An Adaptable Conceptual Model for Construction Technology Transfer: The BRI in Africa, the Case of Ethiopia

Zahra Abdulhadi Shukra 1,2, Ying Zhou 1 and Lingling Wang 1,*

1 Civil & Hydraulics Engineering School, Huazhong University of Science and Technology, Wuhan 430074, China; zahraabd@gmail.com (Z.A.S.); ying_zhou@hust.edu.cn (Y.Z.)
2 Department of Technology Transfer, Construction Project Management Institute, Ministry of Urban Development and Construction, Addis Ababa 1000, Ethiopia
* Correspondence: wlling@hust.edu.cn

Abstract: Unlike other developmental relationships, BRI is the most promising icon in transforming the construction industry and built environment in Africa; the infrastructure developments like highways, bridges, skyscrapers, and aviation take in advanced construction technologies, methods, and skills. However, the technological capability of Chinese construction firms is not transferred in the highest capacity to the host countries. Nevertheless, the main focus is on delivering modern railways, highways, and skyscrapers. Thus, this research aimed to propose an adaptable technology transfer model by identifying the theoretical concepts in the body of knowledge, exploring the prior technology transfer models and the best experiences. The findings indicated that the BRI inclusive countries in Africa benefit from infrastructure development with an investment amount of more than US$33 billion with potential technology spillovers, but in an unplanned, and not best suited to their conditions because of the lack of a single-country-based technology transfer model ahead of project implementation. Using a systems thinking approach and a causal loop diagram tool, the authors created a conceptual model to guide the Africa’s construction technology transfer through BRI. The research also examined case study projects in Ethiopia to assert the new model’s practicability over the existing processes. Moreover, the university–industry linkage structures, can facilitate the process through R&D and innovation in the whole project life cycle.

Keywords: Africa; Belt and Road Initiative; construction technology transfer; Ethiopia; technology transfer model

1. Introduction

The Belt and Road Initiative (BRI) has had a progressively significant impact on infrastructure development and economic growth in Africa. Even though the China–Africa relationship existed decades ago, the BRI improved connectivity and cooperation on a transcontinental scale [1]. The initiative also promotes infrastructure construction, trade, and investment, among other activities, between China and those countries along the Belt and Road [2,3]. It added value in stimulating Africa’s construction industry through job creation, investment, and technology [4,5]. Since the lack of technology has been one of the severe bottlenecks in African industrialization, technology transfer (TT), or knowledge sharing through the BRI, is imperative. Additionally, China’s economy prioritizes making buildings smarter, improving sustainability using digital technologies [6]. According to Dodge Data and Analytics, China ranked among the top in advanced construction technology implementations such as BIM adopter nations between 2015 and 2017 [7].

Yet, in strengthening China–Africa relations, technology transfer (TT) is one of the less-premeditated subjects, and there is much room for its improvement to achieve mutual benefits [8]. With the opening-up policy, China’s strategic focus on switching to commercial construction also brought related changes in dimension, scale, and depth of technical knowl-
edge in Africa. Hence, the construction industry’s progression in technology advancement is a crucial strategy for sustainable development in Africa.

TT, by definition, is the transfer of knowledge and experience to meet the local conditions of practical use and distribution within individual countries [9]. According to Grosse Robert, TT is “the process of transferring, disseminating technology from the person or organization that owns or holds it to another person or organization.” [10]. The transfer can occur with various bodies like universities, from university to business (and vice versa), from large companies to smaller ones, from the government to business, across geopolitical borders, both formally and informally, and both openly and privately [9,11]. Hoffman and Girvan define TT in terms of achieving three main objectives: the introduction of new technology, the improvement of existing techniques, and the creation of further knowledge [12]. We can also consider TT to transfer scientific and technical information from fundamental science through application and development in manufacturing and services, a typical practice in university–industry TT [13]. After a range of literature reviews, Matthew Good (2019) has obtained the identification of four core components of the TT ecosystem: TT offices (TTOs), incubators, science parks, and university venture funds [11]. In recent research, these four primary components of the TT ecosystem and the emergence of new modes for the facilitation of academic entrepreneurship, such as university-based entrepreneurial ecosystems and accelerators, are also practicable.

Moreover, many kinds of literature indicate that developed countries in Europe and Asia have used TT as a socio-economic development strategy in the past [14–16]. The link between TT and foreign direct investment made by multinational corporations seems prominent [15,17]. Hence, TT could prevail through the BRI. Chinese construction companies can forward technical skills and technological capabilities to local construction firms in Africa. Moreover, for sustainable growth, intensive knowledge, expertise, and TT are essential, contributing a lot to Africa. When we look at the current technology innovation capacity of other successful nations like China, the significant role played in the achievement was the systematic approach in technology adaptation and re-invention from foreign companies [15,18]. Hence, the Africa–China relationship conveys the hope for technology spillover under the BRI in the AEC industry [19]. Given the challenges and complexities of TT, many countries faced many problems: many researchers, consultants, and practitioners propose TT models that could facilitate the effective planning and implementation of TT on projects through a systematic and well-thought approach. Although there have been many scientific TT models since early times, the industry condition and status quo of each country need a contextually adapted transfer model, and many researchers suggest the adopter’s perception and willingness for the acceptance of technology is vital through understanding the cultural and social value.

With the lack of national technical capability, lack of joint efforts of the different actors, including weak national priority research programs, modern technology acquirement endeavors in Africa need enablement. The BRI certainly turns the African construction industry into a new vibrant economic pillar and contributes to advanced technological capability by incorporating successful experiences. Primarily, it envisages a lot of development advantage for East Africa because of its strategic place as tactical access to link China to the Middle East and Europe, as shown in Figure 1.

Similarly, China’s industrial cooperation with Ethiopia focuses on the establishing an economic corridor, the Addis Ababa–Djibouti Port railway line, as shown in Figure 2, including several industrial parks (FOCAC 2016) [20]. Ethiopia is a pioneering country in China–Africa industrial cooperation demonstration [21,22]. Ethiopia, second in population number in Africa, and its economy has grown, on average by 10% per year over the last decade [23]. Ethiopia is a leading example of the relocation of light industries’ production processes from China to Africa. The Chinese companies are already delivering their Ethiopian products to European and US markets [24].
Figure 1. 21st-century maritime Silk Road connection line from China, East Africa, and the Middle East to Europe.

Figure 2. A map of the Addis Ababa–Djibouti railway that connects the capital city to the 21st Century Maritime Silk Road.
Nevertheless, the significance and the limitations of BRI in TT in Africa, specifically in the AEC, has a gap in implementation and R&D [25,26]. The existing financial incapability in Africa to mobilize technology and innovation is a considerable challenge. Yet, technology and innovation gaps exist, and much effort is needed to shift the technical knowledge and innovation capacity [27].

Hence, the important issue is the need for a single-country-based practical construction model in Africa to articulate the transferee and transferor’s environment. Therefore, this research aimed to show the promising iconic significance of the BRI in construction technology transfer (CTT) and provide an adaptable model for further application in each project context using Ethiopia as a case study. Given those substantial multinational Chinese construction companies involved in infrastructural development in Africa bring technological and skill capacities into the country, without a designed model and methodology, both parties will suffer the uncertainty of mutual benefits.

The article includes the research methodology and process map to show the overall research flows. The outline follows a typical research article outline. The current state of TT and BRI in Africa, the existing scientific TT models, and country-based TT experience are summarized in a section. Then, the above theoretical and practical concepts were framed using system thinking and system dynamics modeling to propose the new model adaptable for BRI projects in Africa; the new model design and validation is illustrated in Section 4. Subsequently, three case study projects in Ethiopia were analyzed and discussed to demonstrate the limitations in the CTT processes, and then relate the advantages of using the new contextualized model. Finally, the discussion and conclusion elaborate the proposed TT model implementation and future research direction.

2. The Current State of TT and the BRI in Africa

2.1. The BRI and Technology Transfer

The BRI projects are mainly in infrastructure development in the transport, energy, mining, IT, and communications sectors and consist of industrial parks, special economic zones, and urban development. Most projects got empowered after the official announcement of BRI in 2013. Currently, 42 African countries are under the BRI agreement with more than US$33 billion. Africa is the significant aspect of One Belt One Road in massive demand for rails, roads, and energy. When we look at some of the projects, as shown in Table 1, the initiative prolonged enormous projects like world-class airports, smart city building, and investing in special economic zones/industrial zones.

Since the practice in the construction industry in Africa is very traditional with multiple problems in time and cost overrun, poor quality, unsafe construction, and generally low project management maturity, the presence of Chinese foreign firms is expected to bring more advanced technological and technical knowledge transfer to the domestic host countries. TT is a dominant factor in the economic progress for development. Inward Foreign Direct Investment (FDI) was a significant source of technology transfer in most countries and the import of technology by licensing and purchasing capital goods embodying new technologies. The TT structures from foreign firms in the Africa’s construction industry did not fulfill the anticipated results, because the main focus was the infrastructure development. BRI’s promising feature for the national construction industry transformation is at hand, but the local domestic firms’ technology absorptive capacity negatively affects the process. China’s role in the TT scheme should be a given scenario, since it possesses the advanced construction technologies, environmentally conscious design, building, and experience in TT and innovation.
Table 1. Projects in Africa under BRI.

| Country   | Year | Project Category | Project Name                                      | Investment Amount | Chinese Contractor                                                                 | Project Status   |
|-----------|------|------------------|--------------------------------------------------|-------------------|------------------------------------------------------------------------------------|------------------|
| Djibouti  | 2015 | Port             | Doraleh multi-purpose port                       | US $599 m         | China Civil Engineering Construction Corporation (CCECC)                           | Operating        |
|           | 2011 | Standard Gauge Railway | Addis Ababa-Djibouti Railway                     | US $4 bn          | China Civil Engineering Construction Corporation (CCECC) China Railway Engineering Corporation (CREC) | Operating        |
| Ethiopia  | 2015 | Light Railway    | Addis Ababa Light Rail Ethiopia's Eastern industrial zone | US $475 m         | China Railway Group Limited Shenzhen Metro Group                                    | Operating        |
|           | 2007 | Industrial zone | Ethiopia's Eastern industrial zone               | US $900 m         | Jiangsu Yongyuan Investment Co Ltd.                                                 | Operating        |
| Egypt     | 2015 | Industrial zone | Suez canal economic zone                        | US $1 bn          | China’s TEDA and other Chinese companies                                             | Operating        |
|           | 2015 | Administrative Buildings | New Administrative Capital                      | NA                | China State Construction Engineering Corporation (CSCEC)                            | Under construction |
| Kenya     | 2014 | Standard Gauge Railway | Mombasa-Nairobi Standard Gauge                   | US $3.6 bn        | China Road and Bridge corporation                                                   | Operating        |
| Nigeria   | 2011 | Standard Gauge Railway | Abuja-Kaduna railway line                       | US $876 m         | China Civil and Engineering Construction Company (CCECC)                           | Operating        |
|           | 2016 | Railway construction | Lagos-Calabar railway line                      | US $13 bln        | China Railway Construction (CRC)                                                    | Under construction (2021) |
|           | 2018 | Standard gauge Railway | Lagos-Kano Standard Gauge Railway                | US $6.68 bln      | China Civil and Engineering Construction Company (CCECC)                           | Under construction (2021) |
| Uganda    | 2013 | Energy           | Karuma Hydropower project                       | US $1.7 bn        | Sinohydro Corporation Limited (EPC) Shandong Taikai Transformer                     | Under Completion |
| Zimbabwe  | 2018 | Transport        | Harare Airport expansion                        | US $153 m         | Jiangsu International                                                             | Under construction |

Note: 1 MOU = Memorandum of understanding. Data source: official website of BRI (www.beltroad-initiative.com, accessed on 7 January 2021).

2.2. The Existing Technology Transfer Models

This section initially discusses the TT models in the body of knowledge. Then, the advantages and drawbacks to extract critical parameters in developing a new, improved model in point are summarized. There have been a significant number of TT models since the 1970s. For this research purpose, the ones that emphasize TT at the country-level are discussed; few also consider transferring from foreign firms to the local firm level.

2.2.1. The Bar-Zakay Model

The earliest model on the topic is the Bar-zakay model [28], a comprehensive one based on a project management approach [29]. Its workflows include Search, Adaptation, Implementation, and Maintenance stages. It also outlines the transferors activities and requirements of the transferee in detail, the emphasis on both the transferor and transferee acquiring skills to undertake technological forecasting, long-range planning, and gathering of project-related intelligence [30]. The most notable application of this model is applicable in both organization and country-level, like developing countries importing technologies from developed countries. However, the drawback of this model is that it has limited relevance today, because many of the activities, terms, and ideas expressed do not fully reflect current settings [31].

2.2.2. The Dahlman and Westphal Model

Another viable TT model is the Dahlman and Westphal Model. The model consists of a nine-stage process. The model might not be feasible in developing countries with less access and low skill in high-level engineering skills [32,33]. Nevertheless, it plays a significant role in developing sound engineering and project management skills effectively [32,33]. Moreover, it involves the transferee being involved in the planning right from the beginning. The model’s most crucial feature is the transferee’s involvement at all TT project stages; this is the fundamental element drawn for BRI in Africa. However, this model’s critical disadvantage is it assumes the transferee has access to a high engineering skill; that is not the case in most countries in Africa.
2.2.3. The Schlie, Radnor, and Wad Model

The Schlie, Radnor, and Wad Model outlines seven elements that can influence the planning, implementation, and eventual success of any TT [28]. The practical issues in TT transfer considered in this model are the transferee environment, the transferor environment, and the higher environment, which are very imperative to a successful output, and it identifies the enabling environment of both transferor and transferee, including the external environment, which is the most cultured feature of this model. The model manifests the overall context, but it does not specify the guidelines on how to do it, and it does not clearly show the relationship between the elements [28,34].

These models can also be implemented either at a project or organization level. Yet, country-level TT needs an enormous consideration of government commitment to adopting the TT methods related to project type and technology recipients’ absorptive capacity. The development relationship between countries like BRI has a positive technology spillover effect. Nevertheless, the technique and process affect how both parties should plan together and involve in the whole process.

2.3. The Experience of China in TT and Innovation

The research explored China’s TT and innovation experience, since it accomplished a remarkable development through TT. On the other hand, China’s TT and innovation model shows China’s technical capability progress involved the TT model from formerly developed and industrialized countries. The Chinese government encouraged local firms to adopt foreign technologies and has attached more importance to the transfer of institutions–industry technology research in economic development [35]. In China, research institutions, including universities, develop most technologies, which makes universities the source of new technologies. Transferring technology, therefore, from research institutions to the industry has always been a strategic issue for the Chinese government [36].

Moreover, China’s government encouraged that foreign investors in specific sectors form joint ventures with a local Chinese partner. Empirical studies also show all joint ventures in China from 1998 to 2007 promoted TT from foreign investors to domestic operations [37]. In a typical TT and innovation model in China, international firms intend to share the local firms’ techniques in exchange for market access. Their TT model also reflects TT through joint-ventures, later supported by R&D by local universities for adaptation and innovation, led to the current state of advanced technological capability.

2.4. The Current Problem

Even though there is an enormous investment in Africa’s construction industry, the BRI impact on the TT process is not well recognized. There is a need for CTT research in Africa under the initiative; moreover, a research collaboration between two nations shall uplift the anticipated mutual benefit. The TT experience of other successful countries depicts the role of government commitment and a transformational strategy at the country level. However, the main focus of those countries under BRI in Africa is the flow of investment and infrastructure development. The studied models also implicated that the TT process’s significant factors are the transferee and the transferor, understanding the environment, and agreement, which signifies the technology demand, absorbing capacity, and transferring mechanism. The other critical factor is the adaptation and implementation process that needs detailed guidelines, training, piloting, and operation plans. However, planning ahead of a project for TT, will address this issues. Additionally, when we looked at the representative models implemented in China, the primary strategy at the beginning was the incorporation of domestic firms with foreign technology owners, either with incentives. Here, the commitment of government and involvement in the process led from adapting technologies to innovations. The need for an adaptable CTT model that can fit the scenarios of a technology seeker country that understands the demand, the enabling environment, and absorptive capacity for empowering BRI in Africa to bring technological advancement in AEC is inevitable.
3. Methods

This research aims to design an adaptable CTT model for the Africa’s AEC industry under BRI. The study mainly focused on analyzing existing TT models, experiences, and the significance of BRI for TT, in a system thinking approach.

The whole idea is described in a diagram in Figure 3 below; based on the existing research, the limitations and concepts in scientific TT were summarized, the experiences of China in TT also incorporated, and then the BRI projects in Africa some relevant information on the TT gaps that help construct the proposed model were obtained. Then, the proposed model was built using a system dynamics tool. System dynamics is a system thinking technique for modeling a structural or mathematical model to discuss and understand processes such as technology transfer in an organization or country level [38]. A causal loop diagram was implemented to devise the construction technology transfer model (CTTM). A causal loop diagram is a simplified drawing of a model with all its variables and co-dependence; it merely shows the whole system’s structure in a model by identifying the main variables and indicating their relationships [39]. It consists of four essential elements: the variables, the links between them (cause and effect), the signs on the links (either positive or negative), and the sign of the loop (either balancing or reinforcing) [40]. The relationship-based parameters are exhausted in developing the model through system thinking. The new model validation followed a structural validation method to guide adopters. Finally, the case studies show the practicality of the new model implementation against the applied TT processes to implicate the significance of CTTM ahead of project implementation.

![Figure 3. The research methodology and process.](image)

4. The Proposed Model

4.1. The Model

The conceptual model has an inherent system thinking structure. To be successfully applied in TT platforms in construction projects in Africa, it needs to be easily understandable by the user. Hence, the causal loop diagram simplifies the concepts, key parameters, and the principles [40,41].
In summary of the above analysis, the authors propose an improved TT model. First, to devise the conceptual TT model, system thinking is vital in exploiting BRI and challenge the boundaries of existing trends into a systematic approach; a causal loop diagram is used to link each of the TT parameters and illustrate the flow direction between two links, and an intermediate link is placed to make the concepts more explicit.

The new model combines technology seekers and technology generators with an intermediate facilitator, mainly the government. The facilitators’ primary role should be boosting the TT between technology seekers and generators. The model CMM 1, Figure 4, shows technology generators and technologies seekers need a facilitated platform at a country level involving a systematic approach in the process for adaptation and re-innovation. In this model, the facilitators, government role, and public institutions working in the construction industry come first.

A summary of the model is provided in Table 2 to help adopters grasp the causal link’s logic; the intermediate variables make the cause and effect relationship more explicit and are critical to effective modeling and model clarity.

**Table 2. Summary of the models.**

| No | Basic Variables                  | The Link Cause/Effect | Signs on the Link | Signs of the Loop |
|----|----------------------------------|-----------------------|------------------|------------------|
| 1. | Technology seeker                | cause                 | +ve              |                  |
| 2. | Government/facilitator           | Intermediate link     | +ve              | Re-inforcing (R) |
| 3. | Technology generator             | cause                 | +ve              |                  |
| 4. | FDI                              | cause                 | +ve              |                  |
| 5. | Joint-venture                    | Intermediate link     | +ve              | Re-inforcing (R) |
| 6. | Domestic technology capacity     | effect                | +ve              |                  |
| 7. | Systematic TT                    | Cause                 | +ve              | Re-inforcing (R) |
| 8. | UIL structure                     | Intermediate link     | +ve              |                  |
| 9. | R&D                              | Intermediate link     | +ve              |                  |
| 10.| Technology incubators            | Intermediate link     | +ve              |                  |
| 11.| Science parks                    | Intermediate link     | +ve              |                  |
| 12.| Technology adoption and dissemination | effect | +ve |                  |

**CTTM 2**

| No | Basic Variables                  | The Link Cause/Effect | Signs on the Link | Signs of the Loop |
|----|----------------------------------|-----------------------|------------------|------------------|
| 1. | Domestic technology capacity     | Cause                 | +ve              |                  |
| 2. | Systematic TT                    | Cause                 | +ve              |                  |
| 3. | R&D, innovation                   | Intermediate link     | +ve              |                  |
| 4. | UIL structure                     | Intermediate link     | +ve              |                  |
| 5. | FDI (BRI)                         | Cause                 | +ve              |                  |
| 6. | AEC technology gap                | effect                | -ve              |                  |

**CTTM 3**

| No | Basic Variables                  | The Link Cause/Effect | Signs on the Link | Signs of the Loop |
|----|----------------------------------|-----------------------|------------------|------------------|
| 1. | Domestic technology capacity     | cause                 | +ve              |                  |
| 2. | Systematic TT                    | Intermediate link     | +ve              |                  |
| 3. | Forced Joint-venture             | effect                | -ve              |                  |

Figure 4a CTTM 1 depicts the primary conceptual model illustrating the parameters’ causal relationship. These parameters are commonly used in previously discussed models; some parameters are included as a new insight into the authors’ system thinking in BRI in the Africa AEC industry. The two sub-models, CTMM 2 and CTTM 3, shown as Figure 4b,
c are the model’s portion but isolated to discuss the potential implications in addressing each essential element aside from the broader network connections.

In Figure 4b, the final goal is uplifting domestic AEC technology capacity through FDI, specifically BRI; therefore, involving the UIL structure has a positive impact in R&D to build a systematic TT. The positive and negative signs imply the influence of each element on the other. For instance, in Figure 4c, the government’s high commitment to facilitate TT positively impacts bringing a systematic TT by forcing joint-venture as an initial stage. When the systematic TT gets momentum, the domestic technology capacity increases, which has the opposite effect on forced joint-venture diverted to incentive one that is a balancing loop. The full model CTTM 1 includes many loops with many variables to communicate clearly and compellingly among TT process stakeholders.

(a) CTTM 1

(b) CTTM 2

Figure 4. Cont.
Figure 4. A conceptual construction technology transfer model (CTTM), “+” represents the positive relationship of the parameters and “−” represents the negative relationship.

4.2. Mathematical Representation of the Loop Diagram

The loop diagram CTTM 3

Setting all else equal, if X increases, then Y increases

\[ \frac{\partial y}{\partial x} > 0 \]

(1)

And in case of accumulations

\[ y(t) = \int_{0}^{t} (x + \ldots) ds + y_{f0} \]

(2)

where,

X = Systematic TT,
Y = Domestic technology capacity, and
Z = Forced joint-venture.

Through time, the central issue of forced joint-venture in FDI reduces, because the model represents a balancing loop that demonstrates the increase in domestic technology capacity through systematic TT intern decreases the demand for forced joint-venture. Instead, the FDI will be encouraged through incentives or the like. This negative link is demonstrated as shown below.

\[ \frac{\partial z}{\partial x} < 0 \]

(3)

And in case of accumulations

\[ Z(t) = \int_{0}^{t} (-Y + \ldots) ds + z_{f0} \]

(4)
Even though forced joint-venture is positively correlated with domestic technology capacity in the causal loop, a systematic TT label is set in the middle to create the model. The systematic TT can be quantified through R&D done under the BRI projects jointly between the regional UIL and the Chinese contractors.

The other significant part of the model, the facilitators, considers the UIL (university–industry linkage) as a crucial factor in technology adoption and dissemination at a country level. The importance of UI linkage in TT is a priority, because academia is highly involved in construction projects in technology adaptation, R&D, and innovation. It has a significant role in developing a systematic TT through technology gap identification and absorptive capacity. Since the construction industry UIL structure in Ethiopia is established to link the research institutes to the practicing industry in research, technology adaptation, TT, and innovation in each region would empower the TT process under BRI. Yet, the UIL TT modal does not discard the role of government as an intermediate institution, since the process needs considerable effort and finance to adopt and disseminate the technology in an organizational and nationwide.

4.3. Structural Validation of the Causal Loop Diagram

The designed conceptual model should be validated so that the system thinking has reasonableness, and adopters can readily accept to assess the typical models implemented in all-time TT. The validity of a link in a causal loop can be tested manually, according to Burns and Musa [42]. This model’s capability in the effectiveness and response to the practicality is identified as reputable, because the most common feature of TT models is the identification of technology seekers and generators at the project initiation stage. To assess the validity of the above model before it is employed in TT under BRI, diagnosis using a structural validation is vital, since the model is created using a causal loop diagram to facilitate TT in Africa under BRI leading to a practicable model.

The structural validation of a causal loop diagram adapted by Burns and Musa (2001) proposed eight possible validation criteria: clarity, quantity existence, connection edge existence, cause sufficiency, additional cause possibility, cause/effect reversal, predicted effect existence, and tautology [42,43]. The model’s aim is to facilitate TT among technology seekers and technology generators; the model adopters can easily understand dynamic cycles of parameters in the loop diagram, and the improved model depicts the UIL structure’s involvement to help study the internal and external environment ahead of project implementation. The structural model validation can also be assessed by an external body ahead of model adoption, but for this research purpose, the following assessment would suffice otherwise (see Table 3).

The other appropriate validation is whether the TT process has system ineffectiveness. Nevertheless, the TT process is a simple setting for application and controlling the process to enable the model to function effectively. However, the efficient validation needs a practical implementation and monitoring of the challenges. The case studies below help to underline and guide the vital step in the model adaptation as pilot projects. Additionally, the Table 4 below emphasizes the significance of the new model comparing to the preceding ones.
Table 3. Structural model validation.

| No | Validation Criteria         | Assessment                                                                                                                                 |
|----|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| 1. | Clarity                     | The model communicates the implied causality (clear connection, understanding)                                                             |
|    |                             | The variables can be quantified, and units can be defined (number of BRI projects, number of technologies adopted, number of joint-venture contracts) |
| 2. | Quantity existence          | There exists a causal link between parameters (FDI, joint-venture, systematic TT, domestic technology capacity)                               |
|    |                             | The causal linkages can create the effect expected (increase in forced joint-venture uplifts the systematic TT, which in turn enhances the domestic technology capacity, CTTM 3) |
| 3. | Causality existence         | The same result may be obtained from other variables independently                                                                            |
|    |                             | It is possible the reversal scenario in which both variables are both cause and effect, but in this model, the reversal effect is not feasible |
| 4. | Cause sufficiency           | The predicted effect is domestic technology capacity uplift through FDI (BRI)                                                                  |
| 5. | Additional cause possibility | The causal loop diagrams are logical in terms of cause and effect reasoning                                                                    |

Table 4. The model comparison for validation.

| No | Model Type       | Project/Program Based | Concept                    | Limitations                                      | System                             |
|----|------------------|-----------------------|----------------------------|--------------------------------------------------|------------------------------------|
| 1. | Preceding models | Not typical           | Theoretical                | Many limitations due to the generality            | Outdated for the new BRI           |
| 2. | The new model    | Yes (BRI)             | Theoretical and practical  | Few limitations, tailor-made                      | New system thinking model          |

5. Case Studies

In this research, the case study projects were vital, since the research’s main objective was to develop an adaptable TT model that enables efficient TT in Africa’s BRI projects. Examining some prototypical projects will allow us to look at the limitations in the existing practice and consider a better approach for the way forward. Based on China’s TT experience, and the scientific TT models, the improved single-country or project-based TT model is crucial. The BRI infrastructural development can transform the AEC industry through TT and innovation. This section presented three case studies to show the existing context of TT in Ethiopia and the methodology implemented on three projects. The three projects selected are because of their significance in technology adoption and infrastructure development in the country. The first one is the BIM project that is part of the country’s Growth and Transformation Plan II for construction industry transformation. The second project is one of the highest skyscraper buildings under construction by a multinational Chinese construction company. The last one is a megaproject in the country’s railway construction history, which connects landlocked Ethiopia to Djibouti’s port, which is the core part of the Belt and Road. The case study mainly investigated the TT methods, their limitations, and failures in achieving TT’s intended accomplishment. Implementing the improved TT conceptual model, which is adaptable for any construction/infrastructural project within the BRI in Africa, shall uplift technology and knowledge capacity in developing countries like Ethiopia.
5.1. Case 1: The Addis Ababa 40/60 Housing BIM Adoption Project

5.1.1. Project Description

The BIM project began in 2016 in Ethiopia to transform the construction industry from conventional design and project management into the integrated design, and effective project delivery. BIM would ensure the integrated delivery of projects that prevail through adopting and implementing the technology in a phase, scaled, and targeted approach. The Addis Ababa 40/60 housing project as shown in Figure 5 is part of the government housing development program. The BIM adoption project was owned and led by the Ethiopian Construction Project Management Institute (ECPMI). A joint venture contractor of a local company and two foreign companies (American and South African) supplied the software packages, installation, and training. The BIM project is part of the country’s technology capacity building program for the construction industry. The TT process followed a model that integrates a foreign company with a local joint-venture and a government institute as an intermediary platform.

5.1.2. The TT Transfer Process

When we look at the project implementation, the project mainly focused on the training package, then the TT in the country-level performance depended on the pilot project. However, the pilot project has brought only technical and skill adaptation for the trainees, not the TT anticipated. It did not incorporate the TT concept of integrating the technology generator and technology seeker in the planning stage. The government institutes role in preparing the BIM road map, and country-level TT and dissemination guidelines did not comprise the joint-venture scheme. The project has a joint venture scheme, and the TT model did not incorporate well.

Thus, the proposed model depicts the intermediate government institutions to enforce the TT through the joint-venture scheme for firm to firm in the procurement process that would enable the local company to acquire the technology adaptation instead of software purchase and training, since learning the technology through training and pilot project does not affirm the adoption and implementation process. The other critical advantage
of the proposed model, instead of depending on the pilot project for country-level TT, the UIL structure in each region would empower by identifying technology gaps, assessing capacity and capability through R&D at each project planning stage. Moreover, the UIL structure in the improved model enables TT and innovation by technology adaptation and re-invention. The integration between FDI-UIL–government/public institutions supports TT and innovation through the envisioned plan and contract agreement. The BIM adoption and implementation project need a systematic TT model to disseminate the anticipated BIM technology implementation at the country level.

5.2. Case 2: The Skyscraper Project

5.2.1. Project Description

The Commercial Bank of Ethiopia Head-Quarter project is one of the iconic projects in Ethiopia’s development journey. China State Construction and Engineering Corporation (CSCEC) was the contractor operating based on the design and build (DB) contract mode. As shown in Figure 6, it is the tallest building among the few in East Africa, and a modern one in terms of quality, construction technology, health and safety, and efficient project delivery. It is a 266.5 million dollar-cost project with a 14,307.83 m$^2$ site area. This case study focuses on the implemented construction technologies and TT mode. Addis Ababa Institute of Technology (AAiT) is the intermediate institute; AAiT is the leading Institute of Technology in Ethiopia, established 60 years ago. This institution’s primary objective other than project supervision was to promote the TT process through on-site training, R&D, and best practice recording for documentation.

Figure 6. The Commercial Bank of Ethiopia Head-Quarter project status on the left and 3D architectural design on the right.

5.2.2. The Construction Technologies and the Transfer Process

This case study examined the construction technologies implemented on the project and the TT process at the firm and country level. CSCEC is known for its modern and state-of-the-art technology worldwide, and has an essence of TT to local engineers during the project’s construction phase as a practical teaching center. It has established several measures to ensure the safety and health practice for workers’ safety by providing safe work areas, reliable methods, training, personal protective equipment, and adequate fire protection systems. The Job Hazard Analysis (JHA) [44,45] technique was applied to
identify hazards before they occur. Simultaneously, accident preventive strategies, the “three E’s of safety”, Engineering, Education, and Enforcement, were used [46]. The steel integrated framework employed for formwork is remarkable, since timber wood formwork and scaffoldings are the leading cause of accidents and challenging practices in the Ethiopian construction industry, and using efficiency tools to the newest technical level led to efficient project delivery with maximum potential. They implemented laser leveling devices that enable an accurate and straight extension of control lines. BMS (building management system) is a computer-based control system installed in buildings to control and monitor the building’s mechanical and electrical equipment. According to the case study, the most challenging issue was the time elapse for practical training on the site. The other barrier was the language barrier; information was conveyed in three languages: Amharic (the local language), Chinese, and English.

Even though the project involves a company with remarkable technology capacity, TT’s effort from the intermediate academic institute (AAiT) was partial. The technology adaptation is limited to internship and postgraduate research and employee capacity building. Since, CSCEC is known worldwide for undertaking super high-rise, innovative projects with great technological capacity, and the implemented technologies in this project have many excellent techniques that could consider TT at the country level. It is one of the many skyscraper public projects in the country built by multinational Chinese construction companies. However, the improved model shows that projects with joint-venture schemes help the local firms. Additionally, China’s experiences indicated joint-venture schemes allow TT from foreign firms to domestic firms primarily. Moreover, research and higher education institutes like AAiT could substantially impact TT and re-invention. The UIL structure in Ethiopia, as indicated in the improved model, AAiT, could take over the TT and innovation plan envisioned in such public projects. The purpose of the government or public sector, should facilitate the TT process for advanced technologies implementation and pave the way for original innovations. The proposed TT model can support this kind of project by encouraging or enforcing joint-venture schemes, mobilizing the UIL structure to be engaged in technology adaptation, R&D, and innovation for the industry transformation.

5.3. Case 3: The Railway Project

5.3.1. Project Description

The Addis Ababa–Djibouti railway system was the project examined for a case study. The project consists of constructing the railway, train, personnel training, and operational management, and it is the biggest railway project in East Africa. In China–Africa, the developmental relationship railway construction is a substantial part. China has a good reputation in railway technology in innovative development, scientific and technological management, and mechanisms [47,48]. The project as shown in Figure 7, is constructed and operated by Chinese state-owned companies China Railway Group (CREC) and China Civil Engineering Construction Corporation (CRCC) with 3.52 billion dollars. It is a new standard gauge international railway that serves as the backbone of the contemporary Ethiopian National Railway Network. It is the gateway for landlocked Ethiopia to access the sea, Djibouti port Doral [49,50]. The standard is based on the Chinese National Railway Class II, with a sub-heavy track structure and designed as an ordinary line, which conforms to Ethiopia’s conditions.
5.3.2. The Railway Technologies and Transfer Process

This project adopts heavy modern equipment, and construction technologies, since Chinese railway construction companies are competitive and world-class. Such projects play a vital role in Africa under the BRI for attaining technological capability. The investigation pointed out that the TT was mainly carried out through training in three stages. The TT process was based on technical standards training for Ethiopia, and Djibouti Railway Corporation’s staff, professionals, was the first endeavor at the project beginning. At the construction stage, there was practical on-site training on state-of-the-art electric rail-track design and construction, sustainability, the green transport system. The most evident TT was in the operation phase, which consists of practical training for train operators such as captains, attendants, technicians, and transportation management staff. This phase of the project led the Ethiopian professionals to manage the transportation system independently after the extensive technical and knowledge transfer from their Chinese counterparts. In the other stages, the TT process lacks a well-planned and designed methodology that would reflect the acquired functional capacity for adaptation and innovation for ongoing railway projects. Technology adaptation leads to re-invention and innovation, necessary to endeavor the country’s economic transformation and excellence in railway technology. Ethiopia has planned a vast rail network, eight truck routes predominantly built by Chinese enterprises. Other international companies are involved with a competitive offer in the project, such as Turkish builders, and even interest from Indian contractors. Therefore, using the proposed TT model, the Ethiopian railway corporation as a public body should facilitate and encourage TT at a country-level by involving rail research institutes and local firms in R&D and adaptation. It should also set the standards and guidelines that relate to rail TT in capacity building. The UIL structure in the model can also identify the technology needs, assess the foreign company’s capacity, and develop TT guidelines in railway technology.

6. Discussion and Conclusions

The relationship between China and Africa in development strategy is unlike any other, because it sets the pledge in an exemplary model of Chinese developmental history over the last few decades. However, BRI principally focuses on infrastructure development that profoundly impacts the construction industry in Africa. This study signifies that the defined process approach for the TT process elevates the BRI effect on the AEC industry in Africa. Therefore, such studies are needed to strengthen the China—Africa relationship and confirm the BRI’s other mutual benefits paradigms.
Although there are many scientific TT models since early times, each country’s industry condition and status quo need a contextually adapted transfer model. Any TT model should consider the essential point of foreign firms’/transferor’s technological capabilities, and local firms/host country’s absorbing capabilities. An intermediate government/public body should facilitate this process, as indicated in the improved model. The new model’s substantial advantage is that the government should make a great effort to enforce international companies to transfer technologies and be empowered. Local firms adapt and innovate foreign technologies through facilitation such as joint-venture. The other important paradigm is research, and higher education institutes play a substantial role in innovation and TT through adaptation, re-invention, and mainly R&D.

Hence, the study emphasized the UIL structure in the improved model with the viable, practical ground in Ethiopia. The UIL should be engaged in all FDI projects for technology adoption and innovation at the planning stage. The other vital feature of the improved model is it considers not only foreign firms as technology generators but also universities and small and medium enterprises, and innovative local companies. The technology adaptation and transfer incubation facilitated by the government and the UIL structure can spread the technology into the industry.

The BRI is a promising icon in infrastructural development in developing countries and, most importantly, an ideal platform for East Africa that brings many opportunities in technology and skill development for the construction industry. Hence, the governments should emphasize the policymaking and strive for a practical effort and follow-up on the implementation.

The case studies manifest the technology absorption gap scenario; the overall TT and innovation plan can improve by involving the TT strategies at the project planning stages as a crucial ingredient. Each project relates to the lack of incapacitated joint-venture for its prominent role in TT and underestimation of the part of R&D that could facilitate the technology adaptation and re-invention where the UIL bridges the technology source and the technology seeker, the AEC industry. The improved model envisioned that Chinese multinational construction corporations’ involvement would lead the country’s AEC industry to inevitable technology absorption and re-invention. The ability to transfer and acquire knowledge or technical skill needs understanding among both parties. To accelerate the inter-firm and nationwide CTT; the government should set priorities and prepare envisioned plans for each project with enforced TT in the FDI.

Despite the BRI in infrastructure development, there should be a paradigm shift in TT. The constricted view of BRI only on the massive investment flow, job creation, and trade exchange should move to embrace the opportunity for transforming the construction industry in technology and innovation in Africa. In the case of BRI, the enforcement of a joint venture in the TT plan is substantial. Since public institutions manage most of the infrastructure projects, they should facilitate technology adaptation and re-invention at a country-level. Hence, the most appropriate framework in CTT endeavors in Ethiopia is the UIL to be engaged in all FDI projects in technology adoption, R&D, and innovation. The adaptable TT model can be applied for any China–Africa infrastructural projects adjusting to the status quo. This research’s limitations were that there are no statistical data and analysis on the extent of technology and knowledge transfer among Chinese construction firms in Africa, and in turn in Ethiopia. The case studies have limitations when insights are generalized. For future research, a survey involving a significant number of projects shall be studied, quantifying the impact of BRI in TT. The variables in the model need to be further developed using mathematical modeling to signify the adaptability of CTTM. The other substantial research idea is the overall impact of BRI in construction technology and knowledge transfer; empirical research would strengthen the BRI role in every aspect. Moreover, we suggest that under the BRI projects, a country-based adapted TT model should be developed. It is recommended that collaborative R&D could be carried out by co-authorship among universities and research institutes in China and Africa.
Author Contributions: Writing—original draft preparation, Z.A.S.; writing—review and editing, L.W., Y.Z. and Z.A.S.; supervision, Y.Z.; All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China (NSFC), grant number 71732001.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

AEC Architecture, Engineering, and Construction
BIM Building Information Modelling
BRI Belt & Road Initiative
CTT Construction Technology Transfer
FDI Foreign Direct Investment
MOU Memorandum of Understanding
R&D Research and Development
TT Technology Transfer
UIL University-Industry Linkage

References

1. Herrero, A.G.; Xu, J. China’s belt and road initiative: Can Europe expect trade gains? China World Econ. 2017, 25, 84–99. [CrossRef]
2. Breuer, J. Two belts, one road—The role of Africa in China’s belt & road initiative. CrossAsia-Respiratory 2017. [CrossRef]
3. Zhang, Y.-J.; Jin, Y.-L.; Shen, B. Measuring the energy saving and CO₂ emissions reduction potential under China’s belt and road initiative. Comput. Econ. 2020, 55, 1095–1116. [CrossRef]
4. Ehizuelen, M.M.O. More African countries on the route: The positive and negative impacts of the Belt and Road Initiative. Transnatl. Corp. Rev. 2017, 9, 341–359. [CrossRef]
5. Ehizuelen, M.M.O.; Abdi, H.O. Sustaining China-Africa relations: Slotting Africa into China’s one belt, one road initiative makes economic sense. Asian J. Comp. Polit. 2018, 3, 285–310. [CrossRef]
6. Sun, J.; Zhu, L.; Wu, J. The development status of construction equipment and technology in China. MSE 2018, 399, 012048. [CrossRef]
7. Dodge Data Analytics. The Business Value of BIM in China; SmartMarket Report; Dodge Data Analytics: Bedford, MA, USA, 2015.
8. Li, A. Technology transfer in China-Africa relation: Myth or reality. Transnatl. Corp. Rev. 2016, 8, 183–195. [CrossRef]
9. Battistella, C.; De Toni, A.F.; Pillon, R. Inter-organisational technology/knowledge transfer: A framework from critical literature review. J. Technol. Transf. 2016, 41, 1195–1234. [CrossRef]
10. Grosse, R. Technology transfer in services. J. Int. Bus. Stud. 1996, 27, 781–800. [CrossRef]
11. Good, M.; Knockaert, M.; Soppe, B.; Wright, M. The technology transfer ecosystem in academia. An organizational design perspective. Technovation 2019, 82, 35–50. [CrossRef]
12. Hoffman, K.; Girvan, N. Managing international technology transfer: A strategic approach for developing countries. Manuscr. Rep. IDRC 259e. 1990. Available online: https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=hoffman+managing+international+technology+transfer&btnG= (accessed on 7 January 2021).
13. Siegel, D.S.; Wright, M. University technology transfer offices, licensing, and start-ups. In Chicago Handbook of University Technology Transfer and Academic Entrepreneurship; University of Chicago: Chicago, IL, USA, 2015; Volume 1, pp. 84–103.
14. Hassink, R. Technology transfer infrastructures: Some lessons from experiences in Europe, the US and Japan. Eur. Plan. Stud. 1997, 5, 351–370. [CrossRef]
15. Wong, P.K.; Singh, A. From technology adopter to innovator: Singapore. In Small Country Innovation Systems: Globalization, Change and Policy in Asia and Europe; Edward Elgar Publishing: Northampton, MA, USA, 2008; pp. 71–112.
16. Li, X. Sources of external technology, absorptive capacity, and innovation capability in Chinese state-owned high-tech enterprises. World Dev. 2011, 39, 1240–1248. [CrossRef]
17. Andreossio-O’Callaghan, B. Technology transfer: A mode of collaboration between the European Union and China. Eur. Asia Stud. 1999, 51, 123–142. [CrossRef]
18. Feinstein, C.; Howe, C. Chinese Technology Transfer in the 1990s; Edward Elgar Publishing: Lypiatt, UK; Cheltenham, UK, 1997.
19. Xu, F. Strategic tension for China high-speed railway to go global. In The Belt and Road; Springer: Berlin, Germany, 2018; pp. 75–114.
20. Carey, R.; Xiaoyun, L. China’s Comprehensive Strategic and Cooperative Partnership with Africa; IDS policy Briefing 111; IDS: Brighton, UK, 2016.

21. Demissie, A.; Weigel, M.; Xiaoyang, T. China’s Belt and Road Initiative and Its Implications for Africa; World Wide Fund (WWF): Nairobi, Kenya, 2016.

22. Demissie, A. Special economic zones: Integrating African countries in China’s Belt and Road initiative. In Rethinking the Silk Road; Springer: Berlin, Germany, 2018; pp. 69–84.

23. Oqubay, A. Made in Africa: Industrial Policy in Ethiopia; Oxford University Press: Oxford, UK, 2015.

24. Brätutigam, D.; Tang, X. Going global in groups: Structural transformation and China’s special economic zones overseas. World Dev. 2014, 63, 78–91. [CrossRef]

25. Adzroo, E.K. A Study of e-Business Technology Transfer via Foreign Direct Investment in the Ghanaian Construction Industry; University of Salford: Salford, UK, 2015.

26. Frank, I.U.; Du, R. Factors influencing technology transfer for sustainable construction management in Nigeria. Engineering 2018, 10, 769. [CrossRef]

27. Abbott, F.M.; Correa, C.M.; Drahos, P. Emerging Markets and the World Patent Order; Edward Elgar Publishing: Lytiatt, UK; Cheltenham, UK, 2013.

28. Ramanathan, K.; Jacobs, K.; Bnadyopadhyay, M. An overview of technology transfer and technology transfer models. In Overview of Technology Transfer and Small & Medium Enterprises in Developing Countries; Daya Publishing House: Delhi, India, 2011.

29. Bar-Zakay, S.N. Technology Transfer Model; Rand Corp Santa Monica Calif: Santa Monica, CA, USA, 1970.

30. Bozeman, B. Technology transfer and public policy: A review of research and theory. Res. Policy 2000, 29, 627–655. [CrossRef]

31. Jagoda, K. A Stage-Gate Model for Planning and Implementing International Technology Transfer. Ph.D. Thesis, University of Western Sydney, Sydney, Australia, 2007.

32. Lee, J.; Bae, Z.T.; Choi, D.K. Technology development processes: A model for a developing country with a global perspective. RD Manag. 1988, 18, 235–250. [CrossRef]

33. Abbott, F.M.; Correa, C.M.; Drahos, P. Emerging Markets and the World Patent Order; Edward Elgar Publishing: Lytiatt, UK; Cheltenham, UK, 2013.

34. Khabiri, N.; Rast, S.; Senin, A.A. Identifying main influential elements in technology transfer process: A conceptual model. J. Technol. Transf. 2017, 42, 235–250. [CrossRef]

35. Xu, S.; Zhu, K.; Gibbs, J. Global technology, local adoption: A cross-country investigation of internet adoption by companies in the united states and china. Electron. Mark. 2004, 14, 13–24. [CrossRef]

36. Liu, H.; Jiang, Y. Technology transfer from higher education institutions to industry in China: Nature and implications. Technovation 2001, 21, 175–188. [CrossRef]

37. Miesing, P.; Kriger, M.P.; Slough, N. Towards a model of effective knowledge transfer within transnationals: The case of Chinese foreign invested enterprises. J. Technol. Transf. 2007, 32, 109–122. [CrossRef]

38. Sterman, J.D. System dynamics modeling: Tools for learning in a complex world. Calif. Manag. Rev. 2001, 43, 8–25. [CrossRef]

39. Haraldsson, H.V. Introduction to System Thinking and Causal Loop Diagrams; Department of Chemical Engineering, Lund University: Lund, Sweden, 2004.

40. Tip, T. Guidelines for drawing causal loop diagrams. Syst. Think. 2011, 22. Available online: https://thesystemsthinker.com/wp-content/uploads/pdfs/220109pk.pdf (accessed on 7 January 2021).

41. Haraldsson, H.V. Introduction to systems and causal loop diagrams. In System Dynamic Course; Lumes Lund University: Lund, Sweden, 2000.

42. Burns, J.R.; Musa, P. Structural validation of causal loop diagrams. In Proceedings of the Atlanta SD Conference, Atlanta, GA, USA, 23–27 July 2001.

43. Goldratt, E.M. Theory of Constraints; North River Croton-on-Hudson: New York, NY, USA, 1990.

44. Mattila, M. Job load and hazard analysis: A method for the analysis of workplace conditions for occupational health care. Occup. Environ. Med. 1985, 42, 656–666. [CrossRef]

45. Rozenfeld, O.; Sacks, R.; Rosenfeld, Y.; Baum, H. Construction job safety analysis. Saf. Sci. 2010, 48, 491–498. [CrossRef]

46. Groeger, J.A. How many e’s in road safety? In Handbook of Traffic Psychology; Elsevier: Amsterdam, The Netherlands, 2011; pp. 3–12.

47. Zhang, S. Study on technology system and system integration method of China high-speed railway. In Proceedings of the 2010 Joint Rail Conference, Urbana, IL, USA, 27–29 April 2010; pp. 501–506.

48. Styan, D. djibouti: Changing Influence in the Horn’s Strategic Hub; The Royal Institute of International Affairs: London, UK, 2013.

49. Tarrosy, I.; Zoltán, V. China and Ethiopia, Part 2: The Addis Ababa-Djibouti Railway. The Diplomat. 22 February 2018. Available online: https://thediplomat.com/2018/02/china-and-ethiopia-part-2-the-addis-ababa-djibouti-railway/ (accessed on 7 January 2021).

50. Ali, G.S. Post completion sustainability of Ethiopian railway project: The case of Addis Ababa light rail transit project (AALRTP). Management 2017, 7, 7–28.