthen the produce synergy to prevent and control opportunistic behaviour by suppliers? PLS and the Sobel test were applied to survey data from 231 Chinese manufacturers to test and verify research questions. Pull production and employee involvement can enhance responsible purchasing, emergency-response, manufacturing process coupling, and further strengthen supplier management robustness, further enhance the prevention ability of resilience in dealing with opportunistic behaviour. In addition, enhancing manufacturing process coupling has the indirect effect of strengthening emergency-response ability. The audit mechanism can control the dysfunctional behaviour of the supplier, further guiding cooperation with the practice of pull production and employee involvement; in addition, audits also trigger the supplier's trade-off mindset in terms of risk and profit maintenance.

**Keywords:** sustainable, supplier management, resilience, lean, audit, opportunistic behavior

## 1. Introduction

To deal with heavy competitive pressure, building a supply chain has become an important competitive strategy. Under the supply chain, the effective practice of using more operations between manufacturers and suppliers is critical to promote

competitiveness and increase common economic profit; however, it also leads to increased pollution emissions. Considering social pressure, more manufacturers have adopted remedies to deal with pollution. However, if pollution emissions continue to increase, remedy costs are increased and lead to a reduction in common profits. Reducing remedy costs may cause conflict relative to social awareness.

To avoid this conflict, the development of sustainable supplier management is necessary. Sustainability is the concept of balancing the environmental, social, and economic profit cycles. To realize sustainability, resilience is a critical factor. Resilience is the capability of supply chains to prevent, respond, and recover from uncertainty risk [1, 2]. When they possess stronger resilience, manufacturers can strengthen environmental prevention, continue to detect potential problems caused by environmental pollution and recover from them in the shortest period, avoid large improvement costs, maintain economic profits, and meet green and satisfactory social requirements.

However, it is possible that profit motives will still drive suppliers to engage in opportunistic behavior and indirectly increase pollution emissions, further breaking sustainability. These opportunistic behaviors are hard to prevent and control even when there is awareness of opportunistic behavior, and pollution emissions usually become quite serious. Therefore, opportunistic behaviors are like uncertainty risks. If opportunistic behavior is hard to prevent when it appears, how to reduce and recover from the damage of opportunistic behavior in the shortest time is an important research issue.

To enhance the recovery ability of resilience, current theory indicates that information integration [3] and the preparation of redundancy resources [4] are two critical factors. When opportunistic behavior appears, a great information-sharing mechanism can adjust redundancy resources in the shortest period to recover from damage. Even so, redundancy resources, such as inventories, will increase long-term costs, and their preparation and adjustment also affect operational efficiency. Therefore, although redundancy resources reduce the damage level of opportunistic behavior and provide faster recovery, they also raise recovery costs and affect operational efficiency.

Based on the above, researchers, such as Spieske and Birkel [5], found that the development of the industry 4.0 environment has a positive effect on the improvement of resilience. It can integrate related information and further realize the supply chain visibility, help manufacturers and partners to avoid the preparation of redundancy resources, and raise a fast-responding ability. Therefore, it certainly has a positive effect on resilience ability raising. However, the industry 4.0 environment is hard to implement and establish. Based on the above, a lean environment should be established on a priority basis [6]; in addition, the lean environment should have a great auditing mechanism to ensure the lean practice. Even though, improvement of resilience admits of no delay. Therefore, if the improvement of resilience needs to await the finished development of the industry 4.0 environment, the development period will be vulnerable and is hard to control pollution emission. However, if the combination of lean and audit mechanisms has a positive effect to enhance the prevention ability of resilience, it can help the manufacturer to promote gradually the resilience. When the industry 4.0 environment is established, the resilience will become stronger. Even though, does the combination of lean and auditing have a positive effect on resilience?

Lean practices are used to eliminate redundant activities and achieve the maximization of operational efficiency through pull production, 5S, employee involvement, and total productive maintenance (TPM) [7]. Related research, such as that by

Spiegler et al. and Birkie [8, 9], has indicated that the elimination of redundancy activities goes against the recovery ability of resilience. However, according to a few successful cases, such as the Taiwan Semiconductor Manufacturing Company (TSMC) and Samsung Group, if manufacturers make good use of pull production and employee involvement under lean practices that can strengthen supplier management robustness and further enhance prevention resilience, then they are better able to prevent and control the appearance of opportunistic behavior and reduce recovery costs. If lean practices are combined with an audit mechanism, then synergy will occur and strengthen the prevention ability of resilience.

However, how do manufacturers make good use of pull production and employee involvement under lean practices that can strengthen supplier management robustness and enhance the ability of resilience to prevent and control opportunistic behavior? Why does the combination of lean practices with an audit mechanism strengthen the practice effect of pull production and employee involvement and even produce synergy to prevent and control opportunistic behavior by suppliers? The purpose of this study is to explore these research questions.

This chapter contributes to the operations management and sustainable development literature in two ways. First, our research results can guide managers in setting a suitable mechanism through a combination of lean practices and audits to enhance resilience and ensure sustainable supplier management within their organization, avoid the damage caused by opportunistic behavior of suppliers, achieve the goal of sustainability, and not rely on redundant resources. Second, understanding the role of audit in lean practices can guide manufacturers in knowing how to promote the audit mechanism.

## 2. Literature review and theoretical framework

### 2.1 Prevention and control of opportunistic behavior and resilience

The definition of sustainability in the supply chain is "the strategic, transparent integration and achievement of an organization's environmental, social and economic goals in the systematic co-ordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chains" [10]. Sustainable supply chains also emphasize supplier management and promote the gradual development of sustainable supplier management [11].

To maintain sustainability, Rajesh and Ravi [12] believed that stronger resilience is necessary. Resilience can be defined as the ability of a system to prevent and recover from disruptions with negative effects and unpredictable risk events and return to a better situation [13–15]. Unpredictable risks are hard to avoid; however, compared with unpredictable natural risks, artificial risks are common. Of all unpredictable artificial risks, destructive opportunistic behavior by suppliers is the worst.

Opportunistic behavior by suppliers is not purposeful. The appearance of opportunistic behavior is usually profit-oriented, and suppliers worry about damage to their profits [16], which is a normal mindset. If we analyze a profit distribution based on the product selling price, the supplier's profit is just a small ratio of the selling price. Therefore, it is easy to trigger opportunistic behaviors that attempt to increase profits. These opportunistic behaviors may reduce production costs and increase profits; however, they also may indirectly increase pollution. Crucially, the probability of opportunistic behavior by suppliers is higher than other unpredictable risks and is

hard to prevent. Therefore, researchers believe that manufacturers should enhance the recovery ability of resilience to reduce the damage level of opportunistic behavior. If prevention ability is increased, its efficiency is lower than that of its prevention ability and has no effect on the prevention and control of opportunistic behavior.

However, more manufacturers have indicated that enhancing the prevention ability of resilience has a substantial positive effect on the prevention and control of opportunistic behavior. If the prevention ability of resilience is increased, its efficiency is better than that of its recovery ability. Related studies, such as those by Pereira et al. and Brown and Badurdeen [17, 18], have also found that real-world enhancement of resilience is used to prevent and control opportunistic behavior. Therefore, enhancing the prevention ability of resilience is related to controlling opportunistic behavior. When the prevention ability of resilience is enhanced, opportunistic behavior by suppliers can be effectively prevented and controlled. Therefore, we developed the following hypothesis:

H1. When the prevention ability of resilience is enhanced, opportunistic behavior by suppliers can be prevented and controlled.

### 2.2 Lean and resilience

Lean is a business model that originated with Toyota Production Systems (TPS) that first came to be known in Western countries as "just-in-time" (JIT) manufacturing [19]. In the 1980s, researchers at the Massachusetts Institute of Technology coined the term "lean" to describe the simplicity of some car assembly plants, with Toyota being the best example [20]. Lean focuses on the elimination of everything that does not add value to the product and therefore is considered a "waste" of resources, such as overproduction, wait for time, transport, overprocessing, inventory, unnecessary motion, defects, and rework [21], to deliver quality products at a low cost with high productivity [22]. Studies, such as those by Kalyar et al. and Yu et al. [23, 24], argue that the practice of lean depends on related means or tools, including employees' involvement, pull production, elimination of waste, and 5S or total productive maintenance (TPM). Through lean, redundancy resources will be eliminated and reduce related costs and operational efficiency will also be promoted.

However, how can resilience prevention be enhanced through lean? The critical factor is supplier management robustness. A few successful cases indicate that promotion of the pull production process and driving employee involvement can enhance supplier management robustness. However, why do these two mechanisms have a positive effect on promoting supplier management robustness and further enhancing the prevention ability of resilience? We contemplate the following dynamics:

1. Enhancing responsible purchasing: Responsible purchasing means that every supplier needs to bear responsibility for tracking material quality, maintaining replenishment efficiency, and ensuring stable purchasing sourcing [25]. Lean elicits and avoids redundant production activities. When improving pull production, the supplier is required to bear the purchase responsibility to strengthen the purchasing process and avoid redundant production activities due to purchasing problems with raw material. When responsible purchasing is enhanced, supplier management robustness can be strengthened. Therefore,

according to Carvalho et al. and Azadegan et al. [26, 27], if any supplier exhibits an opportunistic behavior that could affect production efficiency and cause pollution to increase, it is easy to catch due to responsible purchasing. Thus, responsible purchasing becomes an inhibitor to prevent and control the appearance of opportunistic behavior. Based on the above, responsible purchasing has a positive effect on the prevention ability of resilience [28].

2. Enhancing emergency-response ability: Emergency-response ability means that manufacturers or suppliers can respond immediately or even control for damage before it is caused [29]. Lean thinking encourages all employees of manufacturers and suppliers to continually become involved [30, 31] in promoting pull production. To ensure that continuous involvement produces a positive effect, employees need to be trained. Training improves employees' ability to respond to emergencies. Sabadka [32] indicated that when adopting a training programme to promote employee involvement, the emergency-response ability of employees will increase. When a supplier exhibits opportunistic behavior, any employee from a manufacturer or another supplier can be immediately aware of the behavior and respond, even controlling damage before it is caused [33]. Based on the above, enhancing emergency-response ability is deemed to strengthen supplier management robustness and further enhance the prevention ability of resilience [34, 35].

3. Enhancing manufacturing process coupling: Manufacturing process coupling is defined as deployed with manufacturers' and suppliers' processes [36]. According to Ugochukwu et al. [37], to avoid inventory and overproduction and raw material waste and improve just-in-time results, pull production pushes the accumulation of inventory control in the different manufacturing process levels and production process linking suppliers and manufacturers to enhance production efficiency. Therefore, the coupling of the manufacturing process between manufacturers and suppliers is enhanced and shows a closer linkage [38]. At that time, production operations between manufacturers and suppliers will be a staggered arrangement, which will enhance supplier management robustness [39]. However, enhancing manufacturing process coupling may have an indirect positive effect on resilience. The process between manufacturers and suppliers is complex; if that process can become strongly coupled, it can be deemed that manufacturers expand their control power to the supplier. Manufacturers can deeply understand any situation from suppliers, shorten the time to respond to immediate related problems from suppliers, and further control the response to those problems [40], which is similar to promoting the positive effect of emergency-response ability on enhancing the prevention ability of resilience [41, 42].

Based on the above, three hypotheses are developed to explore our first research question.

H2a: Establishing responsible purchasing has a positive effect on enhancing the prevention ability of resilience.

H2b: Enhancing emergency-response ability has a positive effect on enhancing the prevention ability of resilience.

H2c: Enhancing manufacturing process coupling has a positive effect on enhancing emergency-response ability.

### 2.3 Synergy of combination with audit

According to the Oxford dictionary, an audit is defined as a systematic review or assessment [43]. In the past, the concept of an audit has usually been applied in the quality management field, and its purpose is to self-assess to allow continuous improvement to further ensure that the system, process, or product satisfies requirements or criteria [44]. Recently, the concept of audit mechanisms has also been implemented in green improvement. When an audit mechanism is applied to the green improvement field, its purpose is to measure the performance of pollution-prevention activities [45, 46].

With the practice of lean proven to have a positive effect on green environmental improvements, an increasing number of studies, such as those by de Freitas et al. and Leong et al. [47, 48], have found that combining audits can produce synergy to promote green environmental development. Audits can help manufacturers assess and monitor lean processes, avoid any redundant activities causing pollution emissions, and further prevent and control pollution. The audit process can be divided into two phases, including the development of prevention standards or criteria and follow-up and assessment [49]. The development of prevention standards is beforehand work, and suppliers or partners are required to follow. Then, under lean practices, follow-up suppliers or partners follow the standards or criteria. In addition, manufacturers play the role of leader auditors to assess whether these suppliers and partners attend to and obey these standards or criteria. When these two phases are combined with lean, it is similar to the monitoring process of lean practice efficiency in green environmental improvement [50].

Pull production and employee involvement are two important mechanisms in lean practice. This study believes that these two mechanisms can promote supplier management robustness and further enhance resilience to prevent and control opportunistic behavior by suppliers to avoid sustainable disruptions. According to the experiences of a few successful cases, if lean is combined with audits, it can produce positive synergy to strengthen the practice of pull production and employee involvement and have a positive effect on enhancing the prevention ability of resilience. However, why these effects occur requires an understanding of the following dynamics:

1. Development of standards and criteria to control dysfunctional behavior. Dysfunctional behavior is a resistance phenomenon [51, 52] that derives from a conflict of interest. The appearance of opportunistic behavior is based on profit orientation. Pull production and employee involvement can enhance manufacturing process coupling, responsible purchasing, and emergency-response ability to restrain these opportunistic behaviors. However, though they can be restrained, these factors are hard to control further. According to Feld [53], designing the standards and criteria of audits is based on real demand and decisions about the environment. Through these standards and criteria, suppliers will be able to understand their opportunistic behaviors that cause risk and could lead to serious damage which makes it difficult for these suppliers to obtain more profit. Therefore, this strategy can control their dysfunctional behavior. When dysfunctional behavior is controlled, it can ensure the enhancement of manufacturing process coupling, responsibility purchasing, and emergency-response ability to produce better effects [54–56], further strengthening resilience to prevent and control opportunistic behavior. Based on the above, we develop the following three hypotheses to explore.

H3a: Control of dysfunctional behavior through the development of standards and criteria will strengthen responsible purchasing.
H3b: Control of dysfunctional behavior through the development of standards and criteria will strengthen emergency-response ability.
H3c: Control of dysfunctional behavior through the development of standards and criteria will strengthen manufacturing process coupling.

2. Follow-up and assessment will trigger a trade-off. Although the purpose of follow-up and assessment is to establish a process to help and guide suppliers to follow related standards and criteria to cooperate in improving pull production and employee involvement, follow-up and assessment processes trigger supplier trade-off [57, 58]. Specifically, under the follow-up and assessment process, manufacturers have the responsibility to help suppliers to understand that they will encounter related risks and lose related benefits. As a reminder of the previous discussion, the appearance of opportunistic behavior comes from a concern about losing profit and not bearing related costs. Therefore, the process of follow-up and assessment is a chance to communicate thoroughly with suppliers about delivery risks and strengthen cooperative intentions to maintain suppliers' benefits [59]. Based on the above, audits will trigger a trade-off in risks and benefits that will guide suppliers to self-control opportunistic behavior and heighten their intention to cooperate in enhancing supplier management robustness [57, 60, 61]. Trade-off enhances the control effect of dysfunctional behavior. Therefore, we develop the following three hypotheses to explore.

H4a: Triggering of a trade-off has a mediating effect on the control of dysfunctional behavior and the enhancement of responsible purchasing.
H4b: Triggering of a trade-off has a mediating effect on the control of dysfunctional behavior and the enhancement of emergency-response ability.
H4c: Triggering of a trade-off has a mediating effect on the control of dysfunctional behavior and the enhancement of manufacturing process coupling.

### 2.4 Theoretical framework

According to the related literature review and hypotheses development, this study develops the theoretical framework shown in **Figure 1**. In line with **Figure 1**, this study further tests the path relationships amongst the prevention ability of resilience, prevention and control of opportunistic behavior, enhancement of manufacturing process coupling, the establishment of a responsible purchasing process, emergency-response ability training, control of dysfunctional behavior, and triggering of a trade-off. Through the verification of our theoretical framework, we can explore and explain our research questions.

## 3. Materials and methods

### 3.1 Questionnaire, operationalization and variables of the constructs, data collection, and sample profile

To test our research hypotheses and further explore our theoretical framework, this study utilizes survey-based empirical data from Chinese manufacturers. As part

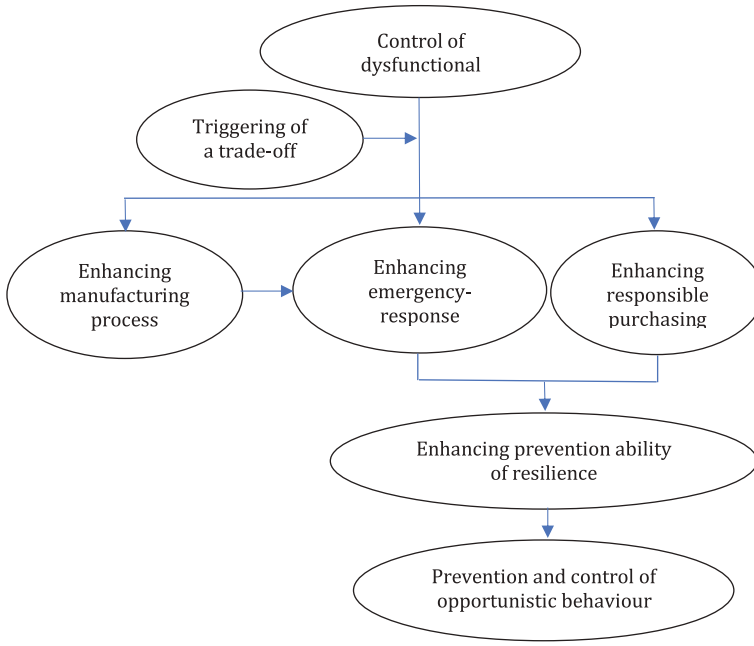


**Figure 1.**
*Theoretical framework.*

of a broader research project, a cross-sectional survey instrument was first designed. In line with the theoretical framework described in **Figure 1**, the questionnaire encompasses seven constructs, including enhancing the prevention ability of resilience, prevention and control of opportunistic behavior, manufacturing process coupling, responsible purchasing processes, and emergency-response ability; controlling dysfunctional behavior; triggering trade-off. According to related studies, we defined the operationalization of each construct and its related variables. These variables became the items or questions in the questionnaire, as shown in **Table 1**.

Based on the questionnaire, we attempted to collect related empirical data. Questionnaires were sent to 373 manufacturing companies in China. We received 231 valid responses, for a response rate of 61.93%. To characterize the profile of the companies in the sample, we investigated three characteristics—enterprise size, product type, and age of implementation of lean and audit for the promotion of supplier management robustness and resilience. According to aggregated results, the characteristics of the respondents are shown in **Table 2**.

### 3.2 Method

Partial least squares (PLS) analysis is a convenient method for estimating path relationship models with latent variables while including mediation effects. Because the theoretical framework of this study involves many path relationships and mediation effects, PLS is adopted as the main method to test our theoretical framework and hypotheses.

In PLS analysis, bootstrapping is used to test the statistical significance of the hypothesized relationships. The bootstrapping procedure entails generating 5000

| Constructs | Variables | Operationalization | Citation source |
|---|---|---|---|
| 1. Through pull production, will the following indices be enhanced significantly and further promote manufacturing process coupling between your company and suppliers? | | | |
| Enhancing of manufacturing process coupling (M) | M1. Efficiency of VMI and Kanban system | Manufacturing process coupling is deployed with suppliers' processes through pull production | [36, 62] |
| | M2. Efficiency of manufacturing information integration | | |
| | M3. Efficiency of production modules integration between manufacturers and suppliers | | |
| 2. When improving pull production, will the following indices be enhanced significantly and further promote the supplier's responsible purchasing? | | | |
| Enhancing of responsible purchasing (P) | P1. Enhancing of purchasing quality of raw material<br>P2. Every supplier has stable purchasing sourcing<br>P3. Every supplier can achieve stable replenishment<br>P4. Every supplier can provide stable inventory planning | Supplier bears the responsibility to track material quality, maintain replenishment, and ensure stable sourcing | [63, 64] |
| 3. Through the promotion of employee involvement, will the following indices be enhanced significantly and further promote your company's emergency-response ability? | | | |
| Enhancing of emergency-response ability (E) | E1. Enhanced forecasting of the damage path when a supplier exhibits opportunistic behavior | Emergency-response ability means that manufacturers can respond immediately and even control damage before it is caused | [65, 66] |
| | E2. Your company can immediately assess the possible damage level and balk early when a supplier exhibits unusual behavior | | |
| | E3. Your company can immediately identify possible damage sourcing and balk early when a supplier exhibits unusual behavior | | |
| | E4. Your company can immediately adjust production operations to reduce the effects when a supplier exhibits unusual behavior | | |
| 4. Can opportunistic behavior by suppliers be prevented and controlled by observing the following situation? | | | |
| Prevention and control of opportunistic behavior (C) | C1. Realizing that a supplier's promised cooperation is usually late | Manufacturers can observe which situation to prevent and control the supplier's opportunistic behavior | [67] |
| | C2. Observing whether a supplier breaches the agreed-upon cooperation to maximize its own benefit | | |
| | C3. Observing whether a supplier takes advantage of accidents to make compromises | | |
| 5. Which capability should be enhanced if a company hopes to obtain greater prevention ability of resilience? | | | |

| Constructs | Variables | Operationalization | Citation source |
|---|---|---|---|
| Enhancing the prevention ability of resilience (R) | R1. Enhancing process monitoring capability | Resilience can be defined as the ability of a system to prevent and recover from disruptions with negative effects and unpredictable risk events and return to a better situation | [65, 66, 68] |
| | R2. Possessing the capability to detect unusual behavior in the pre-crisis stage | | |
| | R3. Enhancing the early response capability to any possible accidents | | |
| 6. Under the audit process, develop and require that the supplier abides by standards and criteria that ensure and control for supplier behavior that is necessary for lean practice. However, how does the development of standards and criteria control the certainty of supplier cooperation with lean practice? | | | |
| Control of dysfunctional behavior (D) | D1. Control of resistance to cooperation | Try to control the resistance phenomenon and raise cooperation intention, cognition, and awareness | [69] |
| | D2. Control of intention to cooperate | | |
| | D3. Control of cooperation cognition | | |
| 7. Under the audit process, follow up and assess whether the supplier follows the standards and criteria related to cooperating with a lean practice that is important at a given stage. However, how can the follow-up and assessment enhance the certainty that the supplier will cooperate with lean practice? | | | |
| Triggering of a trade-off (T) | T1. Supplier begins to think of the risk of opportunistic behavior | Trigger the trade-off in risk and benefit and guide supplier to self-control the opportunistic behavior | [8, 17] |
| | T2. Supplier is aware that opportunistic behavior will lead to unstable profits | | |
| | T3. Supplier understands that opportunistic behavior is undesirable if it hopes to increase its profits through stable cooperation | | |

**Table 1.**
*Questionnaire content, operationalization, variables of each construct, and citation source.*

subsamples of randomly selected cases with replacement. Under the analysis process, the path coefficients are generated for each randomly selected subsample, and the t-value is calculated for every coefficient. According to the calculation results, the path coefficient and t-value are statistically significant and applied to evaluate the research hypotheses. As the analysis tool, we used SmartPLS 3.0.

In addition to PLS, we also used the Sobel test to verify the mediating effect. According to Hayes [70], a large sample may cause an error in evaluating the mediation effect when PLS is used for testing. However, the Sobel test can overcome this problem. For verification, Preacher and Leonardelli developed a free tool to perform the Sobel test. The test results verify the mediating effect. The tool is provided on the lab website of Preacher and Leonardelli.

However, to first test the theoretical framework and hypotheses with PLS, the validity and reliability of the constructs should be tested. To measure validity and reliability, factor loadings, composite reliability (CR), average variance extracted (AVE), and discriminant validity are the main indices. Regarding the requirements of the indices, the factor loadings should exceed 0.4 [71]; the CR and AVE should exceed 0.7 and 0.5 [72]. An exception is that if AVE is lower than 0.5 but higher than 0.36 and CR is above 0.7, then the situation can be accepted [73]. Discriminant validity is

| Characteristics | Profiles |
|---|---|
| Enterprise size (number of employees) | Up to 100 = 4.33%<br>Between 101 and 300 = 28.57%<br>Between 301 and 500 = 30.3%<br>Between 501 and 1000 = 24.68%<br>Above 1000 = 12.12% |
| Type of product | Manufacture of Smart Grid and Intelligent Electrical Apparatus = 23.81%<br>Manufacture of fabricated metal products, except machinery and equipment = 21.21%<br>Manufacture of computer, electronic and optical products = 14.72%<br>Manufacture of electrical equipment = 3.46%<br>Manufacture of motor vehicles, trailers, and semi-trailers = 5.63%<br>Manufacture of other components = 22.08%<br>Others = 9.09% |
| Age of implementation of lean and audit | Under 1 year = 6.06%<br>1 year to 3 years = 37.23%<br>3 years to 5 years = 28.14%<br>5 years to 7 years = 14.29%<br>Over 7 years = 14.29% |

**Table 2.**
*Sample profiles.*

adopted to measure whether each construct can be discriminated from others' constructs. Therefore, the correlation between the constructs should be tested. If the correlation value is lower than 0.7, then every construct can be discriminated [73].

Finally, the model's goodness of fit should be measured. Regarding goodness of fit, the standardized root-mean-square residual (SRMR) is used as the main index. The SRMR was initially proposed for use in combination with CB-SEM, but it has also been extended to PLS. The SRMR is reported to be an approximate measure of model goodness of fit and has been widely adopted for this purpose. Thus, SRMR is adopted to measure the model's goodness of fit.

## 4. Test results

### 4.1 Construct measures

Before testing the hypotheses, we test the validity and reliability of the constructs and discriminant validity. According to **Table 3**, all the factor loadings exceed 0.4. Therefore, the factor loadings satisfied the requirement. Regarding CR, according to **Table 3**, all the CR values exceed 0.7. Regarding AVE, the AVE values for the prevention and control of opportunistic behavior and triggering of a trade-off are higher than 0.5 and satisfy the measurement requirements. However, the values of enhancing manufacturing process coupling, responsible purchasing, emergency-response ability, and the prevention ability of resilience, as well as controlling dysfunctional behavior, are less than 0.5 but higher than 0.36. As noted by Fornell and Larcker [73], this situation may still be considered acceptable. Next, we test for discriminant validity. According to **Table 4**, the correlation values between constructs are lower than 0.7, and the test results satisfy the requirements.

| Constructs | Variables | Factoring loading | CR | AVE |
|---|---|---|---|---|
| Enhancing of manufacturing process coupling (M) | M1 | .532 | .707 | .448 |
| | M2 | .681 | | |
| | M3 | .785 | | |
| Enhancing of responsible purchasing (P) | P1 | .570 | .739 | .414 |
| | P2 | .612 | | |
| | P3 | .717 | | |
| | P4 | .673 | | |
| Enhancing of emergency-response ability (E) | E1 | .681 | .732 | .410 |
| | E2 | .618 | | |
| | E3 | .658 | | |
| | E4 | .616 | | |
| Prevention and control of opportunistic behavior (C) | C1 | .805 | .824 | .610 |
| | C2 | .769 | | |
| | C3 | .769 | | |
| Enhancing of prevention ability of resilience (R) | R1 | .749 | .719 | .462 |
| | R2 | .652 | | |
| | R3 | .634 | | |
| Control of dysfunctional behavior (D) | D1 | .579 | .704 | .429 |
| | D2 | .797 | | |
| | D3 | .570 | | |
| Triggering of a trade-off (T) | T1 | .798 | .783 | .547 |
| | T2 | .686 | | |
| | T3 | .733 | | |

**Table 3.**
*Construct measures assessment: composite reliability and convergent validity.*

| | Mean | SD | (M) | (P) | (E) | (C) | (R) | (D) |
|---|---|---|---|---|---|---|---|---|
| (M) | 3.945 | .549 | | | | | | |
| (P) | 3.930 | .551 | .402 | | | | | |
| (E) | 3.986 | .513 | .338 | .332 | | | | |
| (C) | 3.856 | .785 | .539 | .409 | .489 | | | |
| (R) | 4.196 | .482 | .405 | .268 | .467 | .473 | | |
| (D) | 4.003 | .531 | .278 | .182 | .409 | .297 | .487 | |
| (T) | 4.133 | .589 | .454 | .358 | .406 | .412 | .521 | .437 |

**Table 4.**
*Discriminant validity (correlation).*

### 4.2 Estimation of the theoretical framework

The PLS analysis test results are shown in **Table 5**. This table shows the path coefficients, results of the t-statistics value, and an explanation of the construct variances. In terms of the construct variances, we find that each of the endogenous variables is adequate, explaining 20% of the variance for enhancing manufacturing

| | Hypotheses | Path coefficient | t-value | Results |
|---|---|---|---|---|
| H1 | Enhancing of responsible purchasing ➜ Enhancing of prevention ability of resilience | .487 | 9.354** | Supported |
| H2a | Enhancing of emergency-response ability ➜ Enhancing of prevention ability of resilience | .310 | 4.206** | Supported |
| H2b | Enhancing of manufacturing process coupling ➜ Enhancing of emergency-response ability | .321 | 4.377** | Supported |
| H2c | Control of dysfunctional behavior ➜ Enhancing of responsible purchasing | .195 | 3.230** | Supported |
| H3a | Control of dysfunctional behavior ➜ Enhancing of emergency-response ability | .193 | 2.690** | Supported |
| H3b | Control of dysfunctional behavior ➜ Enhancing of manufacturing process coupling | .385 | 6.097** | Supported |
| H3c | Control of dysfunctional behavior ➜ Triggering of a trade-off | .301 | 4.450** | Supported |
| H4a | Triggering of a trade-off ➜ Enhancing of responsible purchasing | .454 | 7.892** | Supported |
| | Control of dysfunctional behavior ➜ Triggering of a trade-off | .318 | 3.446** | |
| H4b | Triggering of a trade-off ➜ Enhancing of emergency-response ability | .454 | 7.892** | Supported |
| | Control of dysfunctional behavior ➜ Triggering of a trade-off | .168 | 2.093* | |
| H4c | Triggering of a trade-off ➜ Enhancing of manufacturing process coupling | .454 | 7.892** | Supported |
| | Enhancing of responsible purchasing ➜ Enhancing of prevention ability of resilience | .221 | 3.145** | |
| **Variance explained in the endogenous variables** | | | | |
| | Enhancing of manufacturing process coupling | $R^2$ = .200 | | |
| | Enhancing of responsible purchasing | $R^2$ = .194 | | |
| | Enhancing of emergency-response ability | $R^2$ = .356 | | |
| | Enhancing of prevention ability of resilience | $R^2$ = .297 | | |
| | Prevention and control of opportunistic behavior | $R^2$ = .237 | | |
| | Triggering of a trade-off | $R^2$ = .206 | | |
| **Model fit** | | | | |
| | SRMR | .087 | | |

*p < .05.
**p < .01.

**Table 5.**
*PLS structural model results.*

process coupling, 19.4% of the variance for enhancing responsible purchasing, 35.6% of the variance for enhancing emergency-response ability, 29.7% of the variance for enhancing the prevention ability of resilience, 23.7% of the variance for preventing and controlling opportunistic behavior, and 20.6% of the variance for triggering trade-off.

Regarding the test results of the hypotheses, the path coefficient for the relationship between the enhancement of resilience and the prevention and control of opportunistic behavior is 0.487 ($p < .01$); thus, enhancing the prevention ability of resilience has a positive effect on the prevention and control of opportunistic behavior, which supports H1. The path coefficient for the relationship between enhancing responsible purchasing and enhancing the prevention ability of resilience is 0.310 ($p < .01$); thus, enhancing responsible purchasing has a positive effect on enhancing the prevention ability of resilience, which supports H2a. H2b is supported because the path coefficient is 0.321 ($p < .01$); thus, enhancing emergency-response ability has a positive effect on enhancing the prevention ability of resilience. The path coefficient for the relationship between enhancing manufacturing process coupling and enhancing emergency-response ability is 0.195 ($p < .01$); thus, enhancing manufacturing process coupling has a positive effect on enhancing emergency-response ability, which supports H2c.

The path coefficients for the relationship between the control of dysfunctional behavior, enhancement of responsible purchasing, enhancement of emergency-response ability, and enhancement of manufacturing process coupling are 0.193 ($p < .01$), 0.385 ($p < .01$), and 0.301 ($p < .01$); thus, the control of dysfunctional behavior has a positive effect on enhancing responsible purchasing, enhancing emergency-response ability, and enhancing manufacturing process coupling, which supports H3a, H3b, and H3c. The path coefficient for the relationship between the control of dysfunctional behavior and the triggering of a trade-off is 0.454 ($p < .01$), the path coefficients for the relationship between the triggering of a trade-off and the

| Input: | | Test statistic: | Std. Error: | p-value: |
|---|---|---|---|---|
| $a$ 0.454 | Sobel test: | 48.19392924 | 0.00299565 | 0 |
| $b$ 0.318 | Aroian test: | 48.19254578 | 0.00299573 | 0 |
| $s_a$ 0.00375 | Goodman test: | 48.19531282 | 0.00299556 | 0 |
| $s_b$ 0.006053 | Reset all | Calculate | | |

Mediating effect of the triggering of a trade-off in the relationship between control of dysfunctional behavior and enhancing of responsible purchasing. The Sobel test result is 48.194 ($p < .01$).

| Input: | | Test statistic: | Std. Error: | p-value: |
|---|---|---|---|---|
| $a$ 0.454 | Sobel test: | 30.86061235 | 0.0024715 | 0 |
| $b$ 0.168 | Aroian test: | 30.85962805 | 0.00247158 | 0 |
| $s_a$ 0.00375 | Goodman test: | 30.86159675 | 0.00247142 | 0 |
| $s_b$ 0.005264 | Reset all | Calculate | | |

Mediating effect of the triggering of a trade-off in the relationship between the control of dysfunctional behavior and enhancing of emergency-response ability. The Sobel test result is 30.861 ($p < .01$).

| Input: | | Test statistic: | Std. Error: | p-value: |
|---|---|---|---|---|
| $a$ 0.454 | Sobel test: | 44.60555141 | 0.00224936 | 0 |
| $b$ 0.221 | Aroian test: | 44.60423639 | 0.00224943 | 0 |
| $s_a$ 0.00375 | Goodman test: | 44.60686655 | 0.00224929 | 0 |
| $s_b$ 0.004606 | Reset all | Calculate | | |

Mediating effect of the triggering of a trade-off in the relationship between the control of dysfunctional behavior and enhancing of manufacturing process coupling. The Sobel test result is 44.606 ($p < .01$).

**Table 6.**
*Sobel test results.*

enhancing of responsible purchasing with enhancing emergency-response ability and enhancing manufacturing process coupling are 0.318 ($p < .01$), 0.168 ($p < .05$), and 0.221 ($p < .01$), respectively; thus, we find that the triggering of a trade-off has mediating effects on the relationships between controlling dysfunctional behavior and enhancing responsible purchasing, enhancing emergency-response ability, and enhancing manufacturing process coupling, which supports H4a, H4b, and H4c, respectively. In terms of measuring model fit, the SRMR is the main index used. According to the test, the SRMR is 0.087, and the model fit can be accepted.

This study also adopts the Sobel test to verify mediating effects, and the test results are shown in **Table 6**. According to **Table 6**, the test results of the p-value for hypotheses H4a, H4b, and H4c are lower than 0.01, which means that the mediating effect of the triggering of a trade-off exists and has a positive effect on the relationships between the control of dysfunctional behavior, enhancing of responsible purchasing, enhancing of emergency-response ability, and enhancing of manufacturing process coupling.

## 5. Discussion

This section discusses the test results and answers further research questions. The first question is, how do manufacturers make good use of pull production and employee involvement under lean practices that can strengthen supplier management robustness and enhance the ability of resilience to prevent and control opportunistic behavior by suppliers? Our test results indicate that because the good use of pull production and employee involvement under lean practices enhances responsible purchasing and emergency-response ability to promote supplier management robustness, this practice has a positive effect on enhancing the prevention ability of resilience and further proves and controls opportunistic behavior by suppliers. Specifically, enhancing responsible purchasing is much like attributing responsibility. If a supplier exhibits opportunistic behavior based on a profit orientation, its purchasing efficiency will appear unusual and its purchasing quality will decrease, which will indirectly cause an increase in pollution. Due to the attribution of responsibility, each supplier has its own responsible purchase sourcing and needs to bear responsibility for its raw material quality; as a result, manufacturers can quickly become aware of opportunistic behavior by suppliers, which produces a warning effect and restrains any intention of opportunistic behavior. This is just like strengthening supplier management robustness and can be deemed that the prevention ability of resilience is enhanced.

The enhancement of emergency-response ability is based on the promotion of employee involvement. To ensure that lean practices are followed, lean usually encourages employee involvement. To promote involvement efficiency, manufacturers usually design related training programmes. In addition to employees from manufacturers, employees from related suppliers also need to be trained. Through effective training, employees from manufacturers and suppliers can come to possess rich knowledge and cognition not only to improve lean practices and their response-ability but also to increase them [74]. A few researchers, such as Minh et al. [75], have found that increasing response-ability has a positive effect on supplier management. Therefore, when a supplier exhibits opportunistic behavior, employees of manufacturers and other suppliers can adopt emergency responses and further control. Therefore, it can be deemed that supplier management robustness is strengthened and has a positive effect on enhancing the prevention ability of resilience.

Pull production also enhances manufacturing process coupling. When a complex process between manufacturers and suppliers is an effective coupling, it has a positive effect on the promotion of emergency-response ability. More employees of manufacturers or other suppliers will have the chance to intervene in the manufacturing process. Therefore, when any supplier exhibits unusual behavior, employees of manufacturers or other suppliers become aware of this behavior faster and can thus prevent or control it more quickly. Based on the above, manufacturing process coupling can be deemed to have a positive effect on strengthening supplier management robustness and indirectly enhancing the prevention ability of resilience. Therefore, manufacturers make good use of pull production and employee involvement under lean practices that can strengthen supplier management robustness and enhance resilience to prevent and control opportunistic behavior.

The second research question is why does the combination of lean practice with an audit mechanism strengthen the practice effect of pull production and employee involvement and produce synergy to strengthen the prevention ability of resilience and further control opportunistic behavior by suppliers? Developing related standards and criteria and improving follow-up/assessment are two important aspects of the audit process. These standards and criteria are guidelines that guide suppliers to cooperate with the practices of pull production and employee involvement. When suppliers fully follow these guidelines, their emergency-response ability, responsible purchasing, and manufacturing process coupling will be enhanced. The development of these standards and criteria is based on real situational demands. However, before requiring suppliers to follow these guidelines, manufacturers as auditors have the responsibility to explain these standards and criteria and help suppliers to understand efficiency and how they can maintain profits by following these standards and criteria to improve pull production and employee involvement [76]. Actually, the appearance of opportunistic behavior is based on profit orientation. For the appearance of opportunistic behavior, the supplier must exhibit some dysfunctional behavior during the cooperation process. If suppliers can understand the positive efficiency of these standards and criteria and ensure that their profits can be maintained, these standards and criteria can control suppliers' dysfunctional behavior and further eliminate opportunistic behavior [77].

However, to ensure that these suppliers can fully follow these standards and criteria, manufacturers usually play the role of auditors in follow-up and assessment. Under the follow-up and assessment process, manufacturers have the responsibility to communicate with suppliers and help them to understand the risk of opportunistic behavior and the potential damage to profits. In the real world, considerations of profit maintenance certainly trigger a trade-off mindset in terms of risk and profit. According to Bahr and Sweeney [78], this is a powerful influence that guides suppliers to follow the standards and criteria that improve pull production and employee involvement and eliminate opportunistic behavior. Based on the above, this is why combining audit mechanisms with lean practices can strengthen the practice of pull production and employee involvement and enhance the preventive ability of resilience to deal with opportunistic behavior by suppliers.

## 6. Conclusion

To enhance the prevention ability of resilience to deal with opportunistic behaviors by suppliers and further maintain effective sustainability, this study explored two

research questions: How do manufacturers make good use of pull production and employee involvement under lean practices that can strengthen supplier management robustness and enhance the prevention ability of resilience to deal with opportunistic behavior? Why does the combination of lean with an audit mechanism strengthen the practice effect of pull production and employee involvement and even produce synergy to prevent and control opportunistic behavior by suppliers?

According to the test results, effective practice of pull production and employee involvement can enhance responsible purchasing, emergency-response ability, and manufacturing process coupling and further strengthen supplier management robustness, which enhances the prevention ability of resilience to deal with opportunistic behavior. In addition, enhancing manufacturing process coupling has an indirect effect, strengthening emergency-response ability and further enhancing the prevention ability of resilience. The audit mechanism can control the dysfunctional behavior of the supplier, further guiding cooperation with the practice of pull production and employee involvement; in addition, audits trigger the supplier's trade-off mindset in terms of risk and profit maintenance. Based on the prior discussion, this trade-off mindset can enhance the ability of resilience to prevent and control opportunistic behavior.

Regarding the academic implications of this study, although some conflict exists between lean and resilience, our research proved that if manufacturers make good use of pull production and employee involvement when implementing lean, it can enhance manufacturing process coupling, responsible purchasing, and emergency-response ability; strengthen supplier management robustness; further enhance the ability of resilience to prevent and control opportunistic behavior. Therefore, our research results provide a new vision and expand research knowledge on the relationship between lean and resilience. In terms of practical implications, our research results can help manufacturers to understand the importance of the practice of pull production and employee involvement under lean practices and guide manufacturers to think about how to establish an effective audit process and environment to strengthen the practice efficiency of pull production and employee involvement to enhance the prevention ability of resilience to deal with opportunistic behavior by suppliers.

Although our research results provide many valuable suggestions, there are a few limitations. First, although the research results explained how the practice of pull production and employee involvement under lean practices can enhance resilience to maintain sustainable supplier management, how to effectively practice these two mechanisms has not been explored. In addition, the research results clarified why the combination of lean and audits can produce synergy for enacting resilience; however, a method to design an effective audit process is also lacking. Future research can explore these two limitations in greater depth.

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## Conflict of interest

The authors declare no conflict of interest.

## Author details

Ping-Kuo Chen*, Qiu-Rui He and Xiang Huang
Shantou University, Shantou City, China

*Address all correspondence to: a1104100@ms23.hinet.net

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