A Framework to Support Aerospace Knowledge Transfer to Developing Countries via Collaborative Projects

HOMOUD AL-SHAIGI and AHMED AL-ASHAAB
School of Aerospace, Transport & Manufacturing (SATM)
Cranfield University
Cranfield, MK430AL
UNITED KINGDOM
h.s.alshaigi@cranfield.ac.uk a.al-ashaab@cranfield.ac.uk

Abstract: - There are economic, strategic and technological needs for establishing a national aerospace sector in many developing countries. This is to support the growing demands for aerospace related products and to encourage international collaborations. International collaboration projects can cost billions of US dollars, but provide opportunities to access and gain aerospace knowledge in terms of skills, technologies and infrastructure related to the purchased aerospace systems. While there are several options for international technology transfer, there are currently no effective approaches, specifically in aerospace knowledge transfer, for international collaboration projects between developed and developing countries. There is a need for a specific framework to guide developing countries in this task and to overcome different transfer challenges. This paper presents an aerospace knowledge transfer framework (Aero-KT) to effectively manage knowledge transfer into developing countries during international aerospace collaboration projects.

Key-Words: - Knowledge management, Knowledge transfer, International technology transfer, Collaboration projects, Aerospace sector, Developing countries.

1 Introduction

The establishment of an aerospace sector is considered to be a strategically vital asset for the national economy and security in developing countries, as well as a means to create new job opportunities for nationals in a high value-added industrial sector [1].

Many developing countries have decided to develop an aerospace industry, and many of these nations have demanded the transfer of aerospace production skills. Several countries have achieved success in establishing an aerospace sector while many others have failed [2] and [3]. This is due to a lack in aerospace knowledge in term of skills, technology and infrastructure being appropriately transferred in international collaboration projects [4] and [5].

The aerospace sector is a complex and interdependent industry that requires an extensive aerospace knowledge. Knowledge is required in design, production and servicing activities, from single component to full aircraft, in various technological fields, such as aeronautical structures, propulsion systems, and electronics [6]. There are different types of knowledge that need to be accessed, identified and captured in order to be transferred.

In many international collaboration projects the organisations in developing countries may not have the capability to identify their knowledge needs in terms of skills, technologies and infrastructure and so depend heavily on their international foreign partners. Further, transferring aerospace knowledge is a complex issue that requires receiving organisations in developing countries to identify, learn and apply specific knowledge that already exists in the source organisations in developed countries [7].

The theme of international technology transfer has been an important area of research over a period of time [8], [9] and [10]. However, there are currently no effective approaches or solutions, specifically in aerospace knowledge transfer, in international collaboration projects between developed and developing countries. Therefore, the aim of this paper is to develop a holistic aerospace knowledge transfer framework. This is to guide the entire process from selection of the aerospace project and signing the contractual agreement, to successful transfer of required knowledge in order

This is an Open Access article. Published by IJEMS. This is the final published version of the article (version of record).
First online 15 May 2017. Please refer to any applicable publisher terms of use

to establish an aerospace sector in the developing country.

The paper is structured to present the rational of this research in Section 1. The remainder of this paper is divided into four further sections: a review of related literature in Section 2; an analysis of the field study key challenges in Section 3; the development of the aerospace knowledge transfer framework (Aero-KT) and the discussion of findings in Section 4; and conclusion in Section 5.

2 Review of Related Literature

2.1 Motives for establishing aerospace sector

Many developing countries have sought to develop an aerospace industry, and many nations have demanded the transfer of aerospace production capabilities as part of international collaborations [11]. A number of scholars have studied the motives of establishing an aerospace sector in developing countries, including Brazil [12], Indonesia [13], Malaysia [14], and others. Developing nations are variously motivated to build up, or to acquire, aerospace capabilities; these drivers may be political [15], for national security [16], technological [17], economic [18], to overcome trade embargos [4] and for national prestige [11].

2.2 The required aerospace knowledge

The process of identifying the type of knowledge is not straight forward; technology comes as a package, consisting of hardware, software, human capital, and intangible assets [19]. There are several different types of knowledge, with distinct attributes and transference difficulties. Some types of knowledge are embodied in the machinery and capital equipment, while other knowledge forms must be learned through experience, observation, research and development, and apprenticeships [20] and [21].

A complex industry, with multifaceted interdependencies and the obligatory rigorous safety requirements, the aerospace sector requires a wide range of aeronautical knowledge, covering diverse product lifecycle (PLC) activities. This knowledge is necessary for a component or full aircraft in various technological fields, such as airframe structural parts, propulsion systems, avionics and aircraft electronics [22]. Hence, it is critical to understand and carefully select the appropriate aerospace knowledge for the desired aircraft and related systems and subsystems.

The PLC is an engineering approach that addresses the complete projected life of a product [23]. A typical PLC model starts from the design, and ranges to building and assembly processes, finishing with refurbishment or disposal [24],[25] and [26].

Although there are differences between PLC models, a number of common activities can be identified. This paper presents an aerospace product life cycle with nine activities, as shown in Fig. 1.

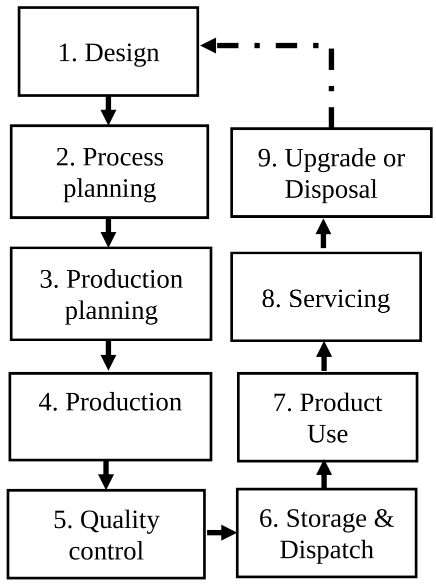

Fig.1 Aerospace Product Lifecycles (PLC) activities

An aerospace project comprises numerous products and processes, and it is impractical for many developing countries to acquire all the knowledge to carry out such a project. Therefore it is necessary for companies in developing countries to be aware of those activities of the PLC to be performed nationally, and the related aerospace knowledge to be transferred during the international collaboration.

2.3 Knowledge management in international collaboration projects

2.3.1 Technology transfer options and mechanisms

Developing countries are faced with different options for technology transfer to acquire new aerospace knowledge, these are: purchase, independent build, steal the technology, and hybrid approaches such as reverse engineering, co-production and co-development to acquire foreign, mature products [11], [27] and [28].

International collaboration using co-production and co-development are the two legitimate approaches available for developing countries to access and acquire aerospace knowledge from foreign countries' organisations. Other options have disadvantages, such as high costs, limited knowledge transfer, long project times and uncertainty of success. They may also require an advanced industrial base and specific knowledge, or risk enormous penalties for infringement of intellectual property rights [28].

There are several mechanisms for international technology transfer from developed to developing countries, such as: foreign direct investment, foreign patenting, personnel mobility and joint ventures [29]. One of the most prominent mechanisms is the use offset programs. Developing countries' governments are increasingly applying offset, which is an advanced form of countertrade, as a potential collaboration option [30] and [17]. Offset programs can take the form of co-production, licenced production, technical agreement, and transfer of technology [18].

2.3.2 Knowledge transfer challenges

Knowledge transfer in international aerospace collaboration projects is extremely challenging. Previous studies provide an understanding of the key challenges that face developing countries in establishing an aerospace sector [30], [31],[32] and [33], and are presented in Table 1.

Table 1 Knowledge transfer Challenges

<table>
<tr><td rowspan="14">Challenges of knowledge transfer</td><td colspan="2">Challenge description</td></tr>
<tr><td rowspan="7">Before the transfer</td><td>1. Expensive projects with long duration</td></tr>
<tr><td>2. Lack of vision & goals</td></tr>
<tr><td>3. Inappropriate acquisition strategy</td></tr>
<tr><td>4. Weak relationship between national stakeholders</td></tr>
<tr><td>5. Less emphasis on design and production activities</td></tr>
<tr><td>6. Large capability gap</td></tr>
<tr><td>7. Lack of negotiation ability</td></tr>
<tr><td rowspan="4">During transfer</td><td>8. Difficult to acquire aerospace knowledge</td></tr>
<tr><td>9. Protectiveness and access limitations</td></tr>
<tr><td>10. Geographical ,cultural & language factors</td></tr>
<tr><td>11. Lack of knowledge management skills</td></tr>
<tr><td rowspan="2">After transf</td><td>12. Using acquired knowledge</td></tr>
<tr><td>13. Evaluate the success of transfer</td></tr>
</table>

As shown in Table 1, some challenges are before the transfer and start of the collaboration projects; for example, challenge No. 4: of not having a strong relationship between national stakeholders. In many developing countries the decisions for aerospace projects and related products are made by the government and Air Force only. There is limited participation of national companies and research and development (R&D) centres. These organisations are the actual receivers of aerospace knowledge, and should be involved in early stages, at the contractual negotiations, to include all their requirements.

Other challenges appear during the transfer of knowledge; for example, challenge No. 11: of lack of knowledge management (KM) skills. This issue is critical and is given limited attention in many international aerospace projects. Many developing countries lack the capability to identify and capture the required aerospace knowledge, then to transfer it to the national facilities to be stored and used to create a product or service.

Finally, some challenges arise after the transfer; for example, Challenge No. 12: of absorbing and using the transferred knowledge at the earliest opportunity to design, manufacture and assemble a product. Unless the knowledge is appropriately captured and stored during the transfer phase, the receiving organisations in developing countries will have difficulties in using the knowledge independently.

Previous studies treat challenges as distinct, and do not relate them in a systematic process to achieve a successful transfer. Hence, developing countries need a holistic approach to manage these key challenges throughout different phases of transfer: from the selection of the aerospace project and signing the contract, to successful transfer and implementation. To this end, the following sections analyse different researchers' viewpoints on the theme of knowledge and technology transfer.

2.3.2 Review of technology transfer phases

Aerospace technology transfer in international collaboration projects cannot be executed in one phase due to the complexity, legal issues and long timescales. The are several technology transfer phases (TTP) that should be considered when planning the production transfer from developed to developing countries [34]. Previously reported technology transfer models of Behrman [35], Dahlman [36], Chantramonklasri [37], Moustafa [38], Miles [8], Rebentisch [39], Minshall [9], Steenhuis [10], Yokozawa [40] and Khabiri [41] have a number of phases, ranging from three to nine. And some authors have provided similar models, specifically for technology transfer from developed, to developing countries [35],[36] and [37].

Phases from the different models can be used to create a new model, with the work of other authors on the issue of technology transfer utilised to integrate key phases from previous research [37], [40], [41] and [10]. For example, Steenhuis' [10] model was synthesised from the different phases of eight existing transfer models into the following three phases: preparation, installation and utilisation.

The literature presents a number of common phases that exist in international technology transfer projects and can therefore be used in this paper. However, the phases were general, lack details and focused on strategic decision factors that affect transferring of production knowledge; thus it is difficult to select one model to apply directly to a developing county. Furthermore, these models describe knowledge transfer from either the perspective of the receiving company or the source company.

International civil and military aerospace projects require collaboration between partners. Therefore, there is a need for a new model with specific phases that is suitable for the aerospace sector. This is to fill the gap in this area and to support transferring knowledge to developing countries. Hence, three phases are recommended; these are: pre-investment, transfer and implementation. The following section explores different knowledge management life cycles models to provide a more systematic process.

2.3.3 Review of knowledge lifecycles

Table 2 illustrates most influential Knowledge Life Cycles (KLC) models in knowledge management with their key stages.

Table 2 Review of Knowledge lifecycles stages

Ref.	Stages	Description of stages
[42]	5	Acquire, Refine, Store, Distribute and Present
[43]	7	Get, Use, Learn, Contribute, Assess, Build/Sustain and Divest
[44]	4	Creation, Storage/Retrieval, Transference and Application
[45]	3	Creation, Documentation and Storage, Transference and Reuse
[46]	5	Discover, Generate, Evaluate, Share and Apply Leverage
[47]	4	Capture and Creation, Sharing and Disseminations, Acquisition and Application
[48]	3	Identify, Capture and Formal Representation
[49]	4	Identify, Create, Store, Share and Apply

Many authors have observed similarities between the stages of KLCs in spite of the lack of commonality in use of terminologies (i.e. identify and creation, get and capture) [50]. The integration of key stages from different models has resulted in the construction of a simple, practical and comprehensive KLC model [49]. For example Dalkir [47] synthesised the previous work of different authors into three major stages: capture and/or creation; sharing and dissemination; and application.

The wide range of KLC models has shown similarities in the essential elements of KM. Each model introduced new stages to be considered in understanding how knowledge is managed through the model's lifespan. Focus has largely been on developing new ideas of knowledge management into a framework; less focus is directed towards applying the KLC to a situation where knowledge transfers from a developed country to a developing country, especially with regard to international aerospace collaboration projects.

Based on the review of many existing KLC models, a new KLC model was developed in this paper that centres on aerospace knowledge transfer across countries. There are six stages: Identify, Capture, Save and Transfer, Store and Install, Use, and Evaluate.

3 The Field Study

A field study was undertaken during 2015 and 2016. Interviews were performed with key personnel from twenty-one national and international aerospace organisations in the Kingdom of Saudi Arabia (KSA). The field study revealed the following challenges:

- The KSA has similar drivers for building an aerospace sector as those of other developing countries. The KSA's vision includes a plan to locally manufacture half of its defensive technologies needs in order to justify its huge procurement costs (the KSA has the third highest defence expenditure in the world, estimated at over $264 billion USD in 2015) [51].

- The field study findings showed that Saudi organisations' manufacturing sectors are not geared to having the capability to fully design and manufacture an entire aircraft locally, but rather to acquire some elements of the product life cycle (PLC) of the products they want to transfer to the KSA during international collaboration projects.
- All offset contractual agreements between the KSA and the developed countries are made without real involvement of the local companies and research and development (R&D) centres.
- The people involved in the aerospace technology transfer projects are not technically learned; they have neither the skills nor the tools and techniques to support their decision making.
- There is weak communication and coordination between all national stakeholders.
- There is a lack of involvement in the design and production activities of the PLC. This is one of the reasons why Saudi organisations are not getting the right knowledge, which clearly indicates a lack of overall knowledge management activity in international collaboration projects throughout the design and production PLC activities.
- The findings showed that all international aerospace companies interviewed are willing to share part of their knowledge and technology in a collaboration project due to the huge financial returns; however, national companies lack the skills, technologies, local workforce and infrastructure to benefit from those projects and to establish a real aerospace sector.

The finding showed similar challenges to those presented in Table 1. The framework should consider the needs of the KSA and address all the challenges of knowledge transfer in international collaborative aerospace projects between developed and developing countries.

4 The Development of the Aero-KT

4.1 Approach of developing the Aero-KT

The Aerospace Knowledge Transfer (Aero-KT) framework was developed based on the findings of the appropriate knowledge transfer literature on three main conceptual strands related to knowledge management: the technology transfer phases (TTP), the product life cycle (PLC) and the knowledge life cycle (KLC); as well as the findings of the field study that were analysed to discover the needs, challenges and practices of knowledge transfer in collaborative aerospace projects in developing countries (e.g. Saudi Arabia). The framework developed addresses the challenges that face developing countries in establishing an aerospace sector.

The study of the different TTP showed different knowledge transfer phases; however each phase contains common meanings and purposes. Three phases (Pre-Investment, Transfer and Implementation) were adopted in order to facilitate the transfer of knowledge (i.e. skills, technologies and infrastructure) to a developing country as shown in Fig.2.

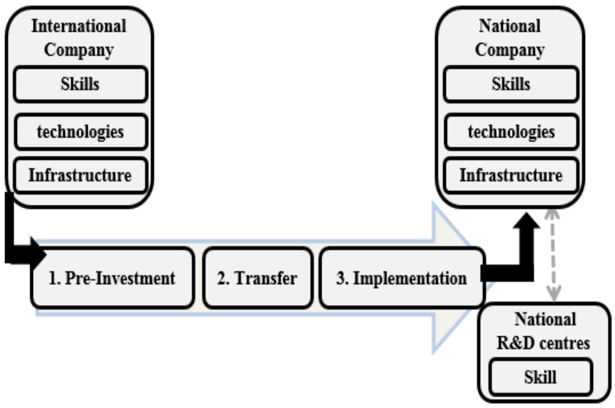

Fig. 2 The Aero-KT three phases

The three phases presented in Fig. 2 provide the building blocks for the Aero-KT. In addition, there is a direct link to national R&D centres. This is important since the field study findings showed a lack of communication, coordination and duplication of effort and competition between all Saudi aerospace companies, government organisations and local research centres. The R&D organisations should participate in the pre-investment phase before signing the contracts to assist the decision making; in addition the R&D centres should be involved in the implementation phase to ensure the development and continuity of transferred knowledge, which is a critical success factor in establishing an aerospace sector.

Previous technology transfer models provided some insight for the pre-investment phase, but a new aerospace knowledge transfer phase was developed in this research to support the pre-investment phase for establishing the aerospace sector. This includes three sequential stages: firstly, a decision making stage to identify what to transfer; secondly, a selection stage of national suppliers to be the receivers of aerospace knowledge; and finally a negotiations stage to include the desired knowledge within the contractual agreement.

The review of the PLC activities of an aerospace product, and the analysis of the AS-IS gap and interests in developing countries, such as the KSA, helped in narrowing down the options for the products and knowledge related to supporting the 'pre-investment phase'. For example, an aerospace project for an aircraft includes different components, parts, sub-assemblies and systems. It is impossible to acquire the knowledge for all these products, so developing countries need to identify the PLC activities (i.e. design, production or servicing) to be performed nationally. In addition, they need to decide on the related aerospace knowledge to be transferred as a result of the international collaboration project.

Fig. 3 illustrates how the PLC activities support top-level decisions in the pre-investment phase. For example, to assist in identifying the top level knowledge required for the design activity of the first product 'p1' for a specific aerospace project (i.e. to decide on acquiring the design capability for an aircraft wing internal structural components). However this top level knowledge is general and only supports the contractual agreement negotiations and is not enough to acquire the detailed knowledge to build a national aerospace sector.

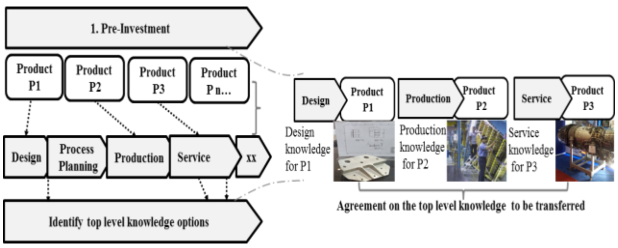

Fig. 3 Approach to support decision making for selecting aerospace products, activities and top level knowledge to be transferred.

In order to access, capture and transfer the detailed knowledge from the international collaborating partner to be used by the national workforce in their national facilities, developing countries require a detailed and systematic process. Therefore, the researcher studied numerous KLC models with key stages arranged in a logical sequence. A specific model was adopted and modified to include a 'Transfer' stage across countries that addresses the challenges and requirements of developing countries based on literature findings and the AS-IS practices of collaboration, challenges and requirements for developing countries (e.g. the KSA). A new international collaborative knowledge life cycle "IC-KLC" with 6 stages was developed in this paper to fill the gap in this area and support the 'Transfer' and 'Implementation' phases, as shown in Fig. 4.

For the purpose of knowledge transfer it is necessary to form an effective knowledge management team that will be responsible for carrying out the tasks at every phase of the proposed Aero-KT framework. A knowledge management collaborative team (KMCT) is proposed by this paper. The national team is to be physically based at the international facilities to work closely with foreign experts. The team members range between four to eight individuals depending on: the size of the aerospace project; the experience of the team (i.e. start with eight team numbers then for future projects the number is reduced to four as their experience increases); and the activities of the product life cycle to be transferred (i.e. small team for design only, or a large team for the whole product life cycle).

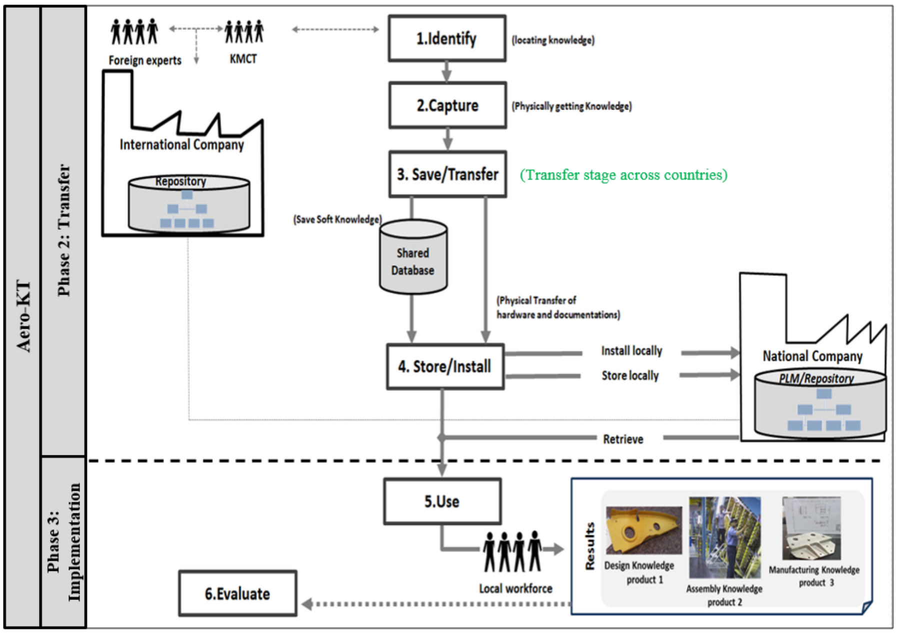

Fig. 4 Approach of developing the transfer and implementation phases of the Aero-KT showing the collaborative knowledge Life Cycle "IC-KLC"

4.2 Description of the Aero-KT

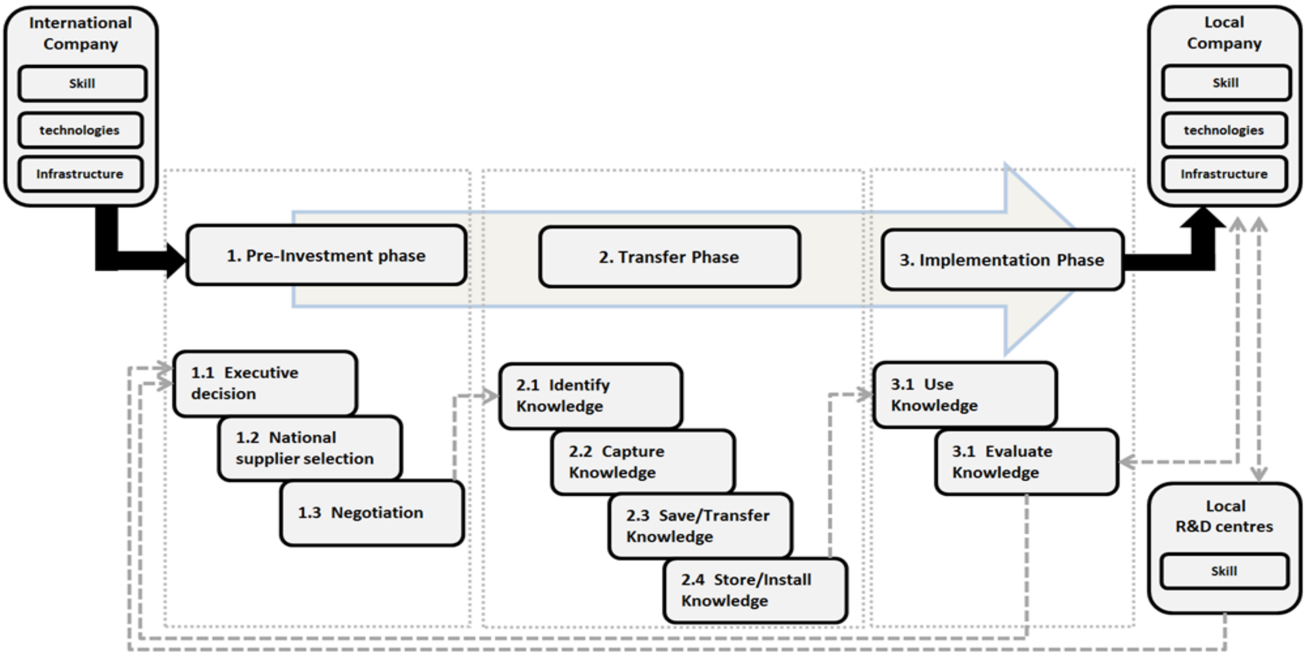

Fig. 5 The Aero-KT framework

Fig. 4 presents the Aero-KT framework that supports the transfer of aerospace knowledge from companies in developed countries to national companies in developing world; the transferred knowledge is the skills (e.g. design skills, processes planning), Technologies (e.g. CAD, Machinery) and Infrastructure transfer (e.g. factory layout).

The Aero-KT framework shows the main stages during each phase of the aerospace project as follows:

1. Pre-investment Phase: This phase starts before the formal signature of the agreement and has three stages:
   1.1 Executive Decision: is where national stakeholders make decisions on potential products (i.e. wings), product life cycle (PLC) activities (i.e. assembly of wings) and top level knowledge (i.e. general related technologies) to be considered in the final contract.
   1.2 Local Suppliers Selection: is about searching for suitable national suppliers to undertake the PLC locally and be the receiver of the knowledge.
   1.3 Negotiating: is where the contractual agreement about what has been agreed is signed.
2. Transfer Phase: The transfer phase starts after the contractual agreement has been signed and includes the top-level knowledge of the products that needs to be acquired by the developing countries. This phase is tactical and consists of four stages:
   2.1 Identify: here, the KMCT will collaborate with the assigned team from the international company in order to identify together the knowledge related to performing the specific PLC activities.
   2.2 Capture: to physically capture the identified knowledge in different forms; for example, to have an agreement with the international company to get a copy of the engineering drawings and technical documentation. In addition, to agree on specialised training courses and on-the-job training for the national workforce to acquire tacit forms of knowledge, such as design skills. However, this stage depends on the skills of the KMCT and the techniques and tools used to formally capture the knowledge.
   2.3 Save and Transfer: save is used for soft knowledge that can be stored in an electronic format in an external shared database. Transfer is to arrange the transfer of knowledge, documentation and hardware from the developed to developing countries using shipment.
   2.4 Store and Install: is the process of storing the knowledge in the national company repository and install machines equipment (i.e. machines and tools) at the national facilities.
3. Implementation Phase: the final phase of the Aero-KT starts after the transfer of knowledge (i.e. skills, technology and infrastructure) to the developing country and has two stages:
   3.1 Use: for the national companies who are officially collaborating with the international company, to retrieve and use the knowledge to enhance their work and begin establishment of the aerospace sector. In addition, to effectively manage lessons learnt and to support decisions for future aerospace projects.
   3.2 Evaluate: to see if the transferred knowledge has enabled the national companies to perform the PLC activities independently; for example, to perform assembly and sub-assemblies projects, and to manufacture basic components with limited foreign support.

5 Conclusion

This paper presents an aerospace knowledge transfer framework (Aero-KT) with three phases. The framework is suitable for use by developing countries to effectively manage knowledge transfer into their countries during international aerospace collaboration projects. In addition, the paper presented a well-established international collaborative knowledge lifecycle “IC-KLC” for transferring knowledge between developed and developing countries.

The development of the Aero-KT is based on critical analysis of the literature on the topic of knowledge and technology transfer from developed to developing countries during international aerospace collaboration projects. This is supported by a detailed analysis of the challenges and motives of establishing a national aerospace sector from the related literature and from an industrial field study in a developing country (i.e. the KSA).

The Aero-KT is designed to guide the entire process, from the decision on selection of the aerospace project and signing the contractual agreement, to successful transfer of knowledge, to actual implementation. However, further research is required to identify formal tools and techniques to support knowledge management tasks.

References:

[1] H. Alshaigi and A. Al-Ashaab, “The evolving issue of aerospace knowledge transfer to the developing countries,” in *Proceedings of the 13 th International Conference on Manufacturing Research (ICMR2015)*, 2015, no. September, pp. 117–122.

[2] H.-J. Steenhuis, E. J. De Bruijn, and H. Heerkens, “Technology transfer and catch-up; Lessons from the commercial aircraft industry,” *Int. J. Technol. Transf. Commer.*,

vol. 6, no. 2, pp. 250–278, 2007.
[3] H.-J. Steenhuis and E. J. Bruijn, "Developing countries and the aircraft industry: match or mismatch?," *Technol. Soc.*, vol. 23, no. 4, pp. 551–562, Nov. 2001.
[4] A. Goldstein, "The political economy of high-tech industries in developing countries: aerospace in Brazil, Indonesia and South Africa," *Cambridge J. Econ.*, vol. 26, no. 4, pp. 521–538, 2002.
[5] S. McGuire, "Sectoral Innovation Patterns And The Rise Of New Competitors: The Case Of Civil Aerospace In Asia∗," *Ind. Innov.*, vol. 6, no. 2, pp. 153–170, 1999.
[6] H. Hollanders, A. VAN CRUYSEN, and D. Vertesy, "Sectoral Innovation Systems in Europe: The Case of the Aerospace Sector," *Final Report, Eur. INNOVA*, 2008.
[7] I. Oshri, P. van Fenema, and J. Kotlarsky, "Knowledge transfer in globally distributed teams: the role of transactive memory," *Inf. Syst. J.*, vol. 18, no. 6, pp. 593–616, Nov. 2008.
[8] D. Miles, *Constructive Change: Managing International Technology Transfer*. International Labour Organization, 1995.
[9] T. Minshall, *Manufacturing Mobility: A Strategic Guide to Transferring Manufacturing Capability*. University of Cambridge, Institute for Manufacturing, 1999.
[10] H.-J. Steenhuis and E. J. Bruijn, "International technology transfer: Building theory from a multiple case-study in the aircraft industry," 2005.
[11] D. R. King and M. L. Nowack, "The impact of government policy on technology transfer: an aircraft industry case study," *J. Eng. Technol. Manag.*, vol. 20, no. 4, pp. 303–318, 2003.
[12] A.-M. Maculan, "Embraer and the growth of the Brazilian aircraft industry," *Int. J. Technol. Glob.*, vol. 7, no. 1–2, pp. 41–59, 2013.
[13] S. Eriksson, "Indonesia's aircraft industry: technology and management impediments," *Int. J. Technol. Transf. Commer.*, vol. 2, no. 2, pp. 207–226, 2003.
[14] L. W. Tat and S. Hase, "Knowledge management in the Malaysian aerospace industry," *J. Knowl. Manag.*, vol. 11, no. 1, pp. 143–151, 2007.
[15] J. Niosi and M. Zhegu, "Anchor tenants and regional innovation systems: the aircraft industry," *Int. J. Technol. Manag.*, vol. 50, no. 3, pp. 263–284, 2010.
[16] F. Texier, *Industrial diversification and innovation: an international study of the aerospace industry*, vol. 215. Edward Elgar Publishing, 2000.
[17] A. Hira and L. G. de Oliveira, "Take off and Crash: Lessons from the Diverging Fates of the Brazilian and Argentine Aircraft Industries," *Compet. Chang.*, vol. 11, no. 4, pp. 329–347, Dec. 2007.
[18] S. Eriksson, "The aircraft industry as a tool for economic and industrial development - the case of Indonesia," *Clusters and Economic Growth in Asia*. pp. 141–164, 2013.
[19] A. La Bella, D. Canzano, and M. Grimaldi, "Critical capabilities and performance in the aerospace industry: a knowledge management approach," in *Aerospace Conference, 2004. Proceedings. 2004 IEEE*, 2004, vol. 6, pp. 3962–3969.
[20] F. Malerba and L. Orsenigo, "Technological regimes and sectoral patterns of innovative activities," *Ind. Corp. Chang.*, vol. 6, no. 1, pp. 83–117, 1997.
[21] P. van der Heiden, C. Pohl, S. Bin Mansor, and J. van Genderen, "The role of education and training in absorptive capacity of international technology transfer in the aerospace sector," *Prog. Aerosp. Sci.*, vol. 76, pp. 42–54, Jul. 2015.
[22] D. J. Harvey and R. Holdsworth, "Knowledge management in the aerospace industry," in *IPCC 2005. Proceedings. International Professional Communication Conference, 2005.*, 2005, pp. 237–243.
[23] Y. Asiedu and P. Gu, "Product life cycle cost analysis: State of the art review," *Int. J. Prod. Res.*, vol. 36, no. 4, pp. 883–908, 1998.
[24] G. Pahl and W. Beitz, *Engineering Design: A Systematic Approach*, vol. 11. Springer Science & Business Media, 2013.
[25] I. Moir and A. Seabridge, *Design and development of aircraft systems*, vol. 68. John Wiley & Sons, 2012.
[26] F. Mas, J. Ríos, J. L. Menéndez, and A. Gómez, "A process-oriented approach to modeling the conceptual design of aircraft assembly lines," *Int. J. Adv. Manuf. Technol.*, vol. 67, no. 1–4, pp. 771–784, Jul. 2013.
[27] K. Hartley, *The Political Economy of Aerospace Industries: A Key Driver of Growth and International Competitiveness?*

Edward Elgar Publishing, 2014.

[28] P. C. Saunders and J. K. Wiseman, *Buy, Build, Or Steal: China's Quest for Advanced Military Aviation Technologies*. National defence univ fort mcnair dc inst for national strategic studies, 2011.

[29] J. Niosi and M. Zhegu, "Aerospace clusters: Local or global knowledge spillovers?," *Ind. Innov.*, vol. 12, no. 1, pp. 5–29, 2005.

[30] A. M. Malm, A. Fredriksson, and K. Johansen, "Bridging capability gaps in technology transfers within related offsets," *J. Manuf. Technol. Manag.*, vol. 27, no. 5, pp. 640–661, Jun. 2016.

[31] J. Jordan and J. Lowe, "Protecting strategic knowledge: Insights from collaborative agreements in the aerospace sector," *Technol. Anal. Strateg. Manag.*, vol. 16, no. 2, pp. 241–259, 2004.

[32] D. Vertesy, "The lion with wings: innovation system dynamics in the aerospa[illegible] Singapore," *Int. J. Technol. Glob.*, vol. 7, no. 1, pp. 118–140, 2013.

[33] K. Balakrishnan and R. Matthews, "The role of Offsets in Malaysian Defence Industrialisation," *Def. Peace Econ.*, vol. 20, no. 4, pp. 341–358, 2009.

[34] S. A. Wahab, R. C. Rose, J. Uli, and H. Abdullah, "A review on the technology transfer models, knowledge-based and organizational learning models on technology transfer," *Eur. J. Soc. Sci.*, vol. 10, no. 4, pp. 550–564, 2009.

[35] J. N. Behrman and H. W. Wallender, *Transfers of Manufacturing Technology Within Multinational Enterprises*. Ballinger Publishing Company, 1976.

[36] C. Dahlman and L. Westphal, "The meaning of technological mastery in relation to transfer of technology," *Ann. Am. Acad. Pol. Soc. Sci.*, vol. 458, no. 1, pp. 12–26, 1981.

[37] N. Chantramonklasri, "The development of technological and managerial capability in the developing countries," in *Technology transfer in developing countries*, M. Chatterji, Ed. The Macmillan Press, 1990, pp. 36–50.

[38] M. Moustafa, "Management of technology transfer: Planning and controlling the implementation process in developing countries," 1990.

[39] E. S. Rebentisch and M. Ferretti, "A knowledge asset-based view of technology transfer in international joint ventures," *J. Eng. Technol. Manag.*, vol. 12, no. 1–2, pp. 1–25, Jul. 1995.

[40] K. Yokozawa, E. J. De Bruijn, and H. Steenhuis, "A conceptual model for the international transfer of Japanese management system," *14th Int. Annu. EurOMA Conf.*, pp. 1–11, 2007.

[41] N. Khabiri, S. Rast, and A. A. Senin, "Identifying Main Influential Elements in Technology Transfer Process: A Conceptual Model," *ASIA PACIFIC Bus. Innov. Technol. Manag. Soc.*, vol. 40, no. 0, pp. 417–423, 2012.

[42] M. H. Meyer and M. H. Zack, "The Design and Development of Information Products," *Sloan Manage. Rev.*, vol. 37, no. 3, pp. 43–59, 1996.

[43] W. R. Bukowitz and R. L. Williams, *The knowledge management fieldbook*. Financial Times/Prentice Hall, 2000.

[44] M. Alavi and D. E. Leidner, "Review: Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues," *MIS Q.*, vol. 25, no. 1, p. 107, Mar. 2001.

[45] M. Schaefer, J. Cook, and J. Barrett, "Creating competitive advantage in large organizations using knowledge management," *Proc. - Annu. Meet. Decis. Sci. Inst.*, pp. 1113–1118, 2002.

[46] A. Jashapara, *Knowledge management: An integrated approach*. Pearson Education, 2004.

[47] K. Dalkir, "Knowledge Management in Theory and Practice," 2005.

[48] K. Rodriguez and A. Al-Ashaab, "Knowledge web-based system to support e-manufacturing of injection moulded products," *Int. J. Manuf. Technol. Manag.*, vol. 10, no. 4, pp. 400–418, 2007.

[49] P. Heisig, "Harmonisation of knowledge management – comparing 160 KM frameworks around the globe," *J. Knowl. Manag.*, vol. 13, no. 4, pp. 4–31, Jul. 2009.

[50] M. Ragab and A. Arisha, "Knowledge management and measurement: a critical review," *J. Knowl. Manag.*, vol. 17, no. 6, pp. 873–901, Oct. 2013.

[51] SIPRI, "SIPRI Militery expenditure database," 2015. [Online]. Available: https://www.sipri.org/databases/milex. [Accessed: 15-Oct-2015].

A Framework to support aerospace knowledge transfer to developing countries via collaborative projects

Al-Shaigi, Homoud

2017-05-15

Al-Shaigi H, Al-Ashaab A. (2017) A Framework to support aerospace knowledge transfer to developing countries via collaborative projects. International Journal of Economics and Management Systems, Volume 2, 2017, pp. 111-120

http://www.iaras.org/iaras/home/caijems/a-framework-to-support-aerospace-knowledge-transfer-to-developing-countries