Chapter 1
Indo-German Center for Sustainable Manufacturing: A Collaboration Between Birla Institute of Technology and Science Pilani and Technische Universität Braunschweig

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1.1 The History of the Indo-German Center for Sustainable Manufacturing

The global challenge of sustainable engineering needs a global community. Together, the Birla Institute of Technology and Science (BITS) Pilani, and Technische Universität (TU) Braunschweig enable their students and researchers to advance the necessary methods and tools to achieve sustainability goals. Through joint projects in India and Germany, students and researchers have the opportunity to visit another academic environment and experience working in intercultural teams as well as living in a different culture. For both sides, the exchange enables a change of perspective and allows seeing different challenges in sustainable engineering.

The history of this cooperation goes back to the year 2009. From this year on, the team started to apply for funding and began its intense exchange of scientific staff and students. Figure 1.1 shows the development of the exchange over the past ten years—more than 100 students and academic staff has been involved, and additionally, Figs. 1.2 and 1.3 illustrate the milestones of this cooperation.

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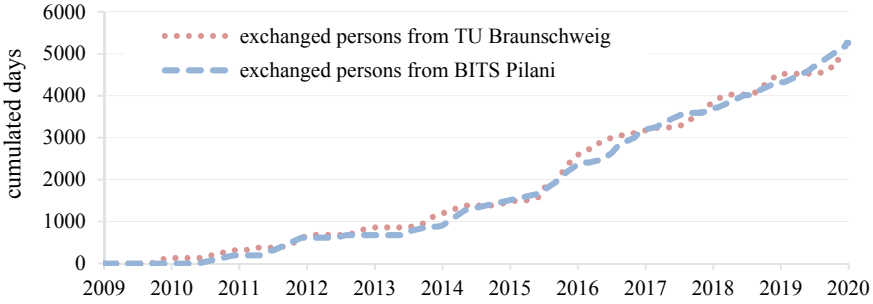

Fig. 1.1 Cumulated days of exchange between TU Braunschweig and BITS Pilani

1.2 Joint Projects and Infrastructure for Research and Education

From the beginning of this cooperation, joint projects are the basis for an exchange, which goes far beyond mutual exchange programs. The projects enable students and researchers to face and tackle future challenges towards a global sustainable development. Besides working on this global challenge, both sides broaden their perspective on different working methods and approaches. In the following, the projects with the greatest effects on society and environment are described in detail.

1.2.1 Lean and Green—Efficiency and Effectiveness in Production

"Lean and Green – Efficiency and Effectiveness in Production" ("Lean & Green") was the first long-term project to be launched within this Indo-German partnership. It started in 2010 and was funded by DAAD's (German Academic Exchange Service) initiative "A New Passage to India" for two years. Within this program, the already existing exchange of students and researchers was intensified.

While the following projects got more specialized, "Lean and Green" provided the basis for further research by creating a common understanding in the topic of sustainable manufacturing. It ought to lead to a better comprehension of the differences and similarities of Indian and German concepts of sustainable manufacturing, of the challenges of adopting and transferring these concepts into new environments, and of the constraints, which occur in this process. Nonetheless, "Lean and Green" was, of course, tracing some major interests. As India's energy requirements increase with rapidly growing Indian economics, a focus of the project was e.g. on how to implement renewable energies, mainly solar energy. This interest rose especially after working with Ghadia Solar in 2009.

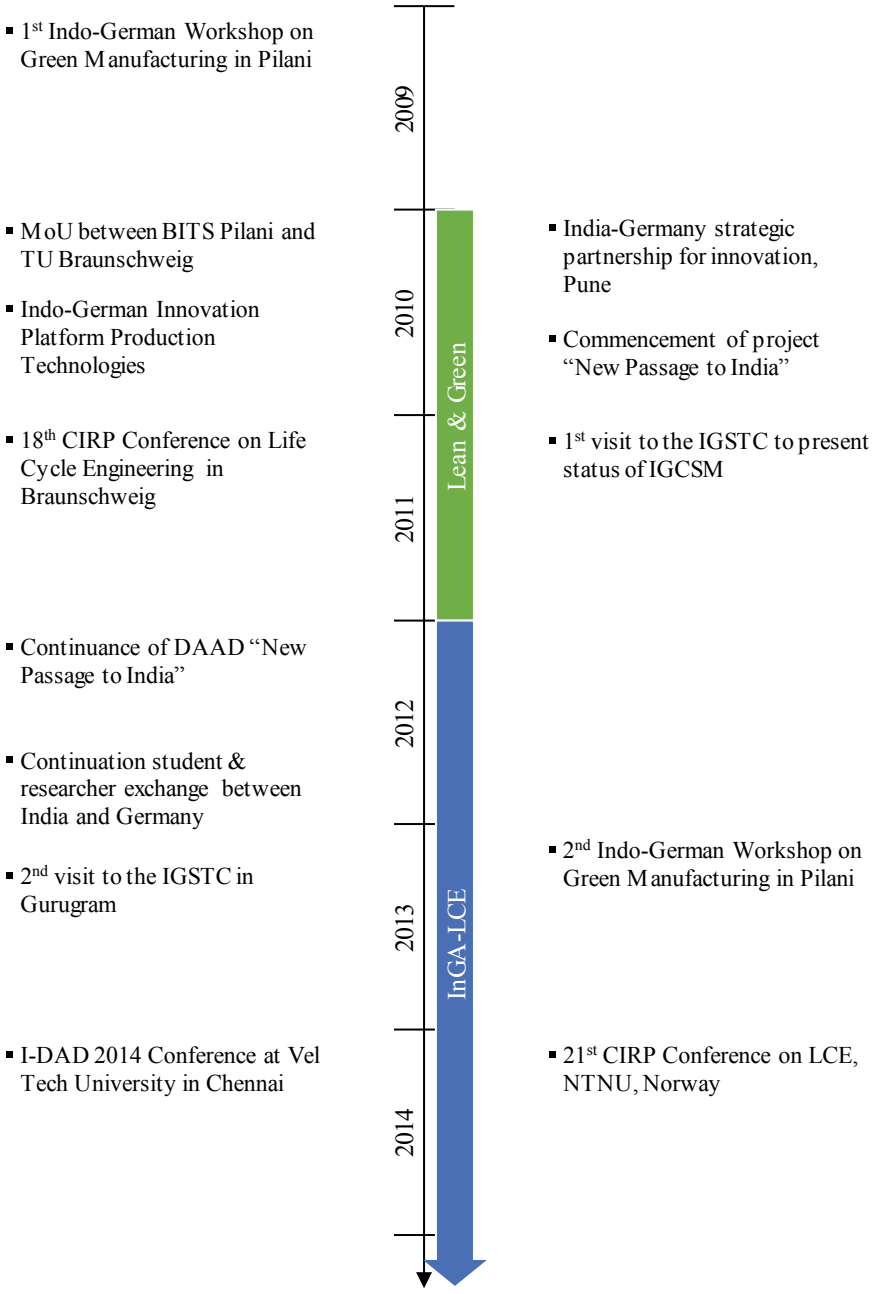

Fig. 1.2 Milestone timeline from 2009 to 2014

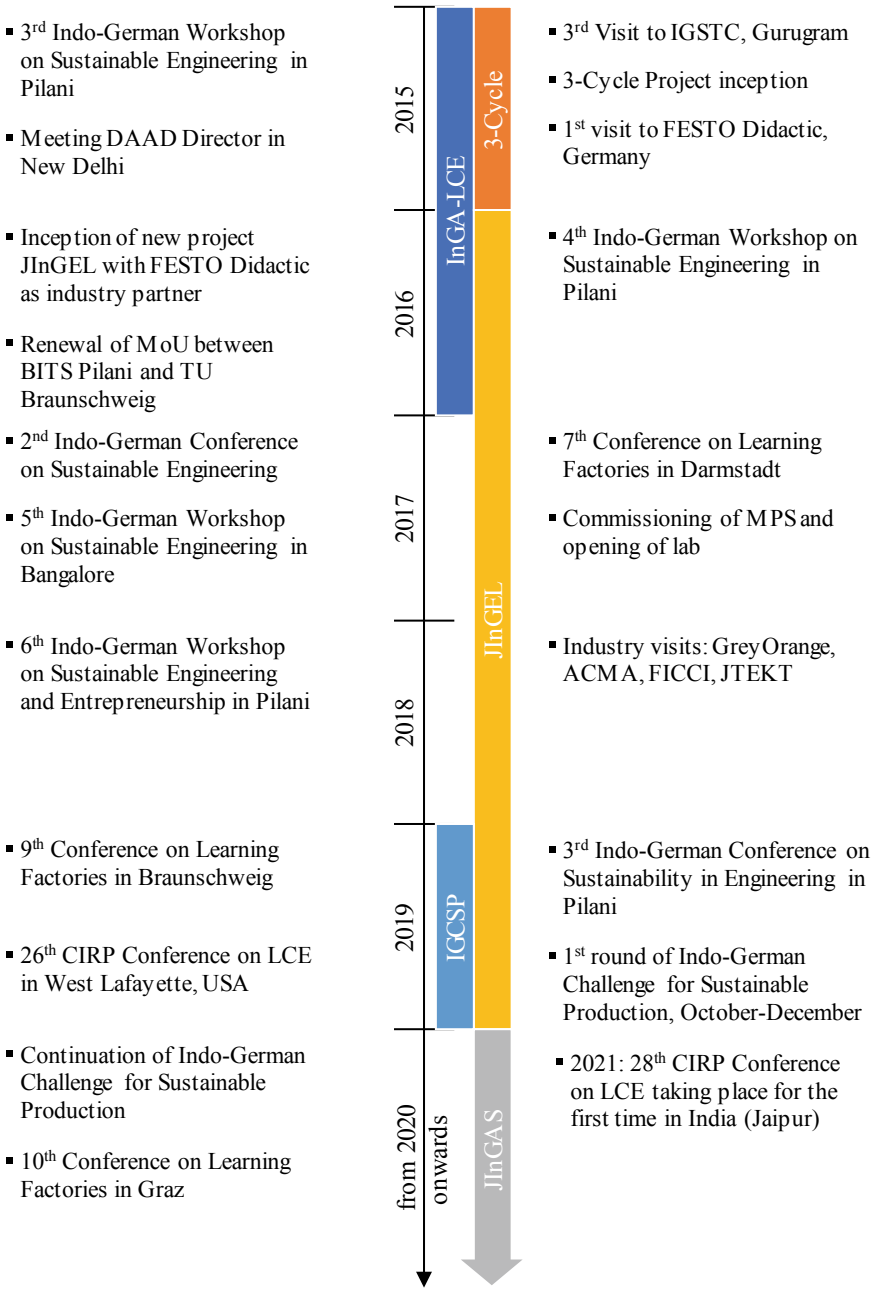

Fig. 1.3 Milestone timeline from 2015 onwards

In general, the project reflected on production systems that were not only economically but also ecologically efficient. Besides an energy-efficient production, the conservation of resources was important. Furthermore, Indian restrictions like availability of qualified employees, capital-intensive equipment, infrastructure, and wage level had to be considered. It was about developing sustainable methods and tools. Technical expertise and principle methods of life cycle engineering had to be adjusted with regard to Indian conditions.

1.2.2 Indo-German Automotive Life Cycle Engineering

Answering to the renewed research call "A New Passage to India" by DAAD, the project "Indo-German Automotive Life Cycle Engineering" ("InGA-LCE") was launched in 2012. With two extensions in 2014 and for a short-term period in 2016, the project lasted in total 4.5 years. It thus has been the longest of the cooperation's projects so far.

It started with the idea to develop a concept of green and electric "Campus Mobility" for BITS Pilani, and aimed, in a broader context, at compiling green transportation systems for India. "Campus Mobility" ought to be an application scenario to think about sustainable, energy-efficient vehicle manufacturing for a country differing from Germany in terms of standards, requirements and infrastructures. India seemed to be the perfect match to the German partners, as it is the country with the world's highest concentration of megacities and quickly increasing mobility needs. The consideration of local particularities of a product's and a vehicle's life cycle, namely different conditions in its development, production, utilization, recycling, was as crucial to the project as the concept of an adaptable vehicle. A comprehensive vehicle concept was to be developed that would work for both of the country-specific mobility scenarios and that could be adapted to the particular characteristics of climate, availability of resources, quality standards, price level, etc. The identification and comparison of two very different mobility concepts constituted the ideal framework for the development of an adaptable vehicle concept, multi-variant, but efficient and effective in production. As the project progressed, the aspect of energy supply became more important. It was crucial to ensure, for instance, that the use of e-mobility would not just shift the problem of CO_2 emissions from traffic to power generation. Starting with a concrete scenario, the project was extended to make the complexity of sustainable mobility concepts visible.

Besides BITS Pilani and IWF (Institute of Machine Tools and Production Technology, TU Braunschweig), the IK (Institute for Engineering Design), and the Automotive Research Association India (ARAI) in Pune were partially involved as they were working on similar topics.

1.2.3 3-Cycle

In recent years, negative environmental impacts due to plastic waste induced by industrial mass production have become visible all over the world and consequently became a global challenge. At the same time, the demand for personalized products, which are manufactured in small batch sizes, has significantly risen and the impact of sustainability on manufacturing companies driven by customer demand and legislation has increased. Subsequently, products made in a more sustainable way can have an economic advantage over their conventional counterparts.

The additive manufacturing technology fused deposition modeling (FDM)—also known as 3D-printing—can be utilized as a production process that can comply with these demands. In FDM 3D-printing a plastic filament is heated and added layer by layer to form a three-dimensional object. With this additive production process, the material is used more efficiently than with conventional subtractive processes, as almost only so much material is added to the part as is actually required.

The production of the basic material for FDM, the filament, has a significant impact on overall costs and environmental impact of the 3D-printed parts. The utilization of filament from plastic scrap material can thus contribute to more sustainable products manufactured with 3D-printing.

In the project "3-Cycle", a small and modular process chain was developed for 3D-printing from extruded waste plastics. Together with researchers and students from BITS Pilani, the process development, application, and evaluation took place both at the Experience Lab at IWF, TU Braunschweig and at BITS in 2015 and 2016. This project was funded by AKB Stiftung.

In the "3-Cycle" project, a great number of students from India and Germany were involved. These students worked individually and in small groups on project tasks mostly during the course of their theses. In total, 16 students and several researchers contributed to the design, construction, testing, and evaluation of the recycling process.

1.2.4 Engineering Education: Joint Indo-German Experience Lab

Engineers do not only participate in the development of products and services, but also in the process of their practical implementation. An education with practical orientation strengthens the competence level of young graduates and provides benefits to industry. Nowadays, the engineering education in Indian universities has a huge potential in combining scientific theoretical education with practical experience. To ease the transition of graduates into the job market, it is advisable to have practical education with industrial context in universities. Especially in reference to management and performing abilities in industrial-like manufacturing environments, shortcomings in current university education have to be compensated. In this context,

the idea to adopt the Experience Lab (xLine) of the IWF to the learning environment of BITS Pilani was an ideal extension. The xLine reproduces the most important manufacturing processes in a smaller scale, which makes it possible for students to work in a safe and industrial-like factory environment. The used control systems are the same as in industrial machines and they use the same resources (electricity, compressed air and heat).

Together with the practice partner Festo Didactic SE, which supplied the educational infrastructure, the four-year DAAD project "Joint Indo-German Experience Lab" (JInGEL) was started in 2016. The goal of this project was to transfer the experiences made in the Experience Lab at TU Braunschweig to the Indian university environment. As reference project for further Indian universities and further education institutions, the concept has been introduced at BITS Pilani.

The project offered students and researchers the chance to visit the partner university for a period of three to five months and write their theses within the context of this project. Furthermore, also students and researchers from the department of industrial/organizational and social psychology at TU Braunschweig participated to analyze the effectiveness of the innovative teaching and learning system before and after the integration of the Experience Lab into the BITS curriculum and educational system.

The project aimed at transferring the experiences made in India back to the German academic education. Didactic methods and the curriculum could be enriched by the findings made in Indian teaching and learning culture embedded in their specific economic, ecologic, and social boundary conditions. After a positive evaluation and proof of principle of the Joint Indo-German Experience Lab at the BITS Pilani, the principle will be published as a template to be rolled-out over other BITS campuses and other universities and technical colleges.

1.2.5 Indo-German Challenge for Sustainable Production

Following the call "MINTernational innovativ", a call for supporting projects, which aim at fostering innovative learning and teaching in STEM fields (science, technology, engineering and mathematics), the team established the "Indo-German Challenge for Sustainable Production" (IGCSP). The Club MINTernational has awarded this project as "Best Practice" for initiating new and innovative teaching methods addressing. As part of this project, a joint seminar between BITS Pilani and TU Braunschweig was initiated. The goal of this seminar is to develop industry-relevant solutions in the field of sustainable production. This task had to be fulfilled within a team, which consists of students from TU Braunschweig and BITS Pilani. From October 2019 until December 2019, the first round of IGCSP took place. In this round, the team could also win two apprentices from TU Braunschweig "Gemeinsame Ausbildungswerkstatt" (GAW, joint training workshop). Figure 1.4 shows the overall structure of IGCSP. The major phases can be described as the following.

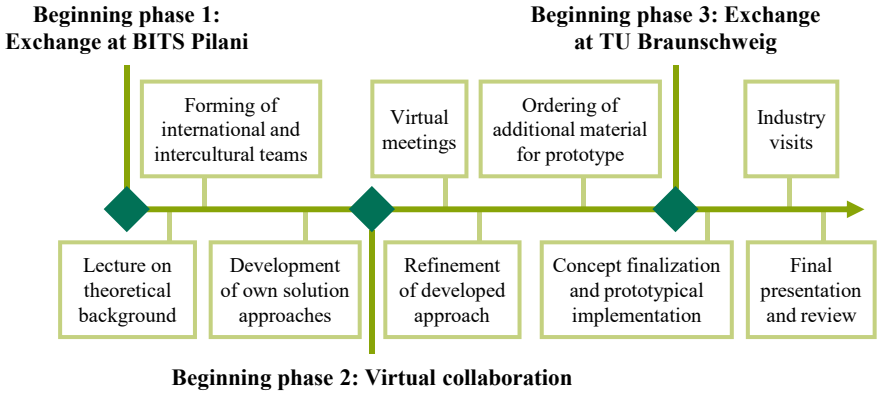

Fig. 1.4 Structure of IGCSP with its three major phases

Phase 1: Exchange at BITS Pilani: Students and teachers from TU Braunschweig and BITS Pilani initially met at BITS Pilani campus in the beginning of October. Here, students gained the required theoretical knowledge during lectures. The lectures have been from the field of Life Cycle Assessment and Sustainable Cyber Physical Production Systems. After that, the students started working in their teams. Each team was working on one specific sub-theme of the seminar. At the end of this phase, a basic procedure of how the problem had to be solved was developed and each of the five groups had created ideas. During this phase, students also had the possibility to gain insights into how industry 4.0 contributes to economic development. Besides this, the participants joint a cross-cultural workshop, in which students, apprentices and teachers jointly developed external image of the other culture and compared these results with the self-image.

Phase 2: Virtual teamwork: After the physical meeting in Pilani, the teams further developed their solution approaches under application of communication software. During their meetings, they discussed how the approach could be implemented in both of the learning factories ("Die Lernfabrik" at TU Braunschweig and "Joint Indo-German Experience Lab" at BITS Pilani). Students also used provided resources such as microcontrollers and sensors. To be able to finalize their prototypes later on in the second phase of exchange, ordering of additional material was possible.

Phase 3: Exchange at TU Braunschweig: In December, the exchange of BITS Pilani students and teachers to TU Braunschweig took place. Here, the teams met for the second time and the students improved and finalized the developed prototype. Then, students presented their approaches to the committee.

1.2.6 Joint Indo-German Academy Towards Sustainability in Engineering, Education and Entrepreneurship

With this project, the teams answers the call "Subject-Related Partnerships with Institutions of Higher Education in Developing Countries" by DAAD. The "Joint Indo-German Academy towards Sustainability in Engineering, Education and Entrepreneurship" (JInGAS) will start in 2020 and end in 2023.

The goal of JInGAS is to successfully continue the 2019 initiated "Indo-German Challenge for Sustainable Production" and thus improving the developed joint seminar in both of the partner universities. It is also intended to support teachers by introducing research-based learning into BITS Pilani curriculum. Besides the field of mechanical engineering, the team will also incorporate other disciplines, namely being education and entrepreneurship. The short-term exchange of the participants of this seminar will be supplemented by long-term exchange of students.

1.3 Joint Workshops and Conferences

Joint research and academic exchange are a major part of this Indo-German cooperation right from the start. To allow the dissemination of research results from the direct partnership's environment to the society, including other universities, industry, NGO and politics, two different formats have been introduced: workshops and conferences.

In September 2009, the **Indo-German Workshop series** started with the 1st Indo-German Workshop in Pilani focusing on measures to increase the energy and resource efficiency in manufacturing companies. Each workshop represented the topics from the current projects and attracted attendees from academia and industry from Germany and India. In 2017, the fifth workshop was jointly organized with Festo India in Bangalore to reach partners from the other side of the subcontinent. One year later, in 2018, the 6th Indo-German Workshop on Sustainable Manufacturing and Entrepreneurship took place in Pilani.

The second format are conferences. As the cooperation heavily grew in recent years, the team started organizing and hosting a **series of academic Indo-German conferences**. Researchers of other institutions from Germany and India joined these series to present their results to foster the topics of the cooperation. The most recent conference was the 3rd Indo-German Conference on Sustainability in Engineering, Education and Entrepreneurship: Enhancing Future Skills and Entrepreneurship. Besides the presentation of the authors' contributions, industry and NGO, partners presented inspiring insights into their work. The contributions follow this chapter of this book.

Right from the beginning, the partners jointly participate in international conferences to present the outcomes of their research. The major two have been the CIRP[1] Conference on Life Cycle Engineering and the conference on Learning Factories (CIRP sponsored). The team actively participates in these conferences and publishes joint research outcomes. On CIRP Conference on Life Cycle Engineering 2011 in Braunschweig, the team had four joint contributions (Herrmann et al. 2011; Jindal and Sangwan 2011; Mittal and Sangwan 2011; Sangwan 2011). On CIRP Conference on Learning Factories 2017 the team published outcomes from engineering education research (Büth et al. 2017; Juraschek et al. 2017). In addition, other conferences in Asia were used to widespread the idea of learning factories (Leiden et al. 2018). One year later 2018, a study on solar energy on campus has been presented (Sangwan et al. 2018). In 2019 CIRP Conference on Life Cycle Engineering, one joint paper on environmental impact of machining (Sihag et al. 2019) has been published. During Conference on Learning Factories, the implementation of cooling processes into learning factories (Vogt et al. 2019) and a study about research-based learning for skill development (Singh et al. 2019) were presented. Further joint publications can be obtained from the references section (Herrmann et al. 2009; Halubek et al. 2010; Mittal et al. 2012; Bhakar et al. 2013; Mittal et al. 2013; Bhakar et al. 2015; Juraschek et al. 2016).

As an outlook, the team is very grateful to announce that the 28th CIRP Conference on Life Cycle Engineering will take place in Jaipur, India (see www.lce2021.in). This will be the first time that such a prestigious CIRP conference is going to be held in India.

1.4 Sponsors and Supporters

From the very beginning of this cooperation, intensive support from different institutions has been realized. Without this support, the cooperation would not be as successful as it is today. Besides the personal efforts of all involved people, the team is very grateful to the sponsors and supporters.

Most importantly, the team wishes to thank DAAD (German Academic Exchange Service) for the long-term support. Without their financial support, it would not have been possible to establish such a successful and intense partnership. DAAD also made it possible to publish this book.

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[1]CIRP: International Academy for Production Engineering.

possible to realize the innovative projects “3-Cycle” and “Indo-German Challenge for Sustainable Production”.

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