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Global supply chain quality integration strategies and the case of the Boeing 787 Dreamliner development

Roland Schmuck*

University of Pécs Faculty of Business and Economics, Rákóczi út 80., Pécs 7622, Hungary

* Corresponding author. Tel.: +36-72-501-599 ext: 23369. *E-mail address:* schmuck.roland@ktk.pte.hu

Abstract

Managing the quality of global supply chains is critical for the success of global companies. Quality disseminates through the supply chains. Supply chain quality integration facilitates each company to use its main expertise which can lead to higher quality and cost reductions. Digital audits enhance the possibilities to ensure the production quality at the suppliers. A global supply chain quality integration is illustrated through the case of the Boeing 787 Dreamliner development. The development process was a major challenge for Boeing because not only several innovations were introduced in the 787 plane, but the supply chain quality integration reached new levels for the company. The 787-program had process, management, labor, and demand risks. The first 787 plane was delivered three years later than planned and the budget was exceeded by 10 billion USD. To solve the issues, Boeing created the Production Integration Center. It sent engineers and production workers to its suppliers in several countries of the world to smooth the supply chain quality integration. Boeing supported its suppliers with its knowledge. Onsite cameras were used as digital audits. The Production Integration Center intervened when it estimated delays in the shipments. Boeing successfully solved the issues, but they cost the company a lot. Examining this supply chain restructuring case can help supply chain managers to diagnose and overcome issues in supply chain quality integrations.

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Keywords: supply chain, quality management, integration, digital audit

1. Introduction

In a globalized world, companies have to work with globalized supply chains. Different cultures of the world use different quality management approaches. Managing the quality from the headquarter of a global company may cause numerous issues in quality management. To succeed in the global market, companies should study examples of good practices in supply chain quality management [1]. The purpose of this paper is to show how global supply chains can work efficiently with high quality in mind. Using a new generation of knowledge management tools with the help of digital technologies can enable the collaboration of teams in different locations of the world [63]. Such a case is shown by the Boeing 787 Dreamliner development which is discussed in detail. The joint development project connected 135 partner sites in about two dozens of countries simultaneously [63]. This case highlights several issues in global supply chain quality integrations.

2. The importance of quality in global supply chains

Globalized companies can have their production in several countries of the world at the same time. The quality of the same products should be the same whenever produced. However, we can see examples of customers perceiving the quality

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otherwise: Japanese cars made in Japan are generally considered to be of higher quality than those Japanese cars which are made outside Japan. The Fender Stratocaster Electric Guitars are made in four countries: the USA, Japan, Mexico, and South Korea. The quality of the guitars should be the same, but customers are willing to pay more for the US-made guitars in the secondhand market because they believe those guitars are of higher quality [2].

Meeting customer satisfaction in all countries of operation is challenging. For Nespresso, this means to provide excellent value to its customers regarding the taste of the coffee taste, its warmth, and caffeine stimulus in 60 countries and over 320 storefronts [3]. The Gap clothing company decided to use a three-pronged strategy based on cost efficiency, speed and flexibility, and quality. For its cost-conscious customers, it manufactures the products in China under its Old Navy brand. Its Banana Republic brand is produced in Italy to ensure quality. Gap also has manufacturing in Central America to provide speed and flexibility to its supply chain [4]. The Swedish Nudie Jeans company uses a transparent supply chain to enhance customer satisfaction through after-sales services and the opportunity of personalization [5].

2.1. The relationship of supply chain and quality

Supply chain networks have to use quality management practices to gain a competitive advantage [6]. The use of quality management techniques enhances supplier performance [7]. According to the Total Quality Management (TQM), theory quality should start from the suppliers, outside the company [8]. Many suppliers implement TQM practices at the request of their buyers. The use of certified ISO quality management systems can speed up joining the international supply chains [9]. A survey of 565 respondents shows ISO 9001 certified companies are more likely to use ISO 9001 certified suppliers [10]. As shown by these examples, quality disseminates in industries through the supply chains, similarly to environmental and ethical demands [11, 12].

When deciding on a partnership we have to decide on cost, quality, and speed [13]. Supply chains have three functional drivers: price, information, and sourcing [14]. Trust is also an issue, especially in high-tech industries where there is high uncertainty regarding the performance of the suppliers [15]. Contracts laying down the base of the agreements should include details on quality assurance [16]. Quality flows through the company and results in the satisfaction of the customer. The supplier should be part of this quality management system. Ideally, the quality of the supplier should be as high, that there should be no need for inspecting the incoming materials, they could be immediately used in the manufacturing process. To be able to do this, a long-term upstream-downstream partnership is needed in the supply chain. Just-in-Time is using this approach [8].

In the EFQM (European Foundation of Quality Management) excellence model partnership is named as part of a scoring aspect [17]. Most quality awards are decided by using this model. An improved model based on EFQM used for airport quality management further breaks down this aspect and mentions the suppliers directly [18].

There is an assumption that internal quality management can be extended to suppliers successfully, but differences in organizational culture may cause issues in reality. A survey from the UK shows that only one of eight supply chain partners has common mission statements [19]. Incentives can enhance the overall supply chain performance and quality [20]. According to the survey of 266 Chinese global suppliers, the quality control of the buyer and the innovation of the supplier are positively correlated in the case of small-sized suppliers [21]. A survey of 81 managers in Taiwan concludes that supply chain quality improvements can be associated with organizational performance improvements [22].

3. Supply chain quality integration

Developing an appropriate supply chain strategy that fits the product helps to increase competitiveness [23]. Companies should strive to create an extended organization including partnering with their suppliers [24]. Integration facilitates that each company does what it can do the best [25]. Supply chain management should include information and material sharing between the organizational units to meet customer satisfaction [26]. This has huge potential because of the different infrastructures available at the partners [27]. However, challenges are appearing as the supplier network can be geographically separated from each other and the customers [28]. Supply chain quality integration deals with the integration with suppliers and customers for quality improvement [29]. Three different levels of cooperation can be defined based on the level of the integration and the number of areas included in the collaboration. Based on this the cooperation can be as simple as communication, or it can be a limited collaboration or a more complex full collaboration [30]. The integration is led by the lead integrator. Research shows that about 40% of them lack visibility to their Tier-1 suppliers and 75% to their Tier-2 suppliers. The lack of supplier control is the biggest barrier to reduce supply chain risks [31].

Supply chain integration can be external or integral. External integration can be customer or supplier integration [32]. Internal integration is the integration inside the company between its functions to collaborate in an organized way to meet the customer requirements. Sharing information, joint planning and collaborative teams can be part of it [32].

Integration of customers is crucial as most quality management theories deal with customer satisfaction first. Getting information from customers on products and services is a supply chain downstream integration [32].

The supplier integration is an upstream integration. Fisher [33] mentions two supplier-based structures. The configuration for cost reduction includes multi-sourcing and price competition of suppliers. On the opposite, it is possible to have configurations for speed, flexibility, and quality by using collaboration strategies [33]. The involvement of the suppliers in identifying new opportunities can lead to cost reduction and more revenue [34]. The use of cross-function teams increases effectiveness [35]. According to a study the Turkish automotive industry receives positive product and process innovation influence through the supply chain but there is no evidence of other positive influences, such as enterprise achievement [36]. A survey conducted in Southeast Asian countries shows that collaboration with suppliers improves quality control [37]. Visibility in the supply chain is an important issue. Activity visibility means monitoring partner actions to solve issues. Knowledge visibility allows partners to access the knowledge through the network [38].

The investigation of 322 manufacturers worldwide concludes that performance improvement is strongly associated with the wide degree of integration with suppliers and customers [39]. An 8-year study of 50 products and their supply chains suggests to first increase the internal integration of the company, secondly the integration with the key suppliers, and thirdly the customer integration [40]. In the manufacturing sector, the three types of supply chain integrations together lead to developments in design quality and conformance quality which fosters the overall product quality [32]. Research of 317 manufacturers in 10 countries shows that delivery and flexibility performance is improved when supply chain quality integration is achieved. A stronger customer integration decreases the total cost of quality, such as inspection, rework, product returns, and warranties [29]. The use of remanufacturing facilitates better coordination of the supply chain [41].

4. Digital audits

To ensure the quality operations of suppliers, factory audits can be used. Traditionally it can check to fulfill the external accreditations or hiring auditors for the factory visit. These audits are planned in advance and they are paper-based. Many of these audits are based on the ISO quality management systems, most frequently the ISO 9001 quality management standard. ISO 9001 expects suppliers to be evaluated however it does not require mutually beneficial partnerships. This is just a recommendation in ISO 9004. A study revealed that companies with ISO 9001 certifications do not have more enhanced supply chain partnerships than those companies that have no ISO 9001 certification [42].

Globalized supply chains brought us to a new digital era [43] where modern digital audits can lead to process improvements and cost savings, furthermore they can encourage long-term partnerships [44]. Audits are beneficial for improving visibility through the supply chain. This advantage is particularly true for global supply chains and for those companies who have no previous experience with integrated supply chains [31]. Digital audits use real-time production data and are not scheduled to a particular date. This decreases the possibility of suppliers hiding their problems [44]. Auditing companies also gain advantages with digital audits, such as optimizing the audit processes, improving the quality of the audit, and adding innovation into the auditing process [45].

New developments for digital audit are spreading. Inspectorio developed an app for auditors. It can collect information, photos, videos and have instant communication with the buyer clients. Sedex developed a platform for sharing audit ratings with other buyers. Adding such technologies to the audit process can give more insight into relationships by analyzing digital data [44].

The Trek Bicycle Corporation is driving up quality through its supply chain. It uses IT-based integration with its suppliers' manufacturing plants in Taiwan and China. The web-based statistical quality control audit software allows the diagnosis of quality problems in the factory. If needed, the local team of Trek can get to the factory to check the problems and correct them there. This increases quality and decreases the cost associated with faulty products because they can be easier noticed inside the factory before shipping [2].

5. Supply chain quality issues in the Boeing 787-program

The supply chain quality integration and digitization are discussed through the Boeing 787 Dreamliner development and production process. This case is illustrating a global supply chain quality integration. Boeing uses cutting-end technology at a complex product and global suppliers where the integration of the supply chain is a must for success.

Boeing, the largest aerospace company in the world, has more than 20.000 suppliers and partners worldwide. It employs 160.000 people in 66 countries and sells its products in more than 150 countries. The company is based in Chicago, but 70% of its revenue comes from outside the USA. Boeing is the largest exporter of the USA by dollar value [46]. Boeing does not only spend huge efforts on its supply chain but takes care of remanufacturing as well, as a reverse supply chain [47, 48].

In 1996, Phil Condit, Boeing CEO stated that Boeing should use large-scale integration in line with the company's new mission statement [38]. The goal of Boeing is to become a lean organization with efficient systems [49]. Its new 787 Dreamliner plane is an innovative product, using light composite materials and other innovative technologies [38]. The composite cabin does not only make the plane lighter, decreasing fuel consumption by about 20%, but also allows increasing humidity and pressure in the cabin for a better customer experience. However, the new composite material creates new challenges, mostly regarding feasibility and safety [50]. There are other innovations as well. The use of 30 partial computers in the 787 plane compared to 80 of them in the previous 777 model enables easier coordination of the functions [51]. The 787 plane consists of 2.3 million parts from suppliers worldwide [52]. Though Boeing uses several innovations, the final control is still traditional. The pilots can execute any command in Boeing planes, in contrast to its main competitor Airbus, where the onboard computer can limit commands and has the final authority [53]. Boeing and Airbus both uses a set of ISO 9000-like quality management standards [8].

Boeing outsourced 70% of the development and production activities of the 787-airplane program to suppliers worldwide [50]. This is a huge increase in comparison to the previous 777 model with a 30% outsourcing rate at the start of its development in 1990 [51]. Boeing had the goal to decrease the development time to 4 years. The 777 model needed 6 years to be developed [52]. Boeing enhanced its supply chain quality integration in the 787-program. The goal was to increase the visibility of actions, and knowledge networks [38]. A global IT-enabled organization structure was essential for the success of the 787-program [49]. The program had process, management, labor, and demand risks [50].

The labor risks included the management and the workers as well. Managers in the 787-program were not experienced in supply chain risk management [50]. Workers were worried about the high amount of outsourcing resulting in a strike. Boeing had to increase the wages by 15% in four years, furthermore, reduce the workweek of employees causing unexpected delays in the development process [50].

The supply chain quality integration of Boeing also includes an incentive, or in another viewpoint, financial risk-sharing in the case of the development of the 787 plane. Boeing only paid its suppliers when the first 787 was certified for flight [50]. This encourages countries involved in this risk-sharing to buy the 787 model. Such happened in Japan, where the All Nippon Airlines ordered 66 new 787 planes [54]. Previously the Japanese government provided backing for local companies getting Boeing contracts, which can be considered as giving an unfair advantage to them [55]. In the case of previous planes, Boeing provided detailed plans and drawings to its suppliers [56], but for the 787, it only provides the detailed requirements to approximately 50 of its Tier-1 suppliers. The detailed planning is the responsibility of these Tier-1 suppliers, as pre-integrators which is shown in Figure 1 [50,60]. There is a very low amount of inventory as Boeing uses air transportation to ship parts to its final assembly plant. Shipments should arrive within one day, instead of its previous planes where it used a 30-day shipment timeframe. This change was in line with Boeing's goal to become a lean manufacturer [38]. In the aerospace industry, the use of lean practices drives the application of resilient practices [57]. Boeing did not have previous experience in such tight supply chain quality integrations. The 787-program did not turn out to be a success story for Boeing. Because of bottleneck problems, the shipments of 787 planes were delayed and the first plane was delivered three years later than scheduled [38]. The use of innovative composite materials caused manufacturing issues. There were shimming problems with matching parts coming from different suppliers [52]. In 2012 workers forgot to put shims between the fuselage and the internal structure causing stress issues of the body. Boeing underestimated the risks of using the new material [58]. Dangerous cracks appeared in numerous places of the plane in the early manufacturing period [55]. Microcracks in composite materials can result in more serious problems when exposed to mechanical loads [59].

At the beginning of its development in 2004, the 787 became the fastest ordered commercial plane in history [51]. However, because of delays in the development, customers started to cancel their orders. For compensating for the late delivery, Boeing offered replacement aircraft and improved its communication about the progress of the development. The communication highlighted the superior technology of the 787 airplane [50]. The total budget of the development process was exceeded by 10 billion USD [29]. Several managers of the 787-program were replaced [58].

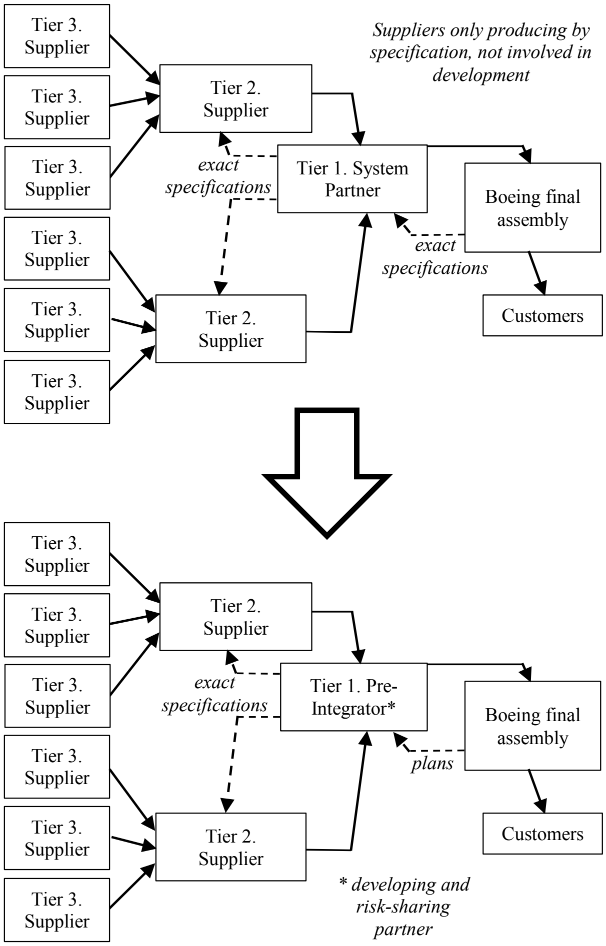

Fig. 1. The change from the conventional supply chain to the decentralized supply chain of the Boeing 787 Dreamliner

To solve the issues, the Production Integration Center (PIC) was created in December 2008. The goal was to enhance awareness and visibility of the 787-program. Multi-functional teams worked at this center, including functional specialists and translators [56]. The PIC operated online cameras at partners to diagnose and solve problems as a way of digital audits. Boeing sent engineers and production workers to its suppliers in several countries of the world to smooth the supply chain quality integration [58]. The PIC monitored the environment for rapid changes affecting the 787-program, such as natural disasters, political risks, or epidemics. If the predictions showed potential delays the PIC tried to solve them before they caused a problem in the lean manufacturing process [56]. To eliminate bottleneck problems, Boeing even had to buy up one of its supplier plants facing financial problems, Vought Aircraft Industries' South Carolina factory for 1 billion

USD [58]. This allowed direct control of this factory and more control over the Tier-2 suppliers associated with this factory [50].

The first commercial flight with a Boeing 787 was done in 2011. Boeing originally planned to sell 1200 of this new type of plane. The breakeven point was planned to be in 10 years from starting the shipments [49]. After several onboard fires caused by the innovative Lithium-Ion batteries, the Federal Aviation Administration (FAA) ordered to ground all 787s in 2013. This issue cost Boeing 600 million USD, furthermore, some airlines decided to cancel their orders. This again turned to be a supply chain quality management issue. Boeing found that one of its French Tier-1 suppliers and a Tier-2 supplier in China owned by a Japanese company was responsible for the problem [31]. According to the airworthiness requirements, a quality inspection method should be provided. As the 787 was the first commercial plane using Lithium-Ion batteries FAA and Boeing faced technical and certification issues. The investigation revealed that the testing process of batteries was done incorrectly prior to installation. The issue was sorted out by Boeing in a few months [60].

The suppliers of Boeing could have done the supply chain quality integration themselves, but as this did not happen, Boeing did it centrally with the help of the PIC center. It facilitated not only the integration of Boeing and its suppliers but also the partnership of suppliers with each other. In the beginning, it dealt with design issues, later it started to deal with production and transportation issues. This allowed sharing Boeing's knowledge and spread the innovation through the supply chain. Knowledge visibility and activity visibility were realized together. When the center reached its goal to realize supply chain quality integration, it was reorganized to help the manufacturing process at Boeing's Everett (Washington, USA) final assembly factory.

Despite the problems, Boeing continues its integration into a global enterprise as its current vision claims. Boeing strives for quality and continuous improvement for excellence. Integrity, responsible partnership, and strengthening communities around the world are also mentioned in its core values [61]. As of 31st December 2019, 859 pieces of 787s were delivered. The number of total orders including planes already delivered is 1485. Despite the enormous efforts, the 787-program still did not meet its breakeven point. It is expected to reach the breakeven point at around 1100 delivered planes [62].

6. Conclusions

Supply chain networks have to use quality management practices to gain a competitive advantage. Quality disseminates through the supply chain. This paper examined two main features of supply chain quality management: the supply chain quality integrations and the digital audits.

The Boeing 787-program case highlights the importance of supply chain quality integration. This program was a dramatic change in the way Boeing handled its suppliers. Not only the technology was innovative, but the whole process itself. It was an enormous effort to tightly integrate the supply chain and develop an innovative product at the same time. Boeing did not have the experience in handling such supply chain quality integration. Process, communication, and human issues caused delays and unplanned expenses in the development process.

The creation of the Production Integration Center (PIC) allowed better integration of the supply chain and introduced digital supply chain quality audits. The goal was to provide better visibility of the supply chain to eliminate bottlenecks and delays. The PIC operated onsite cameras as a way of constant digital audits. Boeing sent engineers and workers to its suppliers sharing its knowledge with the suppliers. The PIC intervened when it estimated delays in deliveries. Boeing successfully tightened the connections with its suppliers. This was done centrally, instead of waiting for the suppliers to do it themselves. Boeing helped its process by providing knowledge to its suppliers. The connections between Boeing's Tier-1 suppliers were also tightened with the help of the PIC. Boeing offered replacement airplanes to its customers for compensating for the delays. Company communication insisted on the superior performance of the 787 airplane. The solutions of Boeing worked, the development was finished, but because of the issues, it took three years more than originally planned. The budget was exceeded by 10 billion USD. However, there were still quality management issues remaining in the early years of the production.

Following the commercial introduction of the 787, a series of problems arose with the innovative Lithium-Ion batteries causing onboard fires. This was again due to a quality problem at a Tier-1 and a Tier-2 supplier. The problem was sorted out in a few months, but it caused again damages to the reputation of the company and 600 million USD loss of profit. As of 31st December 2019, 859 pieces of 787 planes were delivered and further 626 pieces are ordered. The 787-program still has not reached its breakeven point.

The issues with the supply chain quality integration of the 787-program could have been avoided with better supply chain management and better planning of the processes. The case shows a possible solution of a supply chain restructuring project. It allows supply chain managers in any industry to learn how to manage similar supply chain risks and plan the supply chain quality integration to avoid similar problems arising.

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