

Article

Implementing Green IT Transformation for Sustainability: A Case Study in China

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Abstract: Implementing green Information Technology (IT) is an effective way to realize sustainability. In the process of implementing green IT, IT transformation is essential but tends to fail. However, existing literature can't offer effective guidance for implementing green IT. In this article, we conduct a case study of green IT implementation at Shenyang Aircraft Corporation, an aircraft manufacturer. This study sheds light on the process through which green IT transformation and sustainability are achieved. Consequently, we have expanded the Belief–Action–Outcome (BAO) framework to strategic and operational levels, and summed up the capabilities and mechanisms of each phase, as well as the impact relationships and directions between each phase. At a strategic level, the belief formation phase includes the capability to establish direction and required actions, containing formation of belief in sustainability and cultivation of green culture. The action formation phase needs the capability to reshape strategy and required actions, containing green informatization strategy and the establishment of a green IT group. As for operational level, the belief formation phase needs the capability to integrate and engender trust, the combination of production and research as well as production network implementation constitutes required actions. The action formation phase includes the capability to enact a sustainable plan and required actions have two parts: paperless production and a balanced production plan. This study contributes to present literature from three aspects. First, the study provides a qualitatively empirically grounded framework for the study of green IT. Second, this study contributes to the literature on sustainability from an IT perspective. Finally, our study also made important contributions to the BAO framework.

Keywords: sustainability; green IT transformation; Belief–Action–Outcome; case study

1. Introduction

It is believed that numerous Information Technology (IT) applications, especially green IT, have a positive effect on sustainability [1]. IT transformation is essential in the process of implementing green IT. However, the IT transformation fail easily [2] because organizations pursue economic interests more and it is hard to adapt to varying market circumstances. Moreover, the organizational adoption of green IT is complex and is affected by both external drivers and internal motivations [3]. So both strategies and actions are significant to develop organizational capabilities.

Although research findings about sustainability were abundant, several gaps still exist. First, present studies pay more attention to environmental sustainability and the research on economic and social sustainability is not thorough enough. Second, scholars have pointed out that an effective green IT transformation process is an important foundation for organizations. However, existing literature

cannot offer effective guidance for implementing green IT [4]. Third, the question of how to implement green IT by developing organizational resources still has no answer.

Realizing IT transformation in the pursuit of sustainability requires the development of new strategies and effective action within an organization. In order to solve practical difficulties and contribute to existing literature, we conduct a case study of the process of green IT transformation to achieve sustainability, which also bridges the gap between green IT and sustainability. To go deep into the process, we develop the Belief–Action–Outcome (BAO) framework [5] to analyze how Shenyang Aircraft Corporation implements green IT at both strategic and operational levels. We find that companies develop key capabilities and key actions for belief formation and action formation. We have expanded the BAO framework to strategic and operational levels, and summed up the capabilities and mechanisms of each phase, as well as the impact relationships and directions between each stage.

This study contributes to present literature from three aspects. First, this study provides a qualitatively empirically grounded framework for the study of green IT. It complements the literature by unraveling the black box of green IT transformation that realizes sustainability by applying the BAO theoretical framework. Second, this study contributes to the literature on sustainability from an IT perspective. As far as we know, this study is one of the few studies that analyses sustainable development at strategic and operational levels within an organization based on a green IT perspective. Finally, our study also made important contributions to the BAO framework as proposed by Melville [5]. We believe that our research will effectively develop the BAO framework and provide important value to the future green IT transformation for sustainability research.

This article is divided into five sections. A literature review is explored in Section 2. The methodology, case selection, data collection, and data analysis are discussed in Section 3. In addition, case study and model building are reported in Section 4. In Section 5, we reach the conclusions, and analyze the contributions, implications, and limitations of the article.

2. Literature Review

2.1. Sustainability and Green IT

An encompassing definition of sustainability is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [6]. Economic, environmental, and social sustainability, known as “triple bottom line”, have drawn increasing attention from scholars. Economic sustainability means the balance of the pursuit of economic performance and its sustainable development [7]. Environmental sustainability is about the influence that an organization’s business processes, activities, and operations exert on the natural environment, and the influence might be positive or negative [8]. Social sustainability supports the development of a partnership between business and society for sustainable development and bringing about a win-win situation.

It is believed that numerous IT applications—especially green IT, such as e-commerce, smart buildings, artificial intelligence, and intelligent transport systems—have a positive effect on sustainability [1]. For example, green IT could potentially reduce carbon emissions by 15% [9]. The notion of green IT has been defined in a myriad of terms and concepts (See Table 1), such as green IS [10], Information Systems (IS) for environmental sustainability [5], environmental sustainability of IT [11], and IT for green [12]. This article will not analyze the differences among these concepts but will instead define green IT from a comprehensive perspective. Green IT is the integration and cooperation of efficiently and effectively designing, manufacturing, utilizing, and disposing of computers, servers, and other associated subsystems [12], aiming at pollution prevention, product stewardship, and sustainable development [13], and strongly focusing on using information systems to enhance sustainability across the economy [3,5].

Table 1. Terms and definitions of green IT.

Source	Terms	Definition
Watson Boudreau and Chen (2010) [10]	Green IT and IS	Green IT integrates and cooperates with sets of people, processes, software, and information technologies to support individual, organizational, or societal goals. Green IS incorporates a great variety of possible initiatives to support sustainable business processes.
Melville (2010) [5]	Environmental sustainability	IS-enabled organizational practices and processes that improve environmental and economic performance.
Elliot (2011) [11]	Environmentally Sustainability of IT	Activities to minimize the negative impacts and to maximize the positive impacts of human behavior on the environment through the design, production, application, operation, and disposal of IT and IT-enabled products and services throughout their life cycle.
Molla and Abareshi (2011) [13]	Green IT	Practice of applying environmental sustainability (including pollution prevention, product stewardship, and sustainable development in managing IT) as principles.
Barney et al. (2014) [14]	Green IT	An integrated and cooperating sets of people, processes, and IT that aims at pollution prevention, product stewardship, or sustainable development, for the purpose of enhancing environmental and economic performance.
Deng and Ji (2015) [3]	Green IT	The practice of designing, manufacturing, using and disposing of computer, servers and associated subsystems efficiently and effectively with minimal or no impact on the environment, and with a strong focus on using information systems to enhance sustainability across the economy.

2.2. Green IT and Belief-Action-Outcome Framework

To successfully implement green IT requires IT transformation. But IT transformation fails easily [2] because it is difficult to fit the varied market circumstances when mismanagement appears. Strategies and actions are essential to develop organizational capabilities. Moreover, the organizational adoption of green IT is complex and is affected by both external drivers and internal motivations [3]. Externally, it is influenced by technological context (relative advantage, technological complexity, and technological compatibility) [15,16] and institutional pressure (coercive pressure, mimetic pressure, and normative pressure) [17,18]. Internally, there are three motivations: top management support, greening of the organization culture, and strategic intent [19,20].

This article focuses on internal organization aspect. Attitude, policy, practice, technological infrastructure, and governance structures for green IT are key factors in successful green IT implementation [13]. People's understanding of nature and the relationship between humans and nature will influence their environmental beliefs and actions in an organization [21]. Similarly, enterprises need to develop the sustainability belief and value framework, and use the power of external stakeholders to support the green IT development [22]. Eventually, on one hand, the beliefs of organizations focusing on the natural environment and sociopolitical achievements promote green IT actions for eco-sustainability, so as to meet the demands of customers, suppliers, and market forces [13]; on the other hand, firms' social obligations and values for green IT propel them to establish a series of appropriate regulations, norms, and beliefs, and then they take actions, such as energy usage reduction, material toxicity, and reclamation, to achieve eco-effectiveness and eco-efficiency and potentially improve long-term profitability [23].

Realizing IT transformation in the pursuit of sustainability requires develop new beliefs and effective actions within an organization, therefore, the Belief-Action-Outcome (BAO) framework proposed by Melville [5] is particularly suitable to analyze the relationship between green IT and sustainability. The BAO framework holds that to achieve sustainability, organizations must go through two stages. The first one is the belief stage, which forms perception and psychic states of sustainability. The second one is the action stage, which transform sustainability beliefs into actions. Eventually, an outcome that green IT affects economic, environmental, and social sustainability will be achieved [5]. In the process of forming new beliefs, organizations shall develop several capabilities for they are essential to alleviate conflicts among stakeholders and other members, considering their concern values (short-term profit and long-term sustainability) [5]. Apart from the belief formation capabilities, the action formation process also demands that organizations develop certain capabilities to turn beliefs

into reality, such as higher-order learning, continuous innovation [24], clean technology (sustainable competencies of the future), and pollution prevention (capability to minimize waste and emissions from operations) [25].

Even though research findings about sustainability were numerous, several gaps still exist. First, existing studies pay more attention to environmental sustainability instead of integrated “triple bottom line”, so the research of economic and social sustainability is not intensive. Second, few papers focus on how to effectively realize green IT transformation [26]. Scholars have pointed out that an effective green IT transformation process is an important foundation for organizations. However, existing literature cannot offer effective guidance for realizing green IT transformation. Third, the question of how to implement green IT by developing organizational resources still has no answer. To contribute to present literature, we apply the Belief–Action–Outcome framework [5] to analyze the way of implementing green IT at both strategic and operational levels.

3. Research Methodology

3.1. Method and Case Selection

The case study methodology is particularly suitable for this study for three reasons. First, this study aims to answer the question of how a traditional manufacturing company can achieve green IT transformation, belonging to the category of “how” questions. It is also appropriate to use the case study method to present the dynamic strategic transformation process [27]. Second, the purpose of this study is to systematically explore the process mechanisms for the implementation of green IT in enterprises, and the demand for data richness is high. Both green IT and the BAO framework are complicated and multi-dimensional, which make it more appropriate to examine the question by analyzing organizational context rather than adopting a quantitative approach [28]. Third, academic researches on green IT implementation in enterprises are still limited and at the exploratory stage. This study explores the formation of corporate cognition and the formation of actions in the transition of green IT. The exploratory case study is especially appropriate for all new or existing academic fields that lack adequate research [29].

Selecting Shenyang Aircraft Corporation as the object of the case study is based on the following three criteria. First is the principle of importance and representativeness [30]. Shenyang Aircraft Corporation is a first-class airline engaged in equipment manufacturing, and its successful experience of information technology and systems, which expanded the manufacturing capacity of aviation parts, has set up a model in the industry. Therefore, choosing Shenyang Aircraft Corporation as a case study company follows the importance and representative principles of case selection. Second is the principle of theoretical sampling. The case study method selection of cases is based on the need to fill in existing theoretical gaps or develop new theories, rather than statistical sampling reasons [29]. Although previous studies considered the importance of corporate green transformation for sustainability, and some scholars proposed the BAO model [5], many of them are theoretical explanations, and there is also a lack of understanding of the mechanisms of the BAO model. This study takes Shenyang Aircraft Corporation’s green IT transformation process as the research object, tries to open the “black box” for enterprises to implement green IT transformation from the perspectives of key capabilities and actions at the strategic and operational levels, and improves the development of the BAO model, which helps to improve relevant theories. Third is the consistency between the enterprise’s theoretical goal and its practice. The green IT initiatives of Shenyang Aircraft Corporation have achieved significant success thanks to the key capabilities and actions at the strategic and operational levels. We were very impressed during the investigation and the historical data in this area is also relatively complete. In short, Shenyang Aircraft Corporation developing capabilities and taking action in the strategic and operational aspects at the different formations is the key to achieving a green IT transformation for sustainability. This is consistent with the theoretical goal of developing the Process model of Implementing Green IT transformation for Sustainability.

This study follows the case study procedure of identifying a research problem, theoretical review, case study draft design, data collection, and data analysis [31]. By analyzing theory and data, the study maintains its focus and discovers theoretically innovative points [31].

3.2. Data Collection

Data collection began in 2013 and the whole research process, including literature review, data collection and analysis, and finalizing theoretical framework, lasted for more than six months.

At first, prior to on-site data collection, secondary data was gathered from external sources, such as the official website of the enterprise, online documents, news and articles, books, and analysts' reports. Meanwhile, we exchanged emails and conducted interviews with selected government officials and entrepreneurs. The prior stage of information collection provided the basis for field investigation and enhanced our sensitivity in the case study on Shenyang Aircraft Corporation. Besides, we have reviewed relevant literature to figure out the theoretical framework of the study [32]. Green IT and sustainability were finally identified as the theoretical guide of this study, which was employed as a "sensitizing device" [33] in the following on-site data collection and analysis. Having analyzed second-hand information, relevant literature, and the research questions of this paper, the authors came up with the interview question in the preparation stage. Under the theoretical guidance of green IT and organizational transformation, the research team puts forward open-ended and relevant questions [34] and sets up an interview panel of five researchers to enable the validation of interpretations and observations [35]. The corporation did not prepare their own questionnaires. During the interview, the research team further clarified the questions according to actual needs.

Second, the research team conducted a field investigation at the headquarters of Shenyang Aircraft Corporation. Nineteen senior managers and technical leaders from five departments, including the production department, information technology department, and civil machine management department were interviewed. To ensure data validity, our research team asked open-ended questions that focused on strategic and operational issues in green IT and sustainability. The interview lasted for 90 min and was recorded during the whole process; the amount of transcribed words reached nearly 100,000. Because Shenyang Aircraft Corporation is a state-owned military enterprise, to avoid disturbance, the interviewees have declared their anonymity and signed confidentiality clauses in each interview.

Finally, we collected information from internal files in archives, such as meeting summaries, examination materials, and advice notes. Internal information, interview records, and secondary data together allow for triangulation. Our research team has collected data from multiple sources, and conducted formal interviews and informal research in order to form a triangle chain of evidence [29]. The data incorporated views of both organizational insiders and outsiders [29], making the research conclusion more accurate and convincing.

3.3. Data Analysis

Data was analyzed as it was collected, so that the research team could take advantage of the flexibility that the case study method offers [29]. We conducted a literature review on green IT and sustainability, and made a timeline of green IT initiatives (sustainability vision, strategy, and plan) in Shenyang Aircraft Corporation that were pertinent to realizing sustainability [36]. The relevant theoretical constructs are critical to guide subsequent data collection and analysis [29]. Then the team took three steps to examine the primary data while eliminating the preliminary bias.

First, the temporal bracketing strategy, visual mapping strategy, and narrative strategy were used to collect data. Temporal bracketing means to make sense of and structure the empirical data by dividing the temporal change process into successive adjacent periods. The visual mapping strategy means to collect data from different dimensions so as to demonstrate the relations between the data. The narrative strategy meant that we constructed a meta-story of the entire transformation process from the empirical data [37]. The narrative strategy meant that we constructed a meta-story of the

entire transformation process from the empirical data. This step was conducted to eliminate irrelevant data. From the emerging data, we noticed four phases with different activities in the process of realizing green IT and sustainability. Second, we conducted a detailed analysis and classified the activities into the four phases to show what activities were involved in the implementation of green IT. Third, empirical data and theoretical lens were combined to form the analysis model. We finally summarized the key beliefs and key actions on both strategic and operational levels.

Figure 1 provides an overview of the research approach and measures adopted to ensure the reliability and validity of the findings.

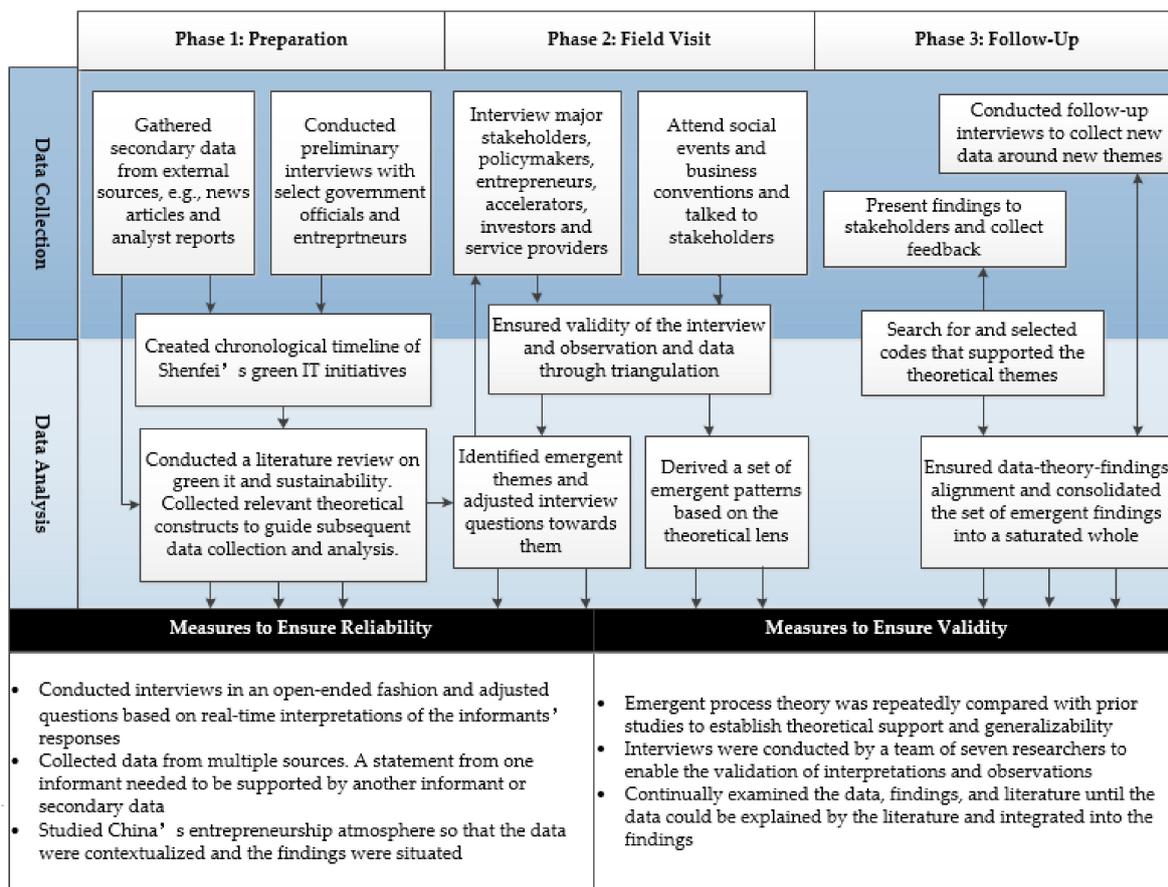


Figure 1. Overview of research approach.

3.4. Data Coding

In this study, the data was triangulated based on multiple data sources and multiple interviewees, and credible data was selected for analysis [35]. The method proposed by Strauss and Corbin [38] was used to encode the collected data. Specifically there are the following three steps:

First, open coding. At this stage, it is necessary to read relevant data repeatedly, maintain an open mind, accurately grasp the meaning of the interviewees, and try to avoid imposing the framework of the literature or researchers on interview data. When coding, the interviewees' own vocabulary is used to express the meaning of each sentence. This stage mainly forms the first-order concept [38], which is usually the vocabularies repeatedly mentioned by the interviewee.

Second, axial coding. This stage, mainly through the researchers' accumulation of the existing literature, and comparison of interview data, summed up a more abstract second-order concept [38]. This stage is a critical period for the emergence of new concepts.

Third, selective coding. This stage needs to check all the encoded data, refining and integrating all second-order concepts with more precise concepts to form a summary concept [38]. The first-order concepts, second-order concepts, and summary concepts involved in this paper are shown in Figure 2.

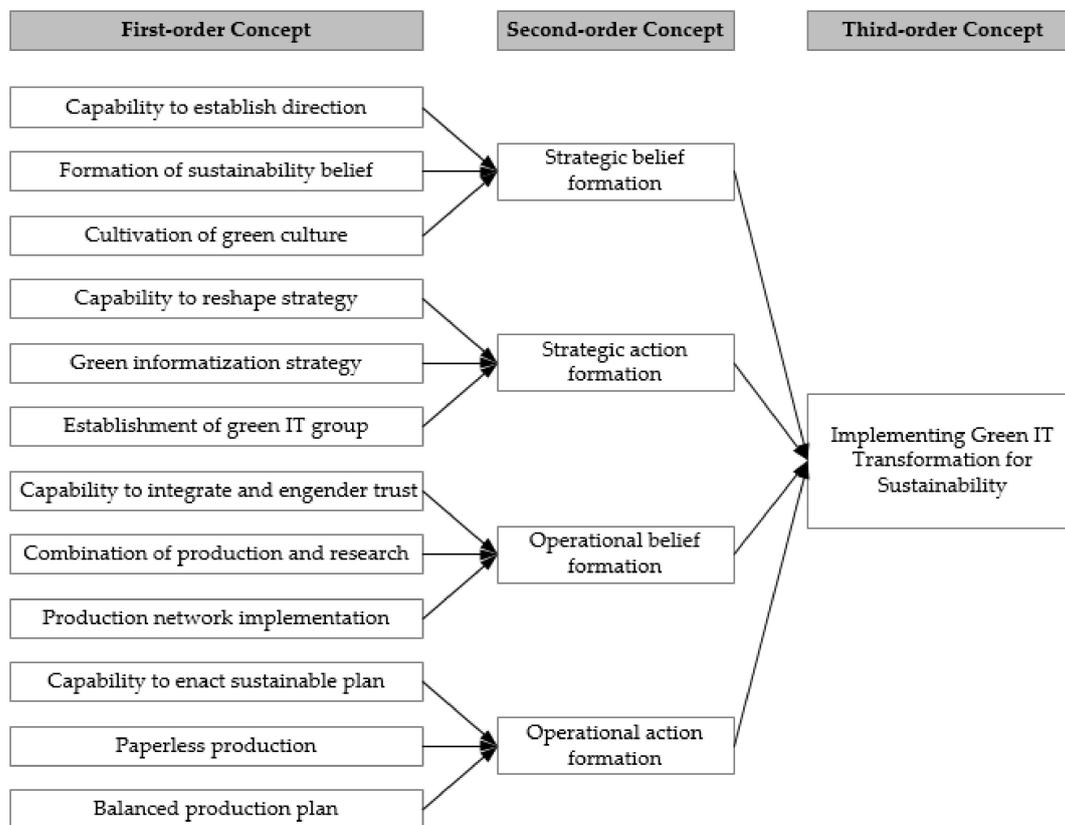


Figure 2. Hierarchical diagram of concepts.

4. Case Description and Analysis

4.1. Case Background

Shenyang Aircraft Corporation is an aircraft manufacturer, and is a subsidiary of the Aviation Industry Corporation of China (AVIC). The organization’s dedication to environmental sustainability was encouraged by the goals of China’s Ministry of Environmental Protection in the 11th “Five-Year Plan” period. The plan aimed to reduce the energy consumption per GDP unit by 20% and the emission of major pollutants by 10% across all businesses in China by 2010.

AVIC adheres to green IT and environmental protection policies, and incorporates energy saving indicators into the performance assessment of its subordinate units. Under the guidance of the AVIC, Shenyang Aircraft Corporation insists on sustainable development, and its total investment in promoting scientific and technological level reaches 3.6%. But that still seems insufficient: Shenyang Aircraft Corporation calls for green IT transformation. Transformation requires activities at both strategic and operational levels to accommodate changes of internal and external circumstances.

4.2. Strategic Belief Formation Phase

Existing literature argued that the vision of an enterprise represents its ultimate goals; it defines the direction, objectives, self-set social responsibilities and obligations in the long-term running; it also answers the question of “where the enterprise will go” from a long-term perspective [39]. Vision affects an enterprise’s strategic decisions, therefore identifying its vision is the very first step of the

decision-making process [40], and the enterprise will incorporate the vision into implementing the decisions. The first step for green IT transformation is to establish a green vision. At this phase, the capability to establish direction was significant. Green IT transformation is a complex and uncertain process. Therefore, when the company's executives first proposed a strategic intent for the transformation of green IT, the ability of companies to adapt dynamically and find the direction of change in a highly dynamic environment must be improved. Preconditions, such as belief differences and culture gaps, are primary causes of different actions. Therefore, the first step for green IT transformation in Shenyang Aircraft Corporation is to develop the capability to establish direction, including sustainability belief and green culture.

The successful green IT transformation in Shenyang Aircraft Corporation is firstly attributed to the sustainability vision: "innovative, coordinated, green, open-minded and shared by all". Under the guidance of this vision, the Corporation implements the sustainability vision from the beginning of product design, strives to develop environment-friendly products; in the manufacturing process, it also applies rating standards for green manufacturing enterprises and restricts practices against the sustainability vision. Just as the vice manager of Shenyang Aircraft Corporation says, "Our parent company AVIC attached great importance to adhering to green policy in the long-term running and it has incorporated energy saving indicators into the performance appraisal standard of our company. Therefore, we've got enough pressure and motivation to put forward sustainability and green IT vision". To further promote the notion of sustainability, Shenyang Aircraft Corporation mobilizes managers and employees in various teams to participate in the competition of "saving energy and reducing emissions". The labor union sets competition targets based on the different nature of work in various teams. It rewards outstanding teams and normalizes the form of competition, ensuring a competition and reward for each quarter of the year. The Corporation collects suggestions from the entire staff, coordinates all departments to publicize all kinds of suggestions, adopts reasonable suggestions, summarizes excellent working experience, and urges managers of all departments to optimize working procedure for better energy-saving and emissions-reducing.

From emphasizing economic benefits to balancing economic benefits and environmental protection, the change in idea is a gradually spreading process. Hofstede [41] believes that there are four major cultural factors that will directly affect the behavior and mode of management. They are: individualism–collectivism, power distance, uncertainty, uncertainty avoidance and masculinity–femininity. And based on oriental culture, Hofstede [41] added one more factor, long term orientation. The long-term orientation has highlighted the persistence and patience of Chinese culture, striving to work diligently and working hard for long-term goals. Therefore, throughout the process of Shenyang Aircraft Corporation establishing a sustainability vision, green culture had vigorously changed to make employees work for the long-term goals. Cultural change is an essential part of business transformation [42,43] and requires the direct leadership of the company's top executives. Therefore, a working group was established and tasked with the execution of cultural transformation, which was directly helmed by a Vice President. The group's responsibility is to establish an awareness of energy-saving and environmental protection within the company. The development of green culture also asks for employees' engagement [44,45]. Shenyang Aircraft Corporation thus leveraged a variety of channels for internal communications and discussions (e.g., emails, posters and presentations) which enabled employees to understand the mutually reinforcing nature of Green culture and sustainable development. The green culture is then embraced by its employees, providers, and clients. When economic and environmental interests conflict, the Corporation expects to balance them by seeking understanding from all relevant parties.

The capability and actions performed in the strategic belief formation phase are summarized in Table 2.

Table 2. Strategic belief formation.

Key Capability	Data Support
Capability to establish direction	"We know very clearly that the green transformation is full of variables and how to find directions in an intricate market was a key capability. In order to achieve a successful transition, companies must improve the ability to establish direction and adapt to changes. We believed that belief and culture were essential factors in cultivating the ability".
Key Actions	Data Support
Formation of sustainability belief	"We adhere to the sustainability vision which is 'innovative, coordinated, green, open-minded and shared by all'. We implement sustainability vision from the beginning of product design, and applies rating standard for green manufacturing enterprises throughout the whole manufacturing process". To unify the top executives' vision of sustainable development, Shenyang Aircraft Corporation would invite experts on relevant fields to train company managers from time to time. The courses cover the role of green IT, the importance of sustainable business and society, and so on. For example, Shenyang Aircraft Corporation has conducted consulting and training cooperation with Beihang University, targeting on green IT strategies for enterprises.
Cultivation of green culture	"Developing environment-friendly economy and shouldering social responsibilities are two notions among our design concepts and original intentions. We should create a green atmosphere and culture in all aspects of enterprise management". "For example, the cooling fluid used in special process line is demanded to go thorough mold test. The test is hard to carry out considering of both production costs and period. However, mold will undermine employees' health and the deterioration of the cooling fluid in summer will harm the workers. Therefore, to continue to use the cooling fluid, we have made several negotiations with providers, and they finally understood the green culture of sustainability in Shenyang Aircraft Corporation".

4.3. Strategic Action Formation Phase

Strategy is the process that integrates resources and transforms particular capabilities into competitive advantages [46], and its essence is to design a set of methods to efficiently utilize the enterprise's core resources and capabilities [47]. Besson and Rowe [48] found that IT transformation is still a new field of strategic research. In the process of IT transformation, the renewal of strategies is essential [36]. Montealegre [49] argued that establishing strategic direction, focusing on strategy, and institutionalizing the strategy are significant capabilities when implementing IT transformation. Furthermore, Chen and Chang [50] pointed out that good leadership in green transformation positively influences green performance. At this phase, the capability to reshape strategy was essential. Having determined the vision for transformation, the problem faced by senior executives is how to restructure corporate strategy. In the past, the issue of green development would not be a key factor in the formulation of corporate strategies. Now that green IT transformation is to be implemented, the ability to overcome resistance to reshape corporate strategy becomes even more important. A green informatization strategy and establishment of a green IT group were two ways to cultivate the ability

Under the leadership of top managers and the green IT group, informatization strategy was introduced to realize the sustainability vision. To implement the sustainability strategy, Shenyang Aircraft Corporation equips each workshop with a specific energy measuring system and inspects it regularly. Thanks to the implementation of the Green IT strategy, the amount of development projects during the eleventh "Five-Year Plan" period has increased by 52.6% over the last period, while the corresponding energy consumption and costs have dramatically decreased over the same period.

Green informatization strategy is the process in which information technology is applied to actual business and it concerns all aspects of an enterprise. Shenyang Aircraft Corporation has been practicing informatization since 2001. Informatization in the 10th "Five-Year Plan" period (2001–2005) was about three dimensions: engineering, design and manufacturing, and performance management and infrastructure construction. It also presented three main goals: "digitalization of design and manufacture, informatization of enterprise management, and realization of networked information processing". In the 11th "Five-Year Plan" period (2006–2010) the goals were further defined as "knowledge-based design and manufacturing, informative procedure management, and securitized networks". This is based on national security considerations, and the Corporation managed to realize informatization considering the stability, security, and reliability of network operation. In the 12th "Five-Year Plan" period (2011–2015), based on strategic plans and green IT, the strategic goal of informatization is to realize intellectualization of Shenyang Aircraft Corporation; main priorities

during this period are to cut costs, shorten working cycles, enhance cooperation, and reduce pollution. As Cui, supervisor of the information technology department, said, “We consider IT is of increasing importance for the success of the enterprise and IT transformation has changed from a dispensable tool into an essential strategic driver”.

To more efficiently promote green IT transformation, in 2011, Shenyang Aircraft Corporation specifically set up a green IT group, including both senior managers and employees at the ground level. The main duty of the group is to consult all branches of the enterprise and to coordinate their relations, so that the group can provide strategic supports and implement plans for green IT transformation. Just as Wang, associate director of the information technology department, said, “Before green IT transformation, IT department hasn’t got much power in making decisions on IT strategies. We just offered IT supports and fulfilled top managers’ requests, but sometimes it’s hard to comply with them. After the establishment of green IT group, we are able to directly participate in decision-making, which facilitates the implementation of strategic plans”.

The capability and actions performed to support the strategic action formation phase are summarized in Table 3.

Table 3. Strategic action formation.

Key Capability	Data Support
Capability to reshape strategy	“In the past, company focused on maximizing economic benefits in the formulation of strategies. Now in the face of green vision, companies needed to reshape green strategies and build the ability to overcome resistances. And in the process of green IT transformation, it is necessary to cultivate this capability from the green informatization strategy and the establishment of green IT group”.
Key Actions	Data Support
Green informatization strategy	“AVIC attached great importance to informatization strategy and we must apply resources to study it. Leaders of the Corporation have made long-term plans based on green IT and they hope to utilize it in daily management by applying it to the practical business of the corporation”. “Thanks to the implementation of green informatization strategy, the amounts of development projects during the eleventh ‘Five-Year Plan’ period have increased by 52.6% over the last period, and during the twelfth ‘Five-Year Plan’ period by 91.8%; the corresponding energy consumption and costs have dramatically decreased over the same period”.
Establishment of green IT group	“At the request of AVIC’s green IT and environmental protection policies, we established the green IT group. The group included both senior managers and employees at the ground level to ensure the green IT strategy could be implemented effectively”. To support the strategic transformation of the Corporation, the newly-formed green IT group, composed of department heads, then established special Key Performance Indicators (KPIs) to assure the continuity of Green IT transformation. These KPIs were decomposed into unit-specific KPIs which became mandatory targets and were tied to financial incentives for every business unit. Shenyang Aircraft Corporation also developed a specific performance appraisal system to evaluate the implementation of the strategy in all departments, which motivated the business units towards the enactment of Green IT transformation.

4.4. Operational Belief Formation Phase

Making plans plays an important role in implementing green IT [51]. With the help of the green IT group and based on the strategies, the sustainable plan was launched in 2012. The crucial values are to realize the economic, social, and environmental sustainability of Shenyang Aircraft Corporation. And at this phase, the capability to integrate and engender trust was important. For manufacturing companies, implementing green IT transformation requires the ability to integrate business to achieve green strategy. At this stage, in order to smoothly promote the transition, companies must be able to obtain the trust and commitment of the business sector. Combination of production and research as well as production network implementation were two measures to develop the ability of implementing plans.

Shenyang Aircraft Corporation used to adopt a working mode in which the office designed a prototype, then the main factory started production, and the design office improved the process and design based on the production situation. This mode had two defects: on one hand, the working response was rather slow; on the other hand, rejection rate at the beginning of production was rather high, causing a tremendous waste of costs. Now by deploying MES, the Corporation realizes the joint

research and development in different places. This grants manufacturer permission to design, and combines design with production, thus rejection rate has been greatly reduced.

In order to fulfill the green informatization strategy, Shenyang Aircraft Corporation implemented a production network including two systems: a delivery system and a manufacturing execution system (MES). Production network comprises planning working hours, checking project progress, matching parts and components, examining the situation of production lines and facilities, warning risks. They are all planned, organized, scheduled, assessed, wound up, and monitored online. During the process, MES plays an essential role. This system allows the Corporation to manage its production with bar codes, that is, each production process requires the scan of bar codes in EMS, including wage settlement and performance assessment of the employees. As Hu, head of coordinating planning department, has said, "Working hour is planned by quota-allocating department. It will reallocate working hours based on performance improvements. MES has increased our production capacity, therefore quota-allocating department can shorten the planned working hours and increase rewards according to the completion of indicators. In this way, the performance of our department improves by 10% annually. We can save the cost of the entire production process and greatly motivate the employees". In addition, by transmitting data to different places, MES allows joint research and development in different places. Just as the Corporation's deputy chief designer said, "The research and development mode in aviation industry used to be 'one place-one manufactory-one office', for example, Xi'an had one manufactory and one design office, and the same goes for Chengdu and Shenyang. But Advanced Regional Jet (ARJ) project allows for nationwide joint research and development".

The capability and actions performed to support the operational belief formation phase are summarized in Table 4.

Table 4. Operational belief formation.

Key Capability	Data Support
Capability to integrate and engender trust	The implementation of a green transformation requires companies to have the abilities to integrate internal resources, gain the trust of business units, and strengthen their determination to transformation. A combination of production and research facilitated integration effectiveness. Production network implementation promoted the rational allocation of resources.
Key Actions	Data Support
Combination of production and research	"When research and manufacture were separated, the working response of the Corporation was rather slow. Besides, lots of our productions lacked manufacturability, resulting in a waste of costs. If the Corporation is granted permission to design, it can seek to combine design with production, that is, to modify the design so that the products meet the manufacturing standard".
Production network implementation	"Generally speaking, we have a production network that contains two systems: a submission system and a MES. Next, we will also have 7 visual monitoring panels". "Through this system we can examine whether our plans are reasonable. We can optimize the investigation, reflecting the different production capacity of various workshops. The system also reflects the problems of various production lines, such as problems concerning facilities, technical quality, and materials and equipment. On visual monitoring panels, we can schedule production and assess production tasks".

4.5. Operational Action Formation Phase

In order to offer a comprehensive perspective of development, strategic level of organizational actions and operational level of departmental actions both need to be emphasized. At this phase, the capability to enact a sustainable plan is necessary. Whether or not the business department can promote green IT in a consistent manner is one of the keys to the success of the enterprise transformation. Therefore, companies need to develop capabilities to achieve the collective implementation of green IT initiatives that are autonomously and voluntarily initiated by its staff. Shenyang Aircraft Corporation implemented the sustainable plan from two aspects: paperless production and a balanced production plan.

Paperless production has always been the pursuit of Shenyang Aircraft Corporation. Thanks to MES, all data and files in research and development process are uploaded. By entering a valid file number, one can retrieve all data about the parts on the production site. Besides the production process, the Corporation also implemented paperless management in offices. Conference notifications, documents, and other files are uploaded directly to the system, ensuring environmental protection.

Paperless production requires the Corporation to focus more on environmental protection and green production on the basis of the original producing and managing modes. It pays more attention to cutting the waste of paper in the original production process, rather than comparing energy consumption between paperless and electronic production. As the head of production department has said, "Paperless production has improved production efficiency and cuts paper waste greatly. It is one of our important means of saving energy and protecting the environment".

Shenyang Aircraft Corporation adopted a balanced way between sustainability and profitability by successfully balanced production plan. By optimizing working process, the balanced production plan offers three benefits: First, it remedies defects in assembly and diminishes risks. Second, it ensures the consistency between management objectives and production targets, thus improving profits. Third, it reduces waste in production to ensure the implementation of sustainability vision.

The capability and actions performed to the operational action formation phase are summarized in Table 5.

Table 5. Operational action formation.

Key Capability	Data Support
Capability to enact sustainable plan	"All visions and strategies will ultimately be implemented into execution. The completion of the transformation requires the ability to implement plans. Paperless production and balanced production plan were two ways to implement the sustainable plan".
Key Actions	Data Support
Paperless production	"We have broadly employed paperless working procedure on production sites. Workers can check 3D models on production sites; they can also retrieve all data about the parts by entering a valid file number. Now we have applied the technology to all production lines in Shenyang Aircraft Corporation".
Balanced production plan	"Balanced production strategy means that products on the production line flow in an orderly manner. Its character is that the defects in assembly can continually decrease or even disappear. Theoretically speaking, production is in a balanced state". "Balanced production strategy was put forward by our enterprise. Its requirements are rather high so we're supposed to take advanced management mode to deal with risks and problems existing in the production lines".

5. Conclusions

Through the two development phases of belief formation and action formation, the green IT transformation is successfully realized. ACIV has managed to balance sustainability and profitability. Environmental protection has been applied from the source of design and the rating standard for green manufacturing enterprises has been applied throughout the whole manufacturing process. AVIC has implemented 162 technological transformation projects for energy-saving and emission-reduction in 2016 and invested 347.3 million yuan in these projects.

5.1. Theoretical and Practical Contributions

We built the BAO framework on the basis of green IT transformation activities to fulfill sustainability in Shenyang Aircraft Corporation. The model contains key capabilities and key actions for belief formation and action formation at both strategic and operation levels. At a strategic level, the belief formation phase includes the capability to establish direction and required actions (formation of sustainability belief and cultivation of green culture). The action formation phase contains the capability to reshape strategy and required actions (green informatization strategy and the establishment of green IT group). As for operational level, the belief formation phase needs the capability to integrate and engender trust; the combination of production and research as well as production network implementation constitutes required actions. The action formation phase includes the capability to enact a sustainable plan and required actions have two parts: paperless production and a balanced production plan. In addition, there are relationships between each phase. Strategic belief formation guides operational belief formation as well as facilitates strategic action formation. Because strategic belief contains company's main direction and obligation, that is broken into specific goals and guides operational belief. Belief and vision are also the foundation of corporate strategy and will facilitate the implementation of the strategy. Strategic action formation exemplifies operational

action formation and Operational belief formation enables operational action formation. This is because strategies and beliefs will ultimately be implemented into plans and operations. Eventually, Shenyang Aircraft Corporation has achieved green IT transformation and the balance between sustainability and profitability, which affects economic, environmental and social sustainability.

Consequently, we have expanded the BAO framework to strategic and operational levels, and summed up the capabilities and mechanisms of each phase, as well as the impact relationships and directions between each stage. The process model of implementing green IT transformation for sustainability is summarized in Figure 3.

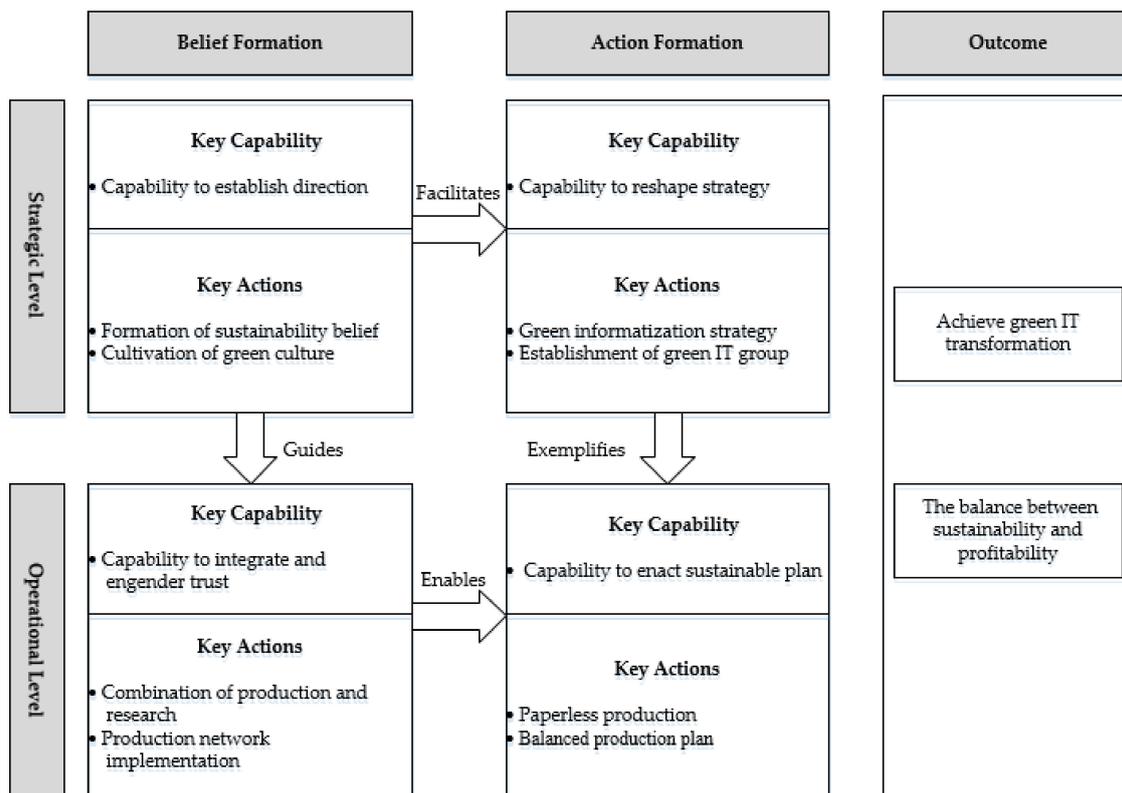


Figure 3. Process model of implementing green IT transformation for sustainability.

First, this study provides a qualitatively empirically grounded framework for the study of green IT [36,52]. Green IT is emerging as a topic and has received more and more attention from scholars [5,53]. However, most of these studies are generalized and lack empirical evidence. Without sufficient empirical evidence, the conclusions of these articles only stay in the hypothetical stage, which is not conducive to the accumulation of relevant knowledge. This study introduces the BAO model, introduces the process of a company’s transformation, and discovers the capabilities as well as actions required by the enterprise’s green IT transformation. The research findings enrich the research of green IT.

Second, this study contributes to the literature on sustainability from an IS perspective. Many researchers have suggested that corporate’s IT-driven sustainable transformation is very difficult to achieve, because corporate sustainability is a complex and multidimensional process that is full of uncertainty [5]. However, based on our inductively derived model, we find that companies develop key capabilities and key actions for belief formation and action formation at both strategic and operation levels. As far as we know, this study is one of the few studies that analyses sustainable development at strategic and operational levels within an organization based on a green IT perspective. Therefore,

this study provides enterprises with actionable prescriptions to increase the possibility of successfully implementing green IT initiatives for sustainability.

Finally, our study also made important contributions to the BAO framework as proposed by Melville [5], because the number of empirical studies that use this model in the context of IT Transformation is small. In particular, through the case study, we have expanded the BAO framework to strategic and operational levels, and summed up the capabilities and mechanisms of each phase, as well as the impact relationships and directions between each stage. We believe that these new ideas will effectively develop the BAO framework and provide important value to the future green IT transformation for sustainability research.

As for practical implications, first, this study proposes a supporting framework for implementing green IT and attaining sustainability. More specifically, the process framework has identified the belief phase and action phase that an organization must go through, and the key points and activities conducted in each phase. Second, organizations that intend to realize green IT transformation can use the BAO framework developed in this article as a guidance to achieve their goals. Last, organizations could leverage their resources and capabilities to contribute to sustainability and an environment-friendly society for future generations.

5.2. Limitation

There are also limitations in this study. Although studies are based on the single case research method which is a “typical and legitimate endeavor” [54] in qualitative research, scholars’ dispute centers on the problem of generality and external validity [32]. While we acknowledge that statistical generalization is impossible from a single case, we nevertheless contend that our research is general beyond its singular context as the derived model is not only grounded in the empirical reality of our case study, but also corroborated by present literature. Hence, this study invokes the principles of “analytic generalization” [35]. Future research could validate propositions of this study statistically, so that the boundary conditions of our findings can be better refined.

Author Contributions: D.Z., X.F. and T.O. designed the research and wrote the paper. D.Z. was responsible for the literature review. D.Z. and T.O. interviewed the case study firm. X.F. analyzed the data. All three authors wrote the conclusion and approved the final manuscript.

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