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CHALLENGES WITH INDUSTRALIZATION IN A SUPPLY CHAIN NETWORK: A SUPPLIER PERSPECTIVE

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Abstract:
The purpose of this study is to explore the challenges with industrialization across a supply chain network, from a supplier perspective. The study focuses on identifying the challenges encountered by the supplier, when working with industrialization alongside the customer's industrialization process, the reasons for and the effects of these challenges, as well as how these challenges can be managed. These issues have been examined through a single case study including a Swedish company from the polymer systems and components industry. Empirical data has been collected through in-depth and semi-structured interviews. This study has identified fourteen challenges as well as their main reasons and effects. In addition, solutions to the challenges have been identified. The challenges can be classified as internal or external. An internal challenge originates from inside the supplier's own organization, while an external challenge originates from the customer's organization or from the collaboration between the two organizations. This study is explorative in nature and is limited to one supplier located in Sweden. Thus, empirical data from similar and other research settings should be gathered to reinforce the validity of the findings.

Keywords: industrialization; production ramp-up; supply chain; supplier

1. INTRODUCTION

Product realization is one of the most critical capabilities within a company. It is vital to develop new products with high quality, low cost, and in a short time to stay competitive (Surbier et al., 2013). Major role in this plays the production ramp-up or the final stage of product realization (Clark and Fujimoto, 1991). The goal of the ramp-up is to reach volume production as quick as possible, which in the end affects the product price and profitability. It is critical to ramp-up quickly to profitable volume production to reduce production costs and to ensure return on investment (Almgren, 1999). During the production ramp-up, many problems may occur, which usually can be traced back to activities conducted during the preceding industrialization stage (Fjällström et al., 2009). Thus, it may be helpful to adopt a holistic perspective and analyze the entire product realization process. The industrialization is concerned with the activities carried out to make it possible to produce the product in planned volumes to the customer (Bellgran and Safsten, 2010). The goal is to design and verify the production system in such a way that it is easy to reach profitable volume production. In other words, prepare for a successful production ramp-up (Almgren, 1999; Terwiesch, et al. 2001).

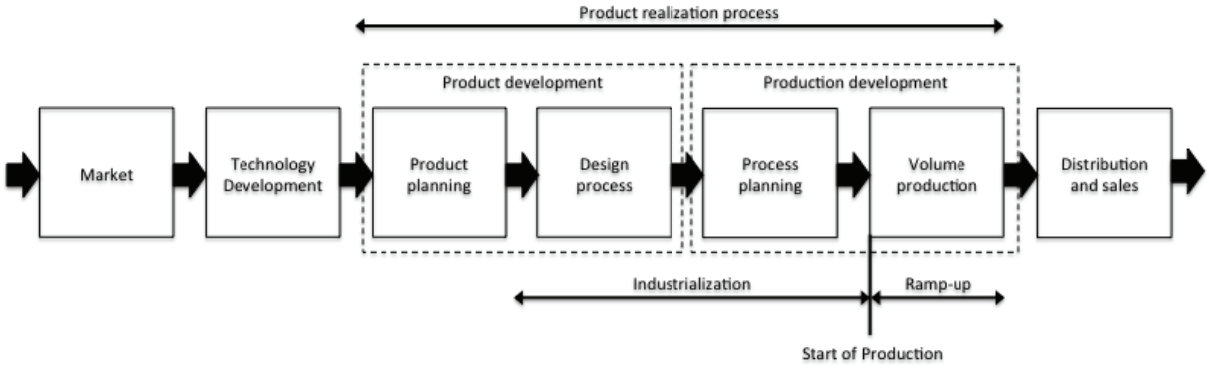
It is usually during the industrialization that the main decisions are taken and the agreements and relations with the suppliers are established. This means that the industrialization is not just an issue for the focal company, it also involves suppliers. Thus, industrialization is not a question of how to prepare for successful ramp-up within the focal company but rather across the whole supply chain network. Even if much research exists with regard to industrialization, the dimension of industrialization across a supply chain network has not been addressed to a greater extent (Raman and Chhajed, 1995; Carrillo and Franza, 2006). In addition, most of the research is conducted from an original equipment manufacturer (OEM) perspective (Surbier et al., 2013; Fjällström et al., 2009; Terwiesch and Bohn, 2001). Thus, it would be of particular interest to know more about the challenges with industrialization across a supply chain network, from a supplier perspective.

The purpose of this study is to explore the challenges with industrialization across a supply chain network, from a supplier perspective. The specific research questions are: (1) “What challenges are encountered by the supplier, when working with industrialization alongside the customer’s industrialization process”; (2) “What are the reasons for these challenges?”; (3) “What are the effects of these challenges?”; and (4) “How can these challenges be managed?”. These questions have been examined through a single case study including a Swedish company from the polymer systems and components industry.

2. LITERATURE REVIEW

The product realization usually is organized into a process consisting of several stages. Figure 1 shows an example of a product realization process, which has been divided into four stages: product planning, design process, process planning, and volume production. In the product planning stage, the initial market research is conducted. The idea is to transform customer demands into a product idea. In this stage, the scope and delimitations of the project also are formulated. In the design process stage, the actual product is designed and constructed based on the product idea while the production process and equipment for the manufacturing of the product are designed and constructed in the process planning stage. In the volume production stage, the product is transferred to production and the continuous production starts. The product realization process is ended when the start of production (SOP) has occurred, and volume production has been achieved, i.e. after production ramp-up (Bellgran and Säfsten, 2010).

Figure 1 – The product realization process (modified from Bellgran and Säfsten, 2010)



Product realization process is important not only for the coordination of the flow of new products internally at the OEM but also to define in what areas, when and how suppliers should be involved in the product development (Carillo and Franza, 2006). Thus, activities performed across organizational boundaries call for effective inter-organizational coordination (e.g. Lakemond et al. 2006; Twigg, 2002; Hartley et al., 1997) through among other things, clear project plans and detailed agreements (Wynstra et al., 2001). Wagner and Hoegl (2006) argue that achievement of supplier involvement and coordination during the product realization is challenging due to for example the need to overcome organizational difference (Tabrizi and Walleigh, 1997). Clear communication and trust are among the prevailing challenges mentioned by researchers (e.g. Wynstra et al., 2001) that have consequences for the mutual expectations and forming of agreements. Further, the degree of commitment of the supplier to the OEM is often associated with the agreed potential sales and hence can be challenging (McCutcheon et al., 1997). Some researchers discuss the importance of the timely involvement of suppliers and propose segmentation (e.g. Wynstra and ten Pierick, 2000). Moreover, the technical expertise of the suppliers and hence the selection of the right suppliers are also issues emphasized in the literature (e.g. Wagner and Hoegl, 2006). Therefore, clearly defined objectives, processes as well as well-established coordination mechanisms and procedures for supplier involvement are perceived as important by researchers (e.g. Ragatz et al., 1997; Lakemond et al., 2006; Wynstra et al., 2001).

3. RESEARCH METHOD

This research aims to explore the challenges with industrialization across a supply chain network from a supplier perspective. This issue is examined through a single case study. The case study was considered appropriate since this research analyzes contemporary events, in a complex setting in which the researcher has no control over the events (Yin, 2009). Case studies serve several purposes and fit the theory building approach of this research well (Voss et al., 2002). The research is mainly inductive since it tries to create explanations and descriptions based on observations (Smith, 1998). The case study is not a data collection method; it is rather a method for combining several data sources in a certain setting (Yin, 2009). Hence, it is not limited to the rigid restrictions of surveys and models (Voss et al., 2002), and can thus have a very high impact on theory development.

The case study includes a Swedish supplier from the polymer systems and components industry. The supplier develops, industrializes, and manufactures polymer systems and components. A polymer system refers to a more complex product consisting of several individual components that are integrated together into a complete system. The supplier works within three separate customer segments: Trucks, Industrial, and Medifarm. A majority of the supplier's products are aimed for the automotive industry since they have specialized themselves in heavy vehicles. The turnover is about 40 MEUR and they have more than 200 employees. The case company was chosen since their business is about industrialization as they develop polymer systems and components to be included in focal companies products.

The required data has been collected during the three-year period of 2013-2015, mainly from in-depth and semi-structured interviews with key persons involved in the industrialization process within the case company. The interviews lasted for 90-180 minutes and included people from various departments, such as logistics, purchasing, production, sales, marketing, and product development.

The data collection further included a review of secondary data, such as internal documentation and economic reports. The data collection and analysis resulted in a number of challenges as well as their main reasons, effects and possible solutions.

The quality of the research has been ensured by using multiple sources of evidence and by allowing key informants to review findings. Internal validity has been ensured by testing explanations derived from the findings, against rival explanations with informants as well as research colleagues. The external validity is ensured by the theoretical foundation of this study while case study reports ensure the reliability (Yin, 2009). The triangulation of data, methods and theory has contributed to the rigor, depth, and breadth of the results (Flick, 2009). This can be compared with validation (Yin, 2009), and also help the researcher to form a more whole understanding of the studied phenomenon (Scandura and Williams, 2000).

4. CASE ENVIRONMENT

The supplier's industrialization work is organized into a process consisting of three stages, the end of each stage being a gate or checkpoint. The industrialization process is project-oriented so each time it is initiated a new project is created. A cross-functional project team is responsible to make sure that a number of critical activities/tasks have been conducted by a responsible person and to evaluate the outcome before the industrialization project can pass on to the next stage. The project team is already established during the quotation process and consists of a project leader, a production engineer, a quality engineer, a tool purchaser, a key account manager, and the head of purchasing.

The first stage of the industrialization process (design) involves the design of the molding tool as well as the related production equipment that allow the component requested by the customer to be manufactured. Normally, the customer provides detail drawings and specifications of the component and the supplier is involved only in the design of the tool and the related production equipment. The design stage begins when the customer (project) order is received. The supplier begins to collect and analyze the customer provided drawings and specifications and then they have a design and contract review meeting together with the customer (project start-up). After the project start-up, the project management is initiated. Then, the molding tool and the related production equipment are designed. The production equipment is designed internally but the needed systems and components are procured from external sub-suppliers. The supplier uses external sub-suppliers to design and manufacture the molding tool. Much of this design work is prepared already during the quotation process, where the supplier prepares and sends molding tool and equipment inquires to sub-suppliers and assesses their offers. In this stage, molding tool and equipment orders are sent to the selected suppliers. In addition, the procurement of material and input components are prepared. An investment request is also made in this stage. The final steps of this stage are quality, production, and sales preparation.

The second stage of the industrialization process (production/assembly) involves the production of the molding tool and the assembly of the related production equipment. The production/assembly stage begins when the molding tool and the production equipment designs are finished. External suppliers, primarily located in low cost countries in Asia, manufacture the molding tool. Historically, all molding tools have been manufactured in Sweden but due to global competition and cost pressure, this is not feasible any longer. This implies that the final configuration of the molding tool and the related production equipment is delayed until the verified molding tool is delivered to Sweden. However, the assembly of the related production equipment starts already in this stage.

The third stage of the industrialization process (verification) involves the verification of the molding tool and the related production equipment. It is about ensuring that all components manufactured by the tool and the related production equipment follow the specifications. The verification stage begins when the molding tool and the related production equipment are ready. The tool is first verified separately at the tool manufacturer during several pre-production (improvement) rounds in collaboration with the customer. Each evaluation round takes around 5 to 6 weeks to complete, including 2 weeks for the tool manufacturer to modify the molding tool. After the molding tool is verified and approved it is delivered to the production plant in Sweden. The delivery time from Asia to Sweden is around 8 weeks (by boat). When the molding tool is delivered and set-up in Sweden it is the first time the component is produces in the correct production equipment. This is also where the fine-tuning of the production equipment takes place, and this could require some additional improvement rounds. When the final verification of the molding tool and the related production equipment is completed and approved

(PPAP - Production Part Approval Process), the component is transferred to the continuous (serial) production (sign-off approved), and the industrialization project is ended. When the industrialization project is ended, a follow-up is performed (lessons learned) and the actual cost is calculated in order to examine if it follows budget and if the product is still profitable to manufacture. The total lead-time from project order to sign-off (ready for SOP) is around 18 months but this includes no disturbances or customer modifications. The SOP occurs when the first batch in the serial production is manufactured. The production is in a ramp-up stage until the production targets are reached.

5. FINDINGS AND ANALYSIS

Fourteen challenges as well as their main reasons, effects and possible solutions have been identified (Table 1). The identified challenges include: (1) Readiness of the component design released by the customer, (2) Changes in the component design after tool order, (3) Time pressure in the customer's development project, (4) The customer's project planning and management, (5) Communication and agreement with the customer, (6) The transition from industrialization to continuous production, (7) PPAP agreement with the customer, (8) The customer request the tool to be moved from overseas supplier before the tool has been verified, (9) The project managers skills at the supplier, (10) Industrialization work model at the supplier, (11) Information exchange between the customer and the supplier, (12) Time of involvement in the customer's project, (13) The customer's forecast accuracy, and (14) Long-term performance of the final tool and the related production equipment,

Some of the identified challenges are also highlighted in the literature. To begin with, the importance of clear project plans and agreements between the customer and the supplier is emphasized in the literature (Wynstra et al., 2001), and this can be linked to challenges 3, 4, 5, and 7. Secondly, the importance of clear communication and trust between the customer and the supplier is highlighted in the literature (Wynstra et al., 2001), and this can be linked to challenges 5 and 11. Thirdly, the importance of timely involvement of suppliers is addressed in the literature (Wynstra and Hoegl, 2006), and this can be linked to challenge 12. Fourthly, the importance of well-defined objectives internally and between the customer and the supplier as well as the need of coordination mechanisms are stressed in the literature (Ragatz et al., 1997; Lakemond et al., 2006; Wynstra et al., 2001), and this can be linked to challenges 7, 8, 10, 11, and 14. Finally, the importance of overcoming organizational differences (e.g., understanding, priorities and motivation) is emphasized in the literature (Wynstra and Hoegl, 2006), and this is linked to challenge number 4.

The challenges can be classified as either internal or external. An internal challenges originates from inside the supplier’s own organization, while an external challenges originates from the customer’s organization or from the collaboration between the two organizations. Most of the identified challenges are external challenges. Consequently, companies should not solely focus on the internal activities and interfaces but also on the activities and interfaces between the actors in the supply chain.

Table 1 – The identified challenges with related reasons, effects and solutions

Challenges	Reasons	Effects	Solutions
(1) Readiness of the component design released by the customer (external)	(1) The customer's development projects are technology oriented; (2) The customer's designers focus on finding new innovative solutions without considering the manufacturability; (3) The customer's development projects have less focus on project planning and management; (5) Market competition forces the customer to reduce the development time.	(1) Longer development time due to many and late design changes, which in turn leads to time pressure; (2) Higher development costs; (3) Difficult to develop tools and related production equipment as conditions change all the time; (4) Less efficient tools and production equipment in the continuous production.	(1) Design freeze at a given time point; (2) Frequent and accurate information exchange between the customer and the supplier.
(2) Changes in the component design after tool order (external)	(1) The readiness of the component design, the released design seldom is the one manufactured in the end; (2) Outcome was not as predicted or desired *(engineering/field test results)*.	(1) Longer development time due to many and late design changes, which in turn leads to time pressure; (2) Higher development costs; (3) Less efficient tools and production equipment in the continuous production; (4) Continuous production starts before the industrialization is ended; (5) Tools modifications made in more costly environment; (6) Obsolete materials throughout the project.	(1) Design freeze at a given time point; (2) Frequent and accurate information exchange between the customer and the supplier; (3) Evaluate the manufacturability earlier in the project; (4) Develop tools in two steps *(prototype and final)*; (5) The supplier needs to communicate the impact on the ability to reach cost targets when the tool is moved from overseas supplier before it has been verified; (6) Design review meetings at the beginning of the project can reduce the number of design changes.
(3) Time pressure in the customer's development project (external)	(1) The customer has a fixed market deadline; (2) The customer does not take into account all the time needed for improvement rounds; (3) The customer has a short and unrealistic project lead-time and time plans; (4) The customer's efforts towards lead-time reduction are impossible to realize in practice; (5) The trade-off between offering realistic lead-time and competitiveness of the supplier's quotation.	(1) Higher development costs; (2) Transport mode not according to initial plan/quotation; (3) More expensive tool; (4) Higher unit costs.	(1) A more realistic time-plan including more time for improvement rounds; (2) Initiate development project earlier due to fixed market deadline.
(4) The customer's project planning and management (external)	(1) The customer and the supplier have very different views on the time needed to developing a tool and the related production equipment; (2) The customer estimate the time needed for different tasks too low; (3) The customer does not update the time plan and deadlines when various problems arise *(market deadline is fixed)*.	(1) Project time plan off from the beginning; (2) Time pressure; (3) Higher costs.	(1) The customer needs to continuously update and revise the time plan; (2) The customer needs to make more honest and true time plans; (3) The customer should initiate projects earlier; (4) The supplier should communicate how suggested changes impact the overall project time plan and speak-up when the suggested changes are not possible to realize within agreed deadlines.

(5) Communication and agreement with the customer (external)	(1) The customer is usually not one customer (voice); (2) The supplier has to interact, communicate, and make agreements with many different people from various department with different agendas and views, sometimes lacking the holistic perspective; (3) Difficult for the supplier to have everyone in the customer organization on board; (4) The customer and the supplier often disagree throughout the project, due to lack of details in the customer order and agreement.	(1) Misunderstandings; (2) Project delays.	(1) The interaction and communication between the supplier and the customer need to be structured and visualized in a better way as well as the decision points between them; (2) The initial agreement between the customer and supplier needs to cover more details.
(6) The transition from industrialization to continuous production (internal)	(1) A process instruction that explains how the transition should be handled exists but is not used; (2) A lack of internal communication around the transition from industrialization to continuous production; (3) Order of pilot run directly after approved PPAP *(without preliminary agreement)*; (4) The customer does not read the customer proposal (quotation) in enough detail; initial customer demand directly after approved PPAP test.	(1) The production organization is not well informed about new components; (2) The production plant is not prepared enough when the component is transferred to the continuous production; (3) The production starts without informing the operators about the new component; (4) Operators are sometimes left without written manufacturing instructions; (5) The supplier has no volumes ready; (6) The supplier has problems with material supply.	(1) A structured PPAP meeting is needed; (2) The customer needs to consider how long the lead time is before the supplier can provide serial produced products, after approved PPAP test.
(7) PPAP agreement with the customer (external)	(1) An agreement of PPAP volume is made in the beginning of the project but not who should pay for it and what happens if the demand is lower than predicted; (2) The customer sometimes delay the PPAP by ordering lower quantities, due to low customer demand (*the supplier wants to conduct a complete PPAP as a final verification before the product is transferred to the continuous production*).	(1) The production system is seldom verified before the continuous production; (2) The PPAP is normally conducted in the first production batch in the continuous production; (3) Problems and issues are identified during continuous production rather than before.	(1) The customer and supplier agreement needs to not only cover PPAP volume but also who should pay for it and what happens if demand is lower than predicted; (2) The supplier could in order to avoid problem identification during the continuous production have a internal sign-off (internal PPAP) before start of production; (3) The supplier should not agree to deliver low serial volumes before approved PPAP; (4) The customer needs to supervise during the PPAP production runs at the supplier.
(8) The customer request the tool to be moved from overseas supplier before the tool has been verified (external)	(1) The customer usually want to take home the tool before it has been approved/verified in order to cope with delays and deadlines (*the supplier wants to make all modifications of the tool at the overseas supplier due to cost advantages*).	(1) Higher development costs; (2) Higher costs for final modification; (3) More expensive tool; (4) Higher unit cost.	(1) Better time planning; (2) The supplier needs to communicate the consequence of taking home the tool before it has been approved and also make demands (*e.g. compensation*).
(9) The project managers skills at the supplier (internal)	(1) The supplier does not have full time professional project managers; (2) The project manager's role and function are limited since they do not have the skills needed to manage projects in an appropriate manner.	(1) Delayed projects; (2) Time-pressure; (3) Continuous production starts before the industrialization is ended.	(1) The supplier needs to have full time project managers; (2) The project managers should focus on managing the project; (3) The project managers should be educated in project management.

(10) Industrialization work model at the supplier (internal)	(1) The supplier's projects tend to not have any agreed-upon critical tasks, no responsible person for the critical tasks, no clear deadlines for the critical tasks, and no regular projects meetings; (2) The supplier tends to work according to the customer's work model or make adaptations based on the individual customer at the expense of their own work model.	(1) Difficult to provide education since no standard work model is used; (2) Difficult to learn lessons and use them in future projects; (3) Not possible to develop new products in a fast and cost-efficient manner.	(1) The project managers should be supported with a standard work model that is used for all customers and projects but also flexible for unexpected events; (2) The project managers should be educated in the standard work model and project management in general; (3) Adaptations for the individual customer should be made based on the standard work model.
(11) Information exchange between the customer and the supplier (external)	(1) The documentation provided by the customer is missing information or is not organized well; (2) The delivery plan system and PPAP is dealt separately through a contract or order; (3) Different people work with delivery plans for new and existing products.	(1) Takes longer time to understand what the customer wants in details (*on what they wants a quotation*); (2) People responsible for the delivery plans might start to request products from the supplier even though the component is not approved.	(1) Complete and organized data needs to be sent to the supplier; (2) Improve the internal communication at the customer; (3) The customer should provide the supplier with clear component's requirements from the beginning; (4) Regular meetings at the supplier.
(12) Time of involvement in the customer's project (external)	(1) The customer initially involve several suppliers in the development project and delay supplier selection; (2) The supplier can not dedicate too much time in a project until it has been selected; (3) The customer focuses on buying the project industrialization service (the tool) to the best possible price and lead-time instead of long-term collaboration and mutual benefits.	(1) Less engaged suppliers; (2) Constant time pressure for the supplier from the beginning of the project; (3) Lower quality of the component design; (4) More changes throughout the project and more improvements rounds; (5) Higher development costs.	(1) The customer needs to use a segmented approach including different approaches for different types of suppliers; (2) The customer needs to develop more strategic relationships with key suppliers and select them earlier.
(13) The customer's forecast accuracy (external)	(1) The customer makes uncertain forecasts with regard to volumes, this is especially a problem in the ramp-up stage but also exists in the continuous production; (2) The forecasts are very volatile, even in a shorter time frame; (3) The supplier receives on a week notice changes in the volumes.	(1) Delayed deliveries; (1) Higher delivery costs in order to be able to deliver according to customer demand; (2) Lack of needed raw material and components in order to produce according to customer demand.	(1) The customer needs to make more robust and predictable forecast *(98-99% forecast accuracy)*; (2) Freezing times in the production plan.
(14) Long-term performance of the final tool and the related production equipment (external)	(1) The customer focuses on cost-reduction in development project rather than the ability to reach initial and future production targets and cost-efficiency throughout the product's entire life cycle; (2) The customer allows frequent changes in the component design after tool order; (3) The finished tool opportunities for long-term profitable production is damaged by too many changes.	(1) Difficult to reach production targets; (2) Difficult to reach cost-efficiency throughout the component's life cycle; (3) Higher manufacturing costs (*unit cost*); (4) Lower quality of the tool; (5) Higher maintenance costs; (5) More expensive tool (*higher development costs*).	(1) The supplier needs to communicate what affect cost-reductions in the tool design could have on the ability to reach initial and future production targets; (2) The supplier needs to communicate the impact on the ability to reach initial and future production targets when modifications of the tool or component design are requested.

6. CONCLUDING REMARKS

This study aimed to explore the challenges with industrialization across a supply chain network, from a supplier perspective. The study focuses on identifying the challenges encountered by the supplier, when working with industrialization alongside the customer's industrialization process, the reasons for and the effects of these challenges, as well as how these challenges can be managed. This study has identified fourteen challenges as well as their main reasons, effects and possible solutions (Table 1). The challenges can be classified as either internal or external. An internal challenges originates from inside the supplier's own organization, while an external challenges originates from the customer's organization or from the collaboration between the two organizations. Most of the identified challenges are external ones. This research provides knowledge to the area of industrialization across a supply chain network and to the area of industrialization from a supplier perspective. Consequently, this research contributes by delving into areas currently not addressed to a greater extent in the scientific literature. In particular, this research provides insights about challenges with industrialization across a supply chain network, from a supplier perspective. The main practical implication is that companies should not solely focus on the systemization and standardization of the internal operations, activities and interfaces but also on the activities and interfaces between the actors in the supply chain, which are of major importance to reach cost and time targets. This study is explorative in nature and is limited to one supplier located in Sweden. Thus, additional empirical data from similar and other research settings should be gathered to reinforce the validity of the reported findings. This limitation should be considered when later researchers attempt to replicate or further test the above findings and can be readily addressed by further research. Other interesting aspects for further research would be to investigate this topic further in different types of industries and countries to see if there are any differences in how these activities are conducted and in the challenges encountered.

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