Training Facility Norms and Standard Equipment Lists
VOLUME 1

PRECISION ENGINEERING OR MACHINING

Fook Yen Chong and Raymond Tay

DECEMBER 2018

ASIAN DEVELOPMENT BANK

ADB

Training Facility Norms and Standard Equipment Lists

VOLUME 1

PRECISION ENGINEERING OR MACHINING

Fook Yen Chong and Raymond Tay

DECEMBER 2018

ASIAN DEVELOPMENT BANK

ADB

6 ADB Avenue, Mandaluyong City, 1550 Metro Manila, Philippines
Tel +63 2 632 4444; Fax +63 2 636 2444
www.adb.org

ISBN 978-92-9261-454-6 (print), 978-92-9261-455-3 (electronic)
Publication Stock No. TCS189798-2
DOI: http://dx.doi.org/10.22617/TCS189798-2

Notes:
In this publication, "$" refers to United States dollars.
Corrigenda to ADB publications may be found at http://www.adb.org/publications/corrigenda.

Photos in this publication were taken by Fook Yen Chong for ADB, except where indicated.
Cover credits (left to right): **Machine tools operation section.** At a marine shipyard (photo by Abir Abdullah for ADB). **Automotive repairs student.** At a workshop in a TVET campus (photo by ADB). **Welding and plasma cutting lab.** Polytechnic students learn how to work with metal (photo by ADB). **Teacher and student.** TVET training workshop (Fook Yen Chong for ADB).

CONTENTS

TABLES AND FIGURES

Tables

Figures

ACKNOWLEDGMENTS

The Asian Development Bank (ADB) has ramped up lending to the technical and vocational education and training (TVET) sector in recent years. TVET institutions are instrumental in strengthening skills and entrepreneurial capabilities of young people. Improving access, quality, equity, and relevance of TVET is therefore critical to meeting the aspirations of the youth and the needs of industry. Speed is also increasingly important to adopt new technologies under the fourth industrial revolution.

This ADB technical specification reference guide aims to provide guidance to TVET policymakers and practitioners in the adoption of good practices for the design of training facility norms and standard equipment lists based on industry standards. This volume is the first in a series of technical specification reference guides that cover four strategic trades in the field of manufacturing: (i) precision engineering or machining, (ii) mechatronics technology, (iii) mechanical technology, and (iv) electrical technology.

Precision machining uses cutting tools to produce parts and components widely used in automotive parts and component manufacturing, aerospace parts and frames, components manufacturing, and die or mold making. Mechatronics technology combines mechanical, electronics, computer, and electrical technology to support automation in manufacturing processes. Mechanical technology is the application of engineering and scientific principles to ensure the smooth operation and efficient use of machinery and mechanical equipment. Electrical technology is the application of science and engineering principles to install, operate, maintain, and repair electrical instruments and wiring in residential, commercial, and industrial settings. We hope this series of reference guides would be useful, but the specifications included in the guide are indicative, and should be further contextualized based on the actual needs of the TVET institutions.

Fook Yen Chong, Social Sector Specialist, Human and Social Development Division (SAHS), South Asia Department, ADB, and Raymond Tay, ADB consultant in Singapore, prepared this volume. The peer reviewers were Shamit Chakravarti, Principal Social Sector Specialist, Human and Social Development Division, Southeast Asia Department; and Francis Arcenal, TVET Consultant in the Philippines. Ryotaro Hayashi, SAHS, provided valuable comments, and Alfredo P. Garcia, SAHS, provided administrative assistance.

Sungsup Ra
Director, Human and Social Development Division
South Asia Department
Asian Development Bank

ABBREVIATIONS

ADB	Asian Development Bank
CAD	computer-aided design
CAM	computer-aided manufacturing
CNC	computer numeric control
ILO	International Labour Organization
TVET	technical and vocational education and training
UNESCO	United Nations Educational, Scientific and Cultural Organization

EXECUTIVE SUMMARY

The design and implementation of technical and vocational education and training (TVET) projects require good guidance to ensure that the project moves forward in the right direction. Currently, many developing Asian countries face challenges, such as time pressure to deliver project outcomes and results, building capacity quickly, making appropriate policy changes, and providing sustainable resources and results.

This reference guide on the indicative norms for the design of training facilities and standard equipment lists was prepared to support developing member countries in delivering better and faster reforms in TVET. It provides examples and guidance to users in making decisions about ideal technical specifications when establishing training facilities for precision engineering training programs. It also identifies equipment specifications aligned with current industry standards.

Ideally, training facility norms and equipment lists should be based on existing curriculum standards defining depth of skills and specific pedagogic requirements. To mitigate possible curriculum discrepancies, the authors adopted a basic principle that the training facility norms and standard equipment lists should be adaptable for postsecondary TVET courses to train entry-level machinists for work in developed and/or newly industrialized countries. The training facility norms and standard equipment lists are aligned to a well-established machining workshop. Care has been taken to consult with industry, and to benchmark against reputable TVET institutions. While this reference guide cannot substitute for up-to-date and industry-aligned curricula and pedagogic requirements, it focuses on critical underlying parameters such as space, safety, student-to-equipment ratio, circulation area, and adequacy of teaching facilities.

The authors also adopted the principle that for conventional equipment and tools, the student-to-equipment ratio should be 1:1. The premise is that all students should already have a good foundation in basic skills. For sophisticated equipment and machinery, the ratio should be 1:2 or 1:4, depending on the available budget and how well teachers can adapt different pedagogical approaches according to training facility configurations.

This reference provides broad guidance and should not be mechanically applied to different settings. Users are encouraged to customize these indicative specifications and guidelines according to industry needs, education requirements, budget availability, local regulatory requirements (safety and building), and curriculum standards. It is necessary to focus on industry–curriculum alignment within the limitations of budget and resources. Predefining teacher–student and student–equipment ratios as well as appointing the right experts to plan and design the training facilities are also crucial.

Training facility norms and standard equipment lists improve the design of TVET projects. There is a need to provide training facilities that meet the requirements of the fourth industrial revolution to develop students with "future-ready" skills (photos by ADB).

1 INTRODUCTION

Between the years 2009–2011 and 2015-2017, the Asian Development Bank (ADB) increased total sovereign lending to the education sector in the Asia and Pacific region by $1 billion from $1.4 billion to $2.4 billion. Within this sector, the share of lending for technical and vocational education and training (TVET) increased from 12.8% to 57.5%, a reflection of the growing emphasis being given by developing member countries to skills development. Many ongoing and proposed pipeline projects have substantial civil works involving upgrading and construction of training facilities and procurement of goods, such as training equipment. However, improvement of the technical specifications can be further defined and incorporated to ensure that training facilities meet both curriculum and industry requirements.

Often, TVET executing and implementing agencies in developing countries lack the technical expertise to design quality training facilities. They may spend considerable time in preparing training equipment specifications without knowledge of the latest industry requirements, and inadvertently procure inferior quality equipment that do not meet the latest curriculum or industry standards.

ADB has initiated the development of training facility norms and standard equipment lists to provide indicative guidance. These are meant to be references for executing and implementing agencies as they plan the construction of training infrastructure and procurement of training equipment. This reference guide will be useful in designing new TVET projects particularly in the precision engineering or machining field.

RATIONALE FOR DEVELOPING TRAINING FACILITY NORMS AND STANDARD EQUIPMENT LISTS

Training facility norms and standard equipment lists will improve the design of TVET projects.

Many TVET buildings have been designed and built like general education school buildings. However, it is very important for TVET training facilities to be designed in line with curricula that reflect industry standards and requirements. Pedagogical, safety, and health requirements should be defined properly and incorporated into the design of the facilities. Electrical loading, floor loading, and space requirements require proper computation and measurement. The ratios of students to equipment, and teacher to students, should also be defined based on industry requirements.

Architects and construction companies should be adequately familiar with the training and equipment requirements of the specific training programs when designing TVET infrastructure. Often, the expectation is that they will incorporate the appropriate technical parameters and specifications as required by the TVET institutions. It is therefore important that executing and

implementing agencies, architects, and contractors work together. In the planning, design, and construction of fit-for-purpose TVET infrastructure, architects and contractors should obtain appropriate inputs and instructions from executing and implementing agencies.

Many trade teachers in developing Asian countries, particularly those working for public training centers, are not actively engaged with industry or do not currently possess in-depth working knowledge and experience in industries. At the beginning of a TVET reform project they may not be sufficiently familiar with the latest technologies and industry practices and processes to provide the detailed inputs. In addition, when new trade areas are introduced, institutions often lack the expertise to develop the technical specifications to procure training equipment and machines.

The concept of developing training facility norms and standard equipment lists for TVET is not necessarily new, but it needs to be updated for emerging trades. For instance, the United Nations Educational, Scientific and Cultural Organization (UNESCO) and International Labour Organization (ILO) developed guidance for developing TVET workshops in the 1970s and 1980s (ILO 1978, ILO 1986, Pitanilabut 1979, UNESCO 1979, UNESCO 1989). However, these were not updated regularly. The National Institute of Building Sciences in the United States, including the National Clearinghouse for Educational Facilities, provided important design considerations for training facilities in 2017 (see National Institute of Building Sciences 2017), but this useful information needs to be elaborated on for emerging trades in developing Asia.

With the fourth industrial revolution, it becomes critical for TVET institutes to realign their facilities to keep pace with the changing technology needs of industry. Schwab (2016) argues that the fourth industrial revolution or Industry 4.0 is different from the first three industrial revolutions in terms of the speed, scope, magnitude, and interconnectedness of the change. Technological advances in different areas are building on and amplifying each other in a fusion of technologies that will transform the world of work.[1]

There is a need to provide training facilities to develop students with "future-ready" skills by meeting the requirements of the fourth industrial revolution. This series of training facility norms and standard equipment lists provides requirements to suit current industry needs and advocates the incorporation of new technologies.

PRECISION ENGINEERING

This volume covers precision engineering or machining.[2] The precision engineering or machining field of study involves the use of cutting tools to manufacture parts and components used across multiple manufacturing and assembly sectors. Precision engineering has been internationally recognized as a key research area for the last few decades (Leach and Smith 2018). It is a key field of study for supporting industrialization initiatives in emerging and even advanced economies with a strong manufacturing sector.

1 At the World Economic Forum, Schwab (2016, p. 7) considers Industry 4.0 as a "confluence of emerging technology breakthroughs, covering wide-ranging fields such as artificial intelligence, robotics, Internet of Things, autonomous vehicles, three dimensional printing, nanotechnology, biotechnology, materials science, energy storage, quantum computing, and mobile phones to name a few," which are changing the way people live, work, interact, produce, and consume.

2 The other volumes are mechatronics technology, mechanical technology, and electrical technology, which are also developed as reference guides of training facility norms and standard equipment lists.

The introduction of Industry 4.0-enabled or enriched precision machines is a recent trend. More specifically, three applications exist in precision engineering or machining: (i) part and components machining, (ii) mold or die making, and (iii) aerospace parts manufacturing. Part and components machining includes vehicle components manufacturing, engine block and head manufacturing, and semiconductor equipment parts. Mold and die making includes plastic injection molds, forging and stamping dies, die cast dies, and forming dies. Aerospace parts manufacturing comprises structural and frames, mechanical components, turbine, and proportional valves.

Possible occupations associated with precision engineering or machining are precision machinist, aerospace component specialist, computer numeric control operator, computer-aided design and/or computer-aided manufacturing specialist, and industrial machine mechanical designers, among others.

TARGETED READERS AND HOW TO USE THE TRAINING FACILITY NORMS AND STANDARD EQUIPMENT LISTS

The training facility norms and standard equipment lists will be useful guides for TVET planners, administrators, and instructors; as well as for architects, design and supervision consultants, and civil works contractors. They would also be helpful to nontechnical staff engaged in TVET project design and development partner institutions. More specifically, training facility norms and standard equipment lists will help expedite the design of future TVET projects involving new construction or upgrading of training facilities. Government officials involved in designing TVET projects need to understand the estimated space, floor loading, lighting, electrical loading, and other building services required for training facilities. The reference guides will also provide a good benchmark and can further improve training facilities.

METHODOLOGIES

Five considerations directed the development of the training facility norms and standard equipment lists. First, these training facility norms and standard equipment lists are aligned with the post-secondary TVET standards of industrialized economies. Second, training facility norms and standard equipment lists are aligned with industry norms for entry-level skilled positions. Third, reputable TVET institutions in the People's Republic of China, Malaysia, Singapore, and other countries were studied as reference points in developing these norms and standard equipment lists. Fourth, the experience of task teams who have worked in TVET institutions and implemented multiple projects in establishing training facilities and procuring training equipment contributed tremendously to shaping the training facility norms and standard equipment lists. Fifth, for basic tools and conventional equipment, the task team proposed a ratio of equipment and tools to student at 1:1; and for advanced sophisticated training equipment, 1:2 or 1:4.

In addition, the task team considered the emerging needs of the fourth industrial revolution, and incorporated some advanced technology features already available in equipment and machines used by industry. A good example is the proposal for Internet of Things (IoT)-enabled or enriched training equipment that can (i) track utilization of training equipment, (ii) monitor student progress on practical skills learning, (iii) support individual student learning plans through big data and data analytics, and (iv) support greater use of formative rather than summative assessment.

LIMITATIONS

Several considerations should be noted in using the training facility norms and standard equipment lists. First and foremost, these reference guides should be adapted to the curriculum. Second, they should be contextualized in each unique setting based on budget, space (including loading capacities and access), industry demand, and institutional capacity. Third, the estimated costs are based on standard industry grades, and could vary depending on specifications, and operation and maintenance requirements. The cost estimate is based on 2018 prices, which needs to be updated when designing a specific project. Fourth, the reference guides are intended for entry-level skills, and the details need to be adjusted for advanced skills. For instance, as discussed earlier, the task team proposed equipment–student ratios of 1:2 or 1:4 for advanced tools and conventional equipment.[3]

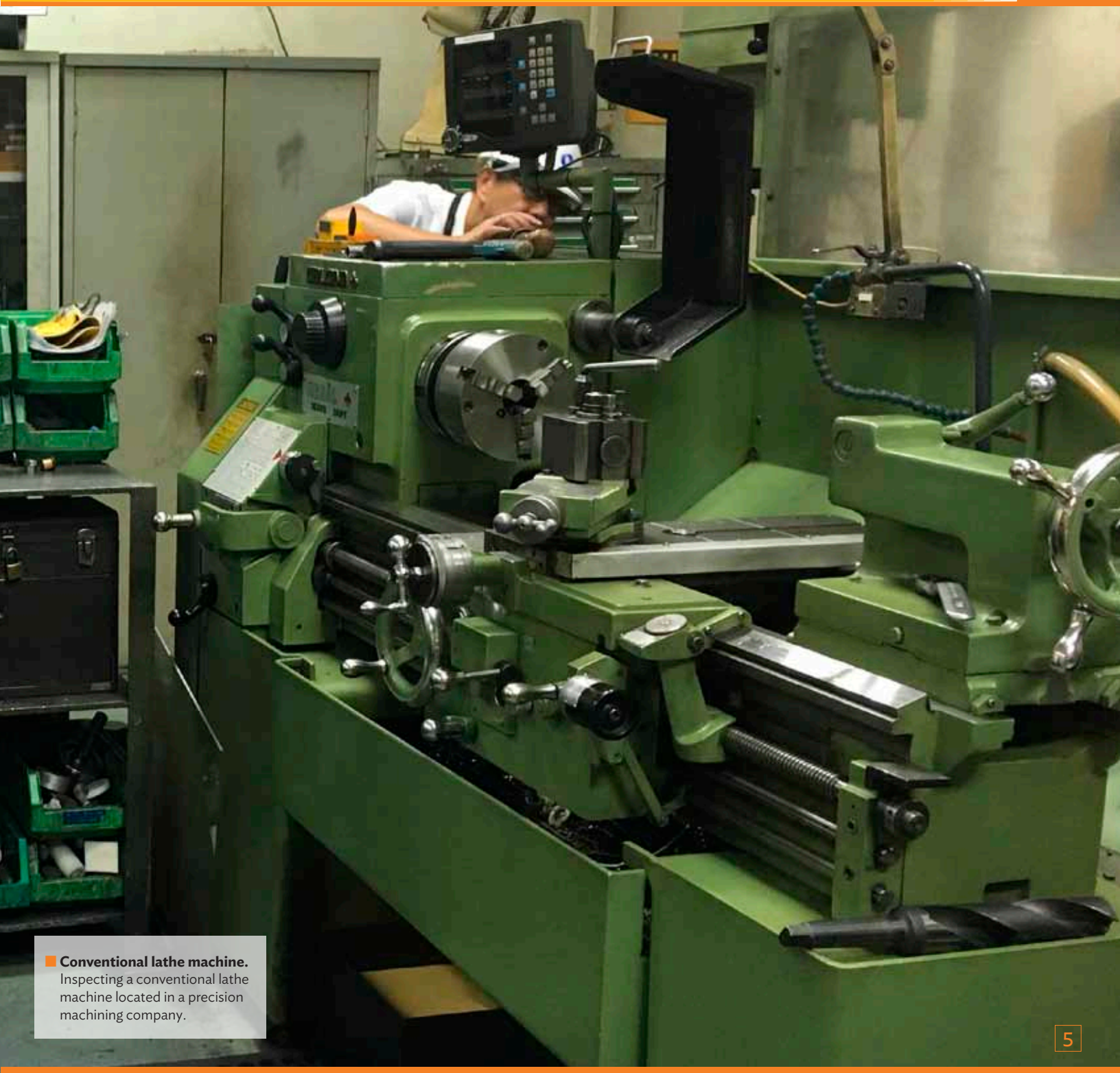
STRUCTURE OF THE REPORT

Section 1 discusses the rationale for developing training facility norms and standard equipment lists in the field of precision engineering or machining training. Precision engineering or machining is largely divided into three areas: (i) a conventional workshop; (ii) a computer numeric control workshop; and (iii) a machining center, metrology, and measurement workshop. The rest of the sections discuss details of these three areas. Each technical section includes training facility norms (such as floor plan layouts and floor area requirements) followed by standard equipment lists and pictures of key equipment.

Section 2 describes a conventional workshop with three associated training courses in milling (section 2.1), turning (section 2.2), and grinding (section 2.3). Section 3 introduces computer numeric control workshops on milling (section 3.1) and turning (section 3.2). Section 4 explains the requirements for machining centers and metrology laboratory.

[3] Details are available from the references or upon request from Fook Yen Chong, Social Sector Specialist, ADB (fchong@adb.org).

2 CONVENTIONAL MACHINE TRAINING FACILITIES



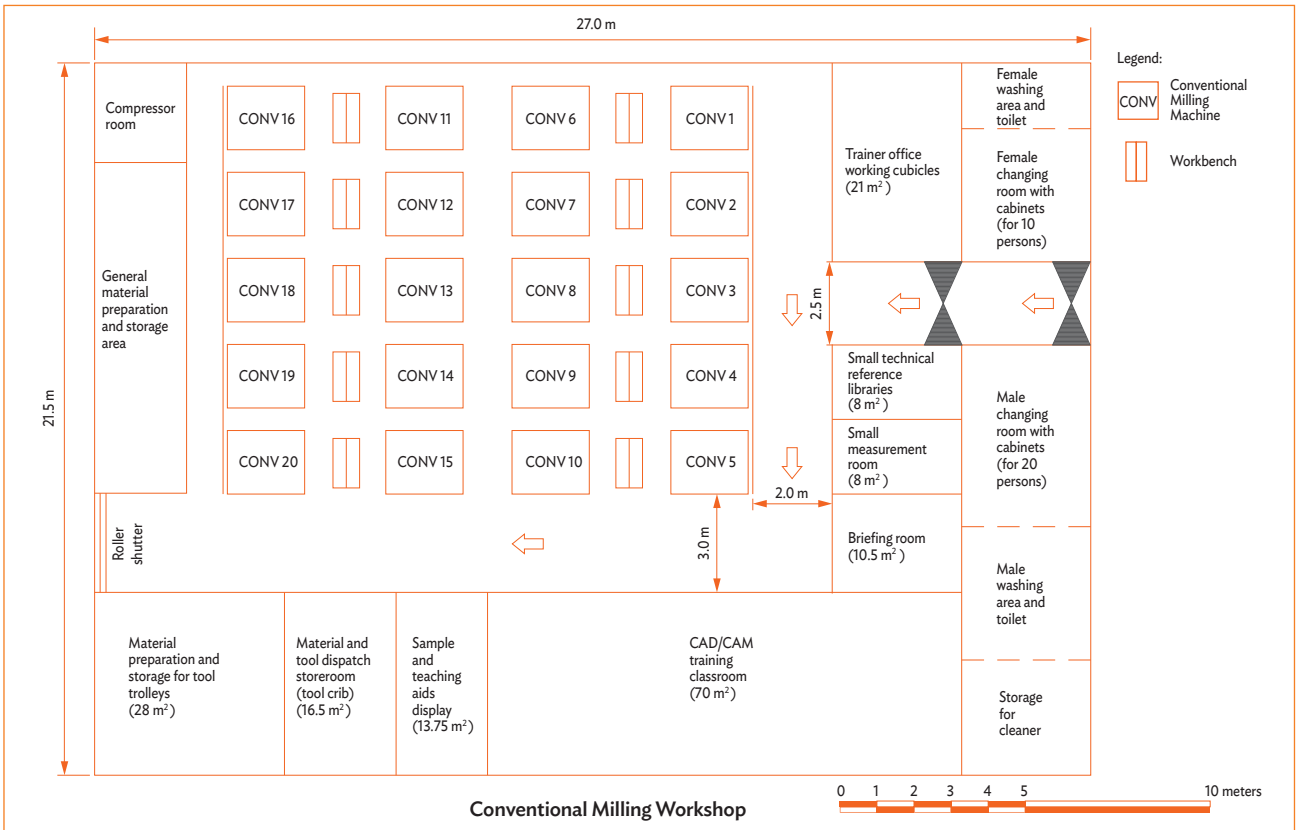
Conventional lathe machine. Inspecting a conventional lathe machine located in a precision machining company.

2.1 CONVENTIONAL MILLING WORKSHOP AND CAD/CAM TRAINING ROOM

2.1.1 Training Facility Norms

A. WORKSHOP FLOOR PLAN LAYOUT AND SIZE

Figure 1: Conventional Milling Workshop Floor Plan



CAD = computer-aided design, CAM = computer-aided manufacturing, CONV = conventional machine, m= meter, m² = square meter.
Source: Asian Development Bank.

Table 1: Floor Area Requirement for Conventional Milling Workshop

S/N	Area	Size (m^2)	Remarks
1	Vertical milling machine area	320	
2	Compressor room	7	
3	Material preparation and storage (for two trolleys)	28	
4	Material and tool dispatch storeroom	16.5	
5	Samples and teaching aids display	13.75	
6	CAD/CAM room	70	
7	Briefing room	10.5	
8	Small technical reference library	8	
9	Small measurement room	8	
10	Trainer office working cubicles	21	
11	General material preparation and storage room	20	

CAD = computer-aided design, CAM = computer-aided manufacturing, m^2 = square meter.
Source: Asian Development Bank.

B. TECHNICAL SPECIFICATIONS FOR THE WORKSHOP

Table 2: Laboratory and/or Workshop for Conventional Milling Workshop

Proposed Student Enrollment Size	**20**
Applicable Field of Usage	**PARTS AND COMPONENTS: AUTOMOTIVE, MEDICAL DEVICE, AEROSPACE, AND ELECTRONICS**

Parameter	Norm	Remarks
Size of Laboratory and/or Workshop	**580 m^2**	
Electrical loading requirement	3-phase supply 220V, 60 Hz with voltage stabilizer and surge suppressor in each machine location Each machine: 10–12 kVA, 60 Amp outlets, total 20 Each workbench: 4 × 13 Amp outlets Wiring type: For machine and workbenches – overhead, for room conceal in wall Type of socket outlet: universal outlet CAD/CAM room: 26 × 13 Amp outlets for computers etc. Small measurement room: 6 × 13 Amp outlets Library: 10 × 13 Amp outlets Briefing room: 6 × 13 Amp outlets Display area: 6 × 13 Amp outlets Tool crib area: 6 × 13 Amp outlets Material preparation: 6 × 13 Amp outlets Staff office room: 10 × 13 Amp outlets General storage area: 5 × 3 phase and 5 × 13 Amp outlets Compressor room: 1 × 3-phase and electrical outlets of 2 × 15 Amp outlets	
Floor loading requirement	Machine location: 12–15 kN/m^2, 400 mm deep concrete Others area: 4–6 kN/m^2	
Lighting requirement (lumen)	LED type lighting tube spread above machine and appropriate places in the room On/off switch: one in each room Emergency lighting: At Emergency exit, along the walking path to the workshop	

continued on next page

Table 2 continued

Parameter	Norm	Remarks
Flooring requirement	Machine area: industrial epoxy paint (hardened type with 2 coatings)	
Location of laboratory and/or workshop (floor)	Ground	
Laboratory and/or workshop climatic condition	Insulation to reduced heat from rooftop Cross-flow natural ventilation 6–7 m if using wide blade (5 m industrial fan) 5–6 m if using air-conditioning	
Building safety code requirement	Local building, safety, and fire code	
Fire fighting requirement	At least eight fire extinguishers	
First aid requirement	Standard first aid box with basic medication installed in a conspicuous position and readily available	
Built-in furniture requirement	By design	
Communication	Wired type - LAN cables Wi-Fi router	
Compressor type	Screw type compressor	
Other requirements	Shuttle door opening for machine move-in: minimum 3.5 m wide × 4 m high	

Amp = ampere, kN/m^2 = kilonewton per square meter, kVA = kilovolt-ampere, LAN = local-area network, LED = light-emitting diode, m = meter, m^2 = square meter.
Source: Asian Development Bank.

2.1.2 Standard Equipment List

Table 3: Conventional Milling Workshop Equipment Specification

Name of the Laboratory and/or Workshop	**MILLING WORKSHOP**
Proposed Student Enrollment Size	**20**
Applicable Field of Usage	**PARTS AND COMPONENTS: AUTOMOTIVE, MEDICAL DEVICE, AEROSPACE, AND ELECTRONICS**

S/N	Name of Item	Description of Item	Quantity	Remarks
A	**Training Equipment/Machine: $30,000 each**			
1	***Vertical Milling Machine (Knee Type) with Digital Display***	General specifications (minimum requirements)	20 units	Machining Area
a	Travel range	X axis, table: 750 mm Y axis, cross: 380 mm Z axis, vertical knee travel: 380 mm		
b	Table specification	Table size: 1.300 × 300 mm Table loading: 200 kg T slot: 16 mm		
c	Ram specification	Ram travel, 500–600 mm Ram swivel: 360 degrees		

Table 3 continued

S/N	Name of Item	Description of Item	Quantity	Remarks
d	Spindle specification	Spindle power: 3.75 kW Spindle speed: 3500 rpm Spindle taper: NT 40 Quill travel: 140 mm Quill auto feed: 0.035, 0.07, 0.14 Head tilt: +/– 45 degrees		
e	Engineering specifications	Power draw bar Digital display Chip pan Hardened and ground guide with turcite Centralized auto-way lubricant X and Y axes power feed Transformer with sufficient length of cable and terminal lugs		
2	***2D and 3D Modelling***			
a	Microcomputer $1,500 each	Configuration suitable to run solid modelling design software	21 units	CAD/CAM Training Room
b	2D and 3D solid modelling software $10,000 for 21 licenses	Examples: Solid work; auto-CAD; unigraphics Education package	21 licenses	
c	LCD projector	4,000 lumens	1 unit	
B	**Tools and Accessories: 20% of equipment price**			
1	Stub milling arbor	16 × 25 mm (diameter × length)	20 units	
2	Stub milling arbor	22 × 25 mm (diameter × length)	20 units	
3	Stub milling arbor	27 × 25 mm (diameter × length)	20 units	
4	Stub milling arbor	32 × 25 mm (diameter × length)	20 units	
5	Collet chuck		20 units	
6	Conical type collet for chuck holders	Diameter: 5 mm Diameter: 6 mm Diameter: 8 mm Diameter: 12 mm Diameter: 16 mm	20 units 20 units 20 units 20 units 20 units	
7	Drill chuck	Range A: up to 8 mm Range B: up to 12 mm	20 units	
8	Wrench for chuck holder		20 units	
9	Fixture for holder clamp/ unclamp		20 sets	
10	Parallel bar	Parallel bar size: 5 × 10 × 100 mm Parallel bar size: 10 × 20 × 150 mm Parallel bar size: 15 × 30 × 150 mm Parallel bar size: 20 × 40 × 200 mm	20 pairs 20 pairs 20 pairs 20 pairs	
11	Rotary table	Diameter: 300 mm c/w mounting accessories	5 units	
12	Hydraulic vise swivel base	Jaw width: 100 mm c/w mounting accessories	1 unit	
13	Hydraulic vise swivel, tilt and swivel	Jaw width: 100 mm c/w mounting accessories	1 unit	

continued on next page

Table 3 continued

S/N	Name of Item	Description of Item	Quantity	Remarks
14	Cutting tools	Angular cutter, 90 degree double equal angle	20 units	
		Twist drill: 1–13 mm diameter Twist drill: 13.5–23 mm diameter	5 sets 5 sets	
		End mills: Series of the HSS end mills 6 mm and 8 mm 10 mm 12 mm 16 mm	 20 units 50 units 50 units 20 units	
		Face mill diameter 30–32 mm diameter face mill arbour with 4 insert pockets	20 units	
		Reamer (taper shank) - Taper shank: 15 mm and 20 mm diameter	5 sets	
		Shell end mill diameter: 30–32 mm	20 units	
		Sitting saw diameter: 1.25–3 mm	5 units	
		Slot drills diameter: 3–20 mm	20 units	
		Dovetail cutter 60-degree diameter: 25 mm	20 units	
		T-slot cutter diameter: 22 × 8 mm	8 units	
15	Splash guard	Front and rear	20 units	
	Measuring Tools			
16	Caliper	Vernier calipers: up to 150 mm Digital Vernier caliper: 0–150 mm Digital gauge Vernier: 0–200 mm Digital dial range: 25 mm max Digital dial range: 50 mm Standard mechanical dial: 0.005 mm graduation Test dial indicator: 0.01 mm graduation, 0.5 mm range; full set magnetic stands; standard type Vernier height gauge	20 units 20 units 10 units 20 units 10 units 10 units 21 units 5 units	
17	Dial indicator	Comes with magnetic stand: range 0–0.8 mm, reading 0.001 mm Comes with accessories and magnetic: 0.001 mm	 10 units 10 units	
18	Micrometer	Depth micrometer: 0–75 mm Inside micrometer, caliper type • 0.5–30 mm • 0.25–50 mm • 0.50–75 mm	10 sets 10 units 5 units 5 units	
19	Combination set		3 units	
20	Bench work tools	Bench vise with jaw - width: 150 mm, approximately	2 units	
21	Common hand tools	Hand files V-blocks Taps and tap wrenches Tri-square Spring dividers Letter punches and number punches Hammers Hacksaws Scriber	20 sets	

continued on next page

Table 3 continued

S/N	Name of Item	Description of Item	Quantity	Remarks
C	**Furniture: $50,000–$70,000**			
1	Wooden workbench	1.5 × 1.2 × 0.8 m, approximately Heavy duty industrial grade thickness: 50 mm	10 units	
2	Heavy duty tool cabinet	1.8 × 1.2 × 1.8 m	2 units	Material Preparation and Storage Room; Material and Tool Dispatch Storeroom
3	Tool crib cabinet	0.75 × 0.75 × 1 m	2 units	Material and Tool Dispatch Storeroom
4	Hydraulic table lift	Load capacity: 600 kg	1 unit	
5	Trainer table and chair		1 set	
6	Whiteboard	1.5 × 1.0 m double-sided with castor wheels	2 units	CAD/CAM Room and Briefing Room
7	Tool cart and work center	0.7 × 0.37 × 0.84 m	20 units	Material Preparation and Storage Room
8	Automatic tool dispenser	0.875 × 0.62 × 1.2 m	1 unit	(Optional)
9	Tool holder cabinet	Capacity: 150 holder slots/cabinet (at tool crib)	2 units	Material Preparation and Storage Room
10	Flip side table and chair Instructor table and chair		20 units 1 unit	CAD/CAM Training Room
11	Table and chair for trainer and staff		4 sets	Trainer office cubicle
12	Library shelf	According to user's needs	1 unit	Technical Room cum Library
13	Display shelf	According to user's needs	1 unit	Sample and Display Room
14	Granite surface table	Industry grade with stand and levelling devices (600 × 450 × 130 mm)	1 unit	Small Measurement Room
15	Computer tables and chairs		21 sets	CAD/CAM Training Room
16	Ceiling-mounted LCD projector with remote switch for main power	4,000 lumens	1 unit	CAD/CAM Training Room
D	**Start-up, Operating, and Maintenance Consumables**			
1	Oil	SSU 335 at 100°F	6 liters	
2	Lubricants	According to machine maker recommendation		

°F = degree Fahrenheit, CAD = computer-aided design, CAM = computer-aided manufacturing, c/w = comes with, HSS = high speed steel, kg = kilogram, kW = kilowatt, LCD = liquid crystal display, m = meter, mm = millimeter, NT = National Machine Tool Builder Association, rpm = revolutions per minute, SSU = Sabolt Seconds Universal.
Source: Asian Development Bank.

2.1.3 Sample Photos for Conventional Milling Workshop

Conventional milling machine. Conventional milling machine setup in a conventional milling workshop.

Computer laboratory. CAD/CAM computer laboratory set up in a discussion style to facilitate group work and discussion.

Conventional milling workshop. Conventional milling workshop with milling machine, workbench, and measuring station.

Workbench. Sample workbench showing proper labeling and tool arrangement.

Conventional digital readout. Close-up photo of a conventional digital readout.

Machine tools cabinet. Sample cabinet for storing machine tools in a conventional milling workshop.

Drilling machine. A drilling machine located in a conventional milling workshop.

Granite table. Close-up photo of a granite table in a measuring station.

Machine tools and accessories cabinet. Sample photo of machine tools and accessories cabinets in a conventional milling workshop.

Workbench. Close-up photo of a workbench designed to facilitate group discussion and group work.

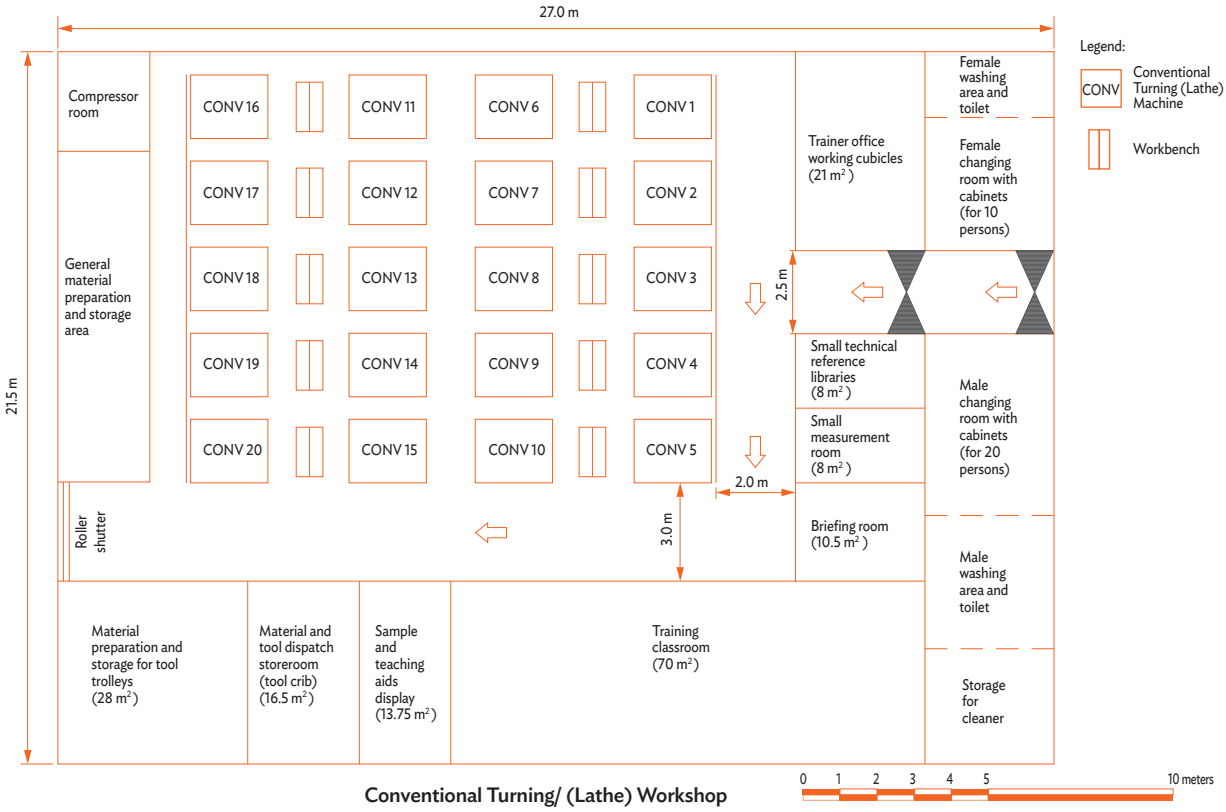
Tool trolley. A tool trolley to store machining tools.

2.2 CONVENTIONAL TURNING (LATHE) WORKSHOP

2.2.1 Training Facility Norms

A. WORKSHOP FLOOR PLAN LAYOUT AND SIZE

Figure 2: Conventional Turning (Lathe) Workshop Floor Plan



CONV = conventional turning (lathe) machine, m= meter, m^2 = square meter.
Source: Asian Development Bank.

Table 4: Floor Area Requirement for Conventional Turning (Lathe) Machine Workshop

S/N	Area	Size (m^2)	Remarks
1	Vertical milling machine area	320	
2	Compressor room	7	
3	Material preparation and storage (for two trolleys)	28	
4	Material and tool dispatch storeroom	16.5	
5	Samples and teaching aids display	13.75	
6	CAD/CAM room	70	
7	Briefing room	10.5	
8	Small technical reference library	8	
9	Small measurement room	8	
10	Trainer office working cubicles	21	
11	General material preparation and storage room	20	

CAD = computer-aided design, CAM = computer-aided manufacturing, m^2 = square meter.
Source: Asian Development Bank.

2.2.2 Standard Equipment List

Table 5: Laboratory and/or Workshop for Turning (Lathe) Machine Workshop

Proposed Student Enrollment Size	**20**
Applicable Field of Usage	**PARTS AND COMPONENTS: AUTOMOTIVE, MEDICAL DEVICE, AEROSPACE, AND ELECTRONICS**

Parameter	Norm	Remarks
Size of Laboratory and/or Workshop	**580 m^2**	
Electrical loading requirement	3-phase supply 220V, 60Hz with voltage stabilizer with surge suppressor at each machine location Each machine: 10–12 kVA, 60 Amp outlet, total 20 Each workbench: 4 × 13 Amp outlets Wiring type: Overhead for machine and workbenches, and for room, conceal in wall Type of socket outlet: Universal outlet Training room: 26 × 13 Amp outlets for computers etc Small measurement room: 6 × 13 Amp outlets Library: 10 × 13 Amp outlets Briefing room: 6 × 13 Amp outlets Display area: 6 × 13 Amp outlet Material and tool dispatch storeroom: 6 × 13 Amp outlets Material preparation and storage area: 6 × 13 Amp outlets Staff office: 10 × 13 Amp outlets Compressor room: 1 × 3–phase and 2 × 15 Amp	
Floor loading requirement	Machine location: 10–12 kN/m^2, 300 mm deep concrete Others area: 4–6 kN/m^2	
Lighting requirement (lumen)	LED type lighting tube spread above machine and appropriate places in the room On/off switch: one in each room Emergency lighting: At emergency exit, along the walking path to the workshop	

Table 5 *continued*

Parameter	Norm	Remarks
Flooring requirement	Machine area: Industrial epoxy paint (hardened type with 2 coatings)	
Location of laboratory and/or workshop (floor)	Ground	
Laboratory and/or workshop climatic condition	Air-conditioned If no air-conditioners at machine area, should select big-bladed fan of diameter 4 m–5 m, but the height has to be 6–7 m to the fan base The ceiling has to be insulated and the air flow has to be good to prevent overheating of the machine	
Building safety code requirement	Local building, safety, and fire code	
Fire fighting requirements	6–8 fire extinguishers	
First aid requirement	Standard first aid box with basic medication installed in a conspicuous position and readily available	
Built-in furniture requirement	By design	
Communication	Wired type - LAN cables Wi-Fi router	
Compressor type	Screw type compressor	
Other requirements	Shuttle door opening for machine move-in: minimum 3.5 m wide × 4 m high	

Amp = ampere, Hz = hertz, kN/m^2 = kilonewton per square meter, kVA = kilovolt-ampere, LED = light-emitting diode, m = meter, m^2 = square meter, V = volts.
Source: Asian Development Bank.

B. TECHNICAL SPECIFICATIONS FOR THE WORKSHOP

Table 6: Turning (Lathe) Workshop Equipment Specification

Name of the Laboratory and/or Workshop	**TURNING (LATHE) WORKSHOP**
Proposed Student Enrollment Size	**20**
Applicable Field of Usage	**PARTS AND COMPONENTS: AUTOMOTIVE, MEDICAL DEVICE, AEROSPACE, AND ELECTRONICS**

S/N	Name of Item	Description of Item	Quantity	Remarks
A	**Training Equipment and/or Machine: $25,000 each**			
1	***Center Lathe with Digital Display***	General specifications (minimum requirements)	20 units	Machine Area
a	Travel range	Swing-over bed range: 450–470 mm Swing-over cross slide: 280–300 mm Distance between center: 1,500 mm		
b	Spindle specification	Spindle bore: Diameter 52–56 mm Spindle nose: D1–6 Type of spindle bore: MT No. 6 Taper of center: MT No. 4 Steps of the spindle speed: 12 steps or more Range of spindle speed: 30–2500 rpm Spindle motor size: 5.5–7.5 kW		

continued on next page

Table 6 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
c	Carriage specification	Cross-slide travel range: 250–280 mm Compound rest travel range: 120–150 mm		
d	Tailstock specification	Tailstock travel: 150–170 mm Tailstock spindle taper: MT No.4 Feed specification: Longitudinal feed (Z axis): 0.06–0.88 mm/revolution Cross feed (X axis): 0.03–0.44 mm/revolution Feed motor (X/Z axes): 1.5 kW or more		
B	**Tools and Accessories: 20% of equipment price**			
1	Boring bar	Boring bar for 3 mm square HSS tool bit Boring bar for 6 mm square HSS tool bit Boring bar for carbide inserts	10 units 10 units 10 units	
2	Dog carriers	Range 10–50 mm	10 units	
3	Driving plate		10 units	
4	Center	Dead center Live center Revolving center Half center	20 units 8 units 20 units 5 sets	
5	Chuck	Drill chuck, keyless-clamping range up to 13 mm diameter Four-jaw chuck Three-jaw self-centering chuck	10 sets 20 units 5 units	
6	Chuck guard		20 units	
7	Splash guard	Front and rear	20 units	
8	Set of collets	15 pieces (5 mm to 20 mm in steps of 1 mm) Collet holders	20 units 20 units	
9	Knurling tool	Self-centering with 3 grades of diamond knurl Straight knurl	10 units 3 units	
10	Test bar		2 units	
11	Tool holder	Straight turning tool holder Right-hand turning tool holder Left-hand turning tool holder Inserts turning tool holder Parting off tool holder	20 units 5 units 5 units 5 units 5 units	
12	Quick change toolpost	4-way	10 units	
13	Pedestal grinder with grinding wheel	Diameter 200 mm approximately	2 units	
14	Bench drilling machine	Minimum capacity: 13 mm diameter Table size: 240 × 240 mm approximately	2 units	
15	Drill	Twist drill: 1–13 mm diameter in steps of 0.5 mm Twist drill: 13–23 mm diameter in steps of 0.5 mm	2 sets 5 sets	
16	Drill sleeve	Drill sleeve: MT1-2 Drill sleeve: MT1-3 Drill sleeve: MT2-3	5 units 5 units 5 units	
17	Reamer taper shank	15 mm and 20 mm	2 sets	
18	Mandrel	16–30 mm diameter	1 set	
19	Bench work tools	Bench vise with jaw - width: 150 mm, approximately	2 units	

continued on next page

Table 6 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
20	Common hand tools	Hand files V-blocks Taps and tap wrenches Tri-square Spring dividers Letter punches and number punches Hammers Hacksaws Scriber	20 sets	
21	Common rests and attachments	Steady rests: 8–145 mm Follower rests: 8–80 mm Taper turning attachments: 10 inches long and 20 degree included angle at any distance from the spindle nose	5 units	
	Measuring Tools			
22	Caliper	Vernier caliper: 0–150 mm Digital Vernier caliper: 0–150 mm Dial Vernier caliper: 0–150 mm Dial Vernier caliper: 0–50 mm	20 units 20 units 5 units 3 units	
23	Gauge	Radius gauge concave and convex Screw pitch gauge round base Surface gauge and ring gauge Taper plug and ring gauge: MT2 Taper plug and ring gauge: MT3 Taper plug and ring gauge: IT30 Thread center gauge Vernier height gauge: 300 mm	5 units 5 units 20 units 1 unit 1 set 1 set 10 units 2 units	
24	Indicator	Dial indicator comes with accessories and magnetic stand: range 015 mm, reading 0.01 mm Dial test indicator comes with accessories and magnetic stand: range 0–0.8 mm, reading 0.001 mm	10 units 4 units	
25	Micrometer	Depth micrometer (0.01) Inside micrometer (0.01), caliper type • 5–30 mm • 25–50 mm • 50–75 mm	5 sets 10 sets 10 sets 5 sets	
C	**Furniture: $50,000– $70,000**			
1.	Wooden workbench	1.5 × 1.2 × 0.8 m, approximately	11 units	
2	Heavy duty tool cabinet	1.8 × 1.2 × 1.8 m	2 units	Material Preparation and Storage Room; Material and Tool Dispatch Storeroom
3	Tool crib cabinet	0.75 × 0.75 × 1 m	2 units	Material and Tool Dispatch Storeroom
4	Hydraulic table lift	Load capacity: 600 kg	1 unit	
5	Trainer table and chair		1 set	Briefing Room
6	Whiteboard	1.5 × 1.0 m double-sided with castor wheels	2 units	Training Room and Briefing Room
7	Tool cart and work center	0.7 × 0.37 × 0.84 m	20 units	Material Preparation and Storage Room

continued on next page

Table 6 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
8	Automatic tool dispenser	0.875 × 0.62 × 1.2 m	1 unit	(Optional)
9	Tool holder cabinet	Capacity 150 holder slots/cabinet (at tool crib)	2 units	Material Preparation and Storage Room
10	Flip side table and chair; Instructor table and chair		20 units 1 unit	Training Room
11	Table and chair for trainer and staff		4 sets	Trainer Office Cubicle
12	Library shelf	According to user's needs	1 unit	Technical Room cum Library
13	Display shelf	According to user's needs	1 unit	Sample and Display Room
14	Granite surface table	Industry grade with stand and levelling devices (600 × 450 × 130 mm)	1 unit	Small Measurement Room
15	Ceiling-mounted LCD projector with remote switch for main power	4,000 lumens	1 unit	Training Room
D	**Start-up, Operating, and Maintenance Consumable**			
1	Oil	SSU 335 at 100° F	6 liters	
2	Lubricants	According to machine maker recommendation		

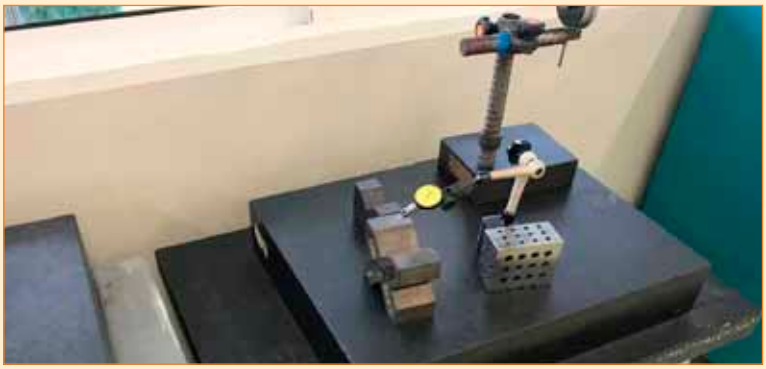
°F = degree Fahrenheit, HSS = high speed steel, kg = kilogram, kW = kilowatt, LCD = liquid crystal display, m = meter, mm = millimeter, MT = morse taper, rpm = revolutions per minute, SSU = Sabolt Seconds Universal.
Source: Asian Development Bank.

2.2.3 Sample Photos for Conventional Turning (Lathe) Workshop

Conventional lathe machine. A conventional turning (lathe) machine in a conventional turning (lathe) workshop.

Conventional turning (lathe) machine. Layout of a conventional turning (lathe) machine in a conventional turning (lathe) workshop.

Digital readout. A digital readout in a conventional turning (lathe) machine.



Granite table. A granite table in a measuring station in a conventional turning (lathe) machine workshop.

Drilling machine. A drilling machine in a conventional turning (lathe) machine workshop.

Workbench. Sample workbench with vise.

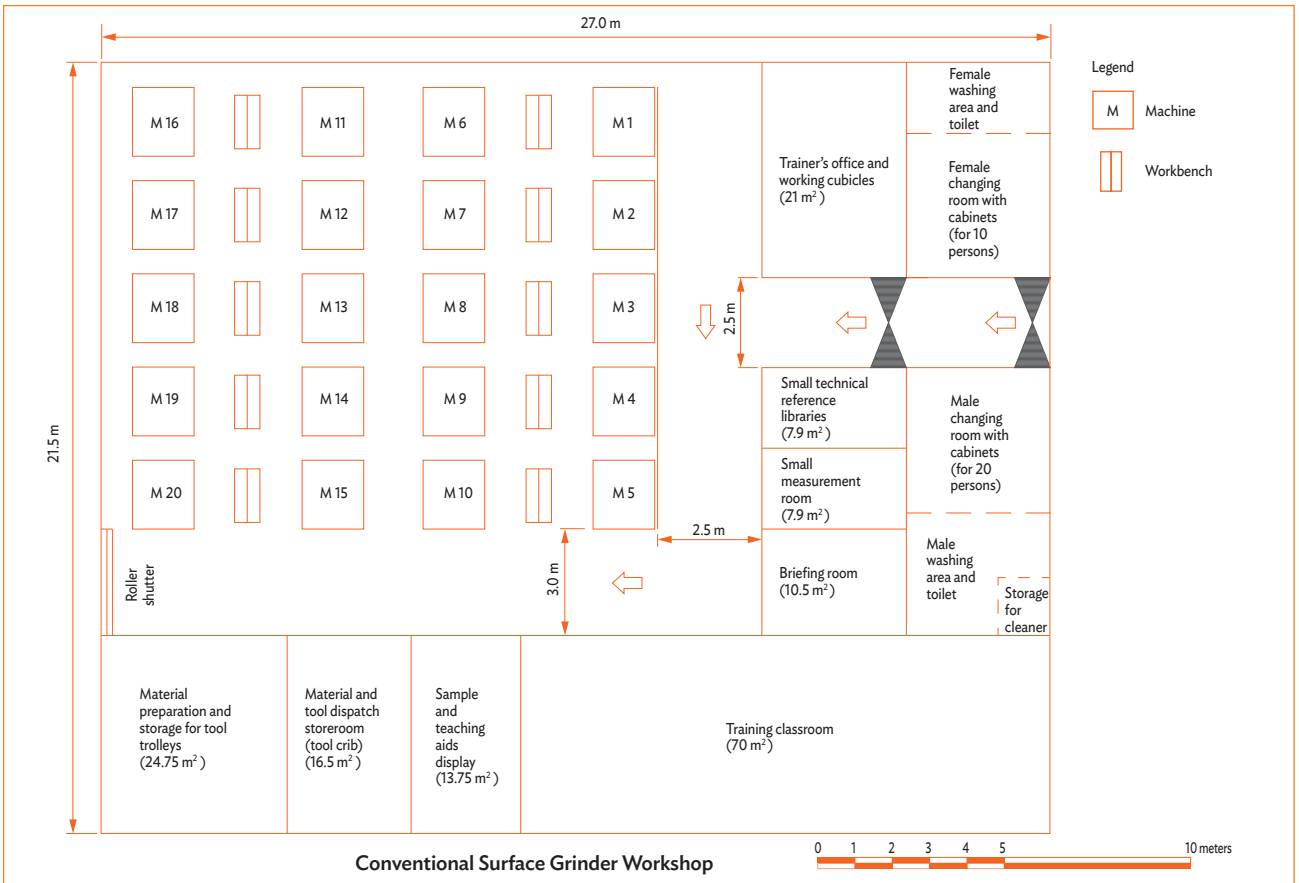
Machine tools and accessories cabinet. Sample photo of machine tools and accessories cabinets in a conventional turning (lathe) workshop.

2.3 CONVENTIONAL GRINDING WORKSHOP

2.3.1 Training Facility Norms

A. WORKSHOP FLOOR PLAN LAYOUT AND SIZE

Figure 3: Conventional Grinding Workshop Floor Plan



M = machine, m= meter, m^2 = square meter.
Source: Asian Development Bank.

Table 7: Floor Area Requirement for Surface Grinding Machine Workshop

S/N	Area	Size (m^2)	Remarks
1	Surface grinding machine area	360	
2	Material preparation and storage (for two trolleys)	24.75	
3	Material and tool dispatch storeroom	16.5	
4	Samples and teaching aids display	14.5	
5	Briefing room	10.5	
6	Small technical reference library	7.9	
7	Small measurement room	7.9	
8	Trainer office working cubicles	21	
9	Training room	70	

m^2 = square meter.
Source: Asian Development Bank.

B. TECHNICAL SPECIFICATIONS FOR THE WORKSHOP

Table 8: Surface Grinding Machine Workshop

Proposed Student Enrollment Size	**20**
Applicable Field of Usage	**PARTS AND COMPONENTS: AUTOMOTIVE, MEDICAL DEVICE, AEROSPACE, AND ELECTRONICS**

Parameter	Norm	Remarks
Size of Laboratory and/or Workshop	**494.5 m^2**	
Electrical loading requirement	3-phase supply 220V, 60Hz with voltage stabilizer with surge suppressor at each machine location Each machine: 10–12 kVA, 60 Amp Outlet, total 10 Each workbench: 4 × 13 Amp outlet Wiring type: For machine and workbenches – overhead, for room conceal in wall Type of socket outlet: Universal outlet CAD/CAM room: 26 × 13 Amp outlets for computers etc. 20 × 13 Amp outlets spread along the wall Small measurement room: 6 × 13 Amp outlets Library: 10 × 13 Amp outlets spread along the wall Briefing room: 6 × 13 Amp outlets Display area: 6 × 13 Amp outlets Tool crib area: 6 × 13 Amp outlets Material preparation: 6 × 13 Amp outlets Staff office room: 10 × 13 Amp outlets General storage area: 5 × 3-phase and 5 × 13 Amp outlets Compressor room: 1 × 3-phase and 2 × 15 Amp outlets	
Floor loading requirement	Machine location: 10–12 kN/m^2, 300 mm deep concrete Others area: 4–6 kN/m^2	
Lighting requirement (lumen)	LED type lighting tube spread above machine and appropriate places in the room On/off switch: one in each room Emergency lighting: At emergency exit, along the walking path to the workshop	
Flooring requirement	Machine area: Industrial epoxy paint (hardened type with 2 coatings)	
Location of laboratory and/or workshop (floor)	Ground	
Laboratory and/or workshop climatic condition	Air-conditioned If no air-conditioners in the machine area, should select big blade fan of diameter 4–5 m, but the height has to be 6–7 m to the fan base The ceiling has to be insulated and the air flow has to be good to prevent overheating of the machine	
Building safety code requirement	Local building, safety, and fire code	
Fire fighting equipment	6–8 fire extinguishers	
First aid requirement	Standard first aid box with basic medication installed in a conspicuous position and readily available	
Built-in furniture requirement	By design	
Communication	Wired type - LAN cables Wi-Fi router	
Compressor type	Screw type compressor	
Other requirements	Shuttle door opening for machine move-in: minimum 3.5 m wide × 4 m high	

Amp = ampere, CAD = computer-aided design, CAM = computer-aided manufacturing, Hz = hertz, kN/m^2 = kilonewton per square meter, kVA = kilovolt-ampere, LAN = local-area network, LED = light-emitting diode, m = meter, m^2 = square meter, V = volts.
Source: Asian Development Bank.

2.3.2 Standard Equipment List

Table 9: Surface Grinding Machine Workshop Equipment Specification

Name of Laboratory and/or Workshop	**SURFACE GRINDING WORKSHOP**
Proposed Student Enrollment Size	**20**
Applicable Field of Usage	**PARTS AND COMPONENTS: AUTOMOTIVE, MEDICAL DEVICE, AEROSPACE, AND ELECTRONICS**

S/N	Name of Item	Description of Item	Quantity	Remarks
A	**Training Equipment and/or Machine: $25,000 each**			
1	***Surface Grinding Machine with Digital Display***	General specifications (minimum requirements)	20 units	Machining Area
a	Travel range	X axis (longitudinal): 500–600 mm Y axis (crosswise): 200–220 mm Maximum grinding area: 500 × 100 mm		
b	Table specification	Size: 200 × 500 mm Longitudinal feed rate: 0.1–20 m/min Maximum table loading: 100 kg		
c	Hydraulic pump	0.75 kW (min)		
d	Spindle motor	Speed: 50 Hz/2850 rpm 2 Power: HP/1.5 kW		
e	Standard grinding wheel	Wheel size: 205 mm (diameter) × 6 mm (width) × 31.75 mm (bore)		
f	Engineering specification	Longitudinal auto feed Grinding wheel balancer devices Magnetic chuck-permanent type AC Servo motor for vertical rapid feed V-V slide way design comes with coolant tank		
B	**Tools and Accessories: 20% of equipment cost**			
1	Wheel balancing unit	Comes with accessories	1 unit	
2	Creep feed grinding wheel	For steel roughing and finishing	5 units	
3	Machine vices	80 mm opening	20 units	
4	Permanent magnet table		20 units	
5	Compound angle vise	60 mm opening	20 units	
6	Cleaning tower with stand		5 units	
7	Tower rolls		5 units	
8	Grinding wheels	Selection of grinding wheels AB60L8V	20 units	
9	Sine plate	Magnetic type: 10 (L = 170, B = 100, angle adjust up to 60 degrees) Nonmagnetic type: 5	1 unit 1 unit	
10	Surface grinder dresser		10 units	
11	Bench work tools	Bench vise with jaw - width: 150 mm, approximately	20 units	
12	Common hand tools	Hand files V-blocks Taps and tap wrenches Tri-square Spring dividers Letter punches and number punches Hammers Hacksaws Scriber	20 sets	

continued on next page

Table 9 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
	Measuring Tools			
13	Caliper	Vernier caliper: 0–150 mm Dial Vernier caliper: 0–150 mm Digital Vernier caliper: 0–150 mm	10 units 5 units 5 units	
14	Indicator	Dial indicator c/w accessories and magnetic stand: range 015 mm, reading 0.01 mm Dial test indicator c/w accessories and magnetic stand: range 0–0.8 mm, reading 0.001 mm	10 sets 5 sets	
15	Micrometer	Outside micrometer (0.01 mm), caliper type • 0–25 mm • 25–50 mm • 50–75 mm	 10 units 10 units 5 units	
16	Surface finishing comparison scales		2 units	
C	**Furniture: $50,000–$70,000**			
1	Wooden workbench	1.5 × 1.2 × 0.8 m approximately Heavy duty industrial grade thickness: 50 mm	11 units	10 in Machining Area; 1 in Small Measurement Room
2	Heavy duty tool cabinet	1.8 × 1.2 × 1.8 m	2 units	Material Preparation and Storage Room; Material and Tool Dispatch Storeroom
3	Tool crib cabinet	0.75 × 0.75 × 1 m	2 units	Material and Tool Dispatch Storeroom
4	Hydraulic table lift	Load capacity: 600 kg	1 unit	
5	Whiteboard	1.5 × 1.0 m double-sided with castor wheels	2 units	CAD/CAM Room and Briefing Room
6	Tool cart and work center	0.7 × 0.37 × 0.84 m	20 units	Material Preparation and Storage Room
7	Automatic tool dispenser	0.875 × 0.62 × 1.2 m	1 unit	Optional
8	Tool holder cabinet	Capacity 150 holder slots/cabinet (at tool crib)	2 units	Material Preparation and Storage Room
9	Flip side table and chair; Instructor table and chair		20 units 2 units	Training Room Briefing Room
10	Table and chair for trainer and staff		4 sets	Trainer Office Cubicle
11	Library shelf	According to user's needs	1 unit	Technical Room cum Library
12	Display shelf	According to user's needs	1 unit	Sample and Display Room
13	Granite surface table	Industry grade with stand and levelling device of 600 × 450 × 130 mm	1 unit	Small Measurement Room
14	Ceiling-mounted LCD projector with remote switch for main power	4,000 lumens	1 unit	Training Room

CAD = computer-aided design, CAM = computer-aided manufacturing, Hz = hertz, HP = horsepower, kg = kilogram, kW = kilowatt, LCD = liquid crystal display, m = meter, mm = millimeter, rpm = revolutions per minute.
Source: Asian Development Bank.

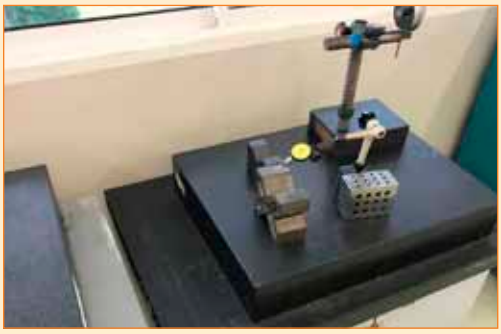
2.3.3 Sample Photos for Conventional Grinding Workshop

Conventional surface grinding machine. A conventional surface grinding machine with digital readout.

Digital readout. A digital readout in a conventional surface grinder.

Workbench. Sample workbench with vise.

Machine tools and accessories cabinet. Sample photo of machine tools and accessories cabinets in a conventional grinding workshop.



Granite table. A granite table in a measuring station.

Drilling machines. Drilling machines in a conventional surface grinding workshop.

3 COMPUTER NUMERIC CONTROL TRAINING FACILITIES

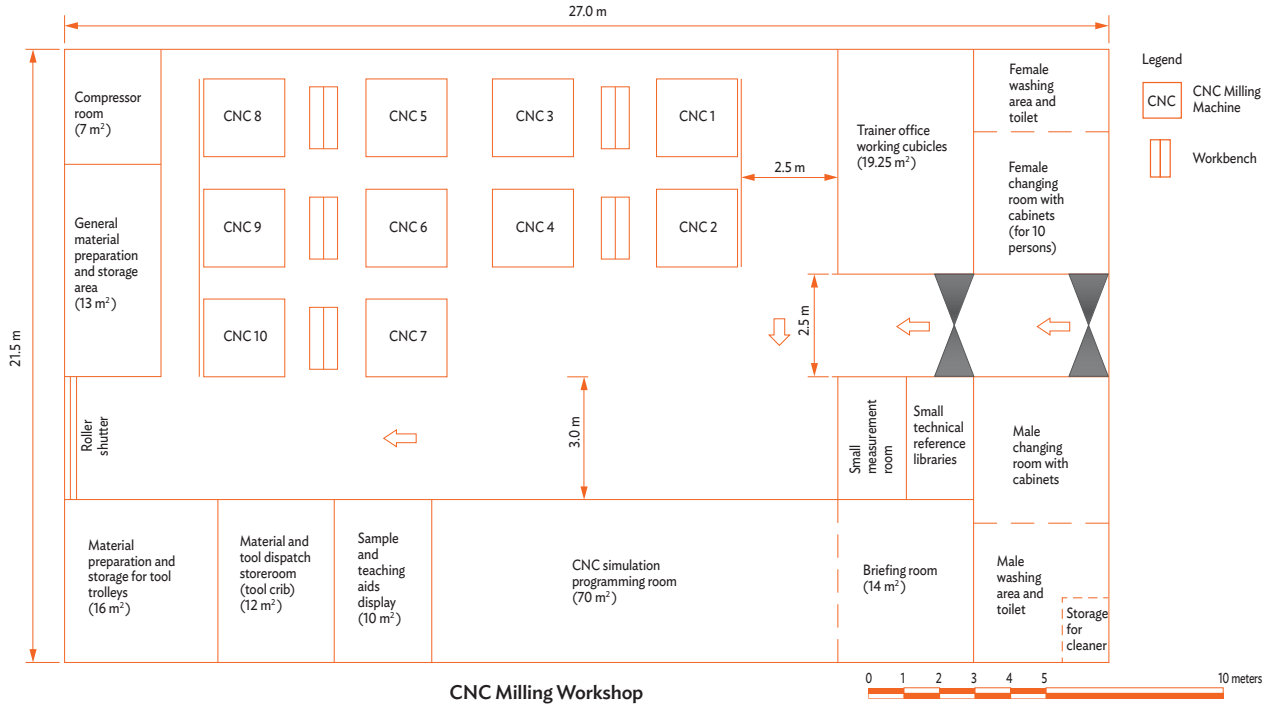
CNC milling machine. A teacher guides a student on how to operate a CNC milling machine.

3.1 CNC MILLING AND CNC SIMULATION TRAINING ROOM

3.1.1 Training Facility Norms

A. WORKSHOP FLOOR PLAN LAYOUT AND SIZE

Figure 4: Computer Numerical Control Milling Workshop Floor Plan



CNC = computer numeric control machine, m= meter, m² = square meter.
Source: Asian Development Bank.

Table 10: Floor Area Requirement for Computer Numeric Control Milling Machine Workshop

S/N	Area	Size (m²)	Remarks
1	CNC milling machine area	220	
2	Compressor room	7	
3	Material preparation and storage room (for two trolleys)	16	
4	Material and tool dispatch storeroom	12	
5	Samples and teaching aids display room	10	
6	CAD Room	42	
7	Briefing room	14	
8	Small technical reference library	5.25	
9	Small measurement room	5.25	
10	Trainer office working cubicles	19.25	
11	General material preparation and storage room	13	

CAD = computer-aided design, CNC = computer numeric control, m² = square meter.
Source: Asian Development Bank.

B. TECHNICAL SPECIFICATIONS FOR THE WORKSHOP

Table 11: Computer Numeric Control Milling Machine Workshop

Proposed Student Enrollment Size	**20**
Applicable Field of Usage	**PARTS AND COMPONENTS: AUTOMOTIVE, MEDICAL DEVICE, AEROSPACE, AND ELECTRONICS**

Parameter	Norm	Remarks
Size of Laboratory and/or Workshop	**400 m²**	
Electrical loading requirement	3-phase supply 220 V, 60 Hz with voltage stabilizer and surge suppressor in each machine location Each machine: 15 kVA, 60 Amp outlet, total 10 Each workbench: 4 × 13 Amp outlets Wiring type: For machine and workbenches – overhead; for room – conceal in wall Type of socket outlet: Universal outlet CNC programing simulation room: 20 × 13 Amp outlets for computers, etc. Small measurement room: 6 × 13 Amp outlets Library: 10 × 13 Amp outlets Briefing room: 6 × 13 Amp outlets Display area: 6 × 13 Amp outlets Material and tool dispatch storeroom: 6 × 13 Amp outlets Material preparation and storage room: 6 × 13 Amp outlets Staff office room: 10 × 13 Amp outlets General storage area: 5 × 13 Amp outlets Compressor room: 1 × 3-phase and 2 × 15 Amp outlets	
Floor loading requirement	Machine location: 12–15 kN/m², 400 mm deep concrete Other areas: 4–6 kN/m²	
Lighting requirement (lumen)	LED lighting tube spread above machine and appropriate places in the room • On/off switch: one in each room • Emergency lighting: At emergency exits, along the walkways to the workshop	
Flooring requirement	Machine area: Industrial epoxy paint (hardened type with 2 coatings)	
Location of laboratory and/or workshop (floor)	Ground	
Laboratory and/or workshop climatic condition	Air-conditioned; floor to ceiling height of 5–6 m If no air-conditioners in the machine area, should select big-bladed fan of diameter 4–5 m; height has to be 6–7 m to the fan base The ceiling has to be insulated and the air flow has to be good to prevent overheating of the machine	
Building safety code requirement	Local building, safety, and fire code	
Fire fighting equipment	At least 6–8 fire extinguishers	
First aid requirement	Standard first aid box with basic medications, installed in a conspicuous position and readily available	
Storage area requirement	28 m²	
Built-in furniture requirement	By design	
Communication	Wired type - LAN cables Wi-Fi router	
Compressor type	Screw type compressor	
Other requirements	Shuttle door opening for machine move-in: minimum 3.5 m wide × 4 m high	

Amp = ampere, Hz = hertz, kN = kilonewton, kVA = kilovolt-ampere, LAN = local area network, m = meter, m² = square meter, mm = millimeter, LED = light=emitting diode, V = volt.
Source: Asian Development Bank.

3.1.2 Standard Equipment List

Table 12: Computer Numeric Control Milling Machine Equipment Specification

Proposed Student Enrollment Size	**20**
Applicable Field of Usage	**PARTS AND COMPONENTS: AUTOMOTIVE, MEDICAL DEVICE, AEROSPACE, AND ELECTRONICS**

S/N	Name of Item	Description of Item	Quantity	Remarks
A	**Training Equipment and/or**	**Machine: $100,000 each**		
1	***CNC Milling Machine***	General specifications (minimum requirements)	10 units	Machining Area
a	Travel range	X axis: 500–600 mm Y axis: 300–350 mm Z axis: 350–500 mm		
b	Table specification	Minimum table size: 800 × 350 mm Table loading: 400 kg		
c	Spindle specification	Spindle speed: 6,000 rpm		
		Spindle taper type: BT 40		
		Spindle power and rating at 30 min/continuous • 5.5kw/3.2 kW continuous		
		Preferred design type: Manual adjusted, stepless, or programmable		
d	Feed control	Auto feed range: 0–12 m/minute or more		
		Least increment in all axes: 0.001		
		Position display: • Showing work coordinate • Showing machine current position		
e	Accuracy	Positioning without feedback scale: within 2.5 µm Repeatability without feedback scale: within 2.0 µm		
f	Spindle collision protection feature	Spindle will not be damaged in the event of direct and/or indirect collision with the workpiece		
g	Coolant flow control and chip management	Coolant and way lubricant not mixing, front chip tray		
h	Axes guideway type	Boxed guide with turcite. If linear guide, the way size must be 50 mm or more with auto lubricant system		
i	Ball-screw size	Diameter: 45 mm or larger		
j	Power failure monitoring and brake system	Manage power failure		
2	***CNC Programming Simulation:*** **$10,000 for 11 Licenses**			
a	Microcomputer	Configuration suitable to run CNC milling simulator	11 units	CNC Programming Training Room
b	CNC milling simulation software	For students to practice CNC milling programming	11 licenses	
c	LCD projector	4,000 lumens	1 unit	

continued on next page

Table 12 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
B	**Tools and Accessories: 30% of Equipment Cost**			
1	Heavy duty end mill holder	Application: End mills, drills, reamers, and solid taps	10 units	
2	Collet chuck		10 units	
3	Face mill arbor	50 face-mill	10 units	
4	Drill chuck	Drills (0–13 mm) and taps	10 units	
5	Clamping set		10 units	
6	Straight collet for heavy duty chuck holder	Diameter 12 Diameter 16 Diameter 20 Diameter 25	6 sets	
7	Spring collet for small holder	Diameter 3 Diameter 4 Diameter 6 Diameter 8 Diameter 10	6 sets	
8	Spring collet for large holder	Diameter 10 Diameter 12 Diameter 20	6 sets	
9	Wrench for heavy duty chuck holder		10 units	
10	Wrench for small chuck holder		10 units	
11	Wrench for large chuck holder		10 units	
12	Pull stud		100 units	
13	Fixture for holder		10 units	
14	Adaptor	For MT number 1, MT number 2, MT number 3 taper shank cutters	5 units	
15	Parallel bar	5 × 10 × 100 mm	10 units	
16	Tool pre-setter		2 units	
17	Machine tap	Course tap, M3, M5, M6, M8, M10, M12 Fine tap, M3, M5, M6, M8, M10, M12	3 sets 3 sets	
18	Reamer	Straight shank: 3–14 mm diameter in steps of 1 mm Straight shank: 15–22 mm diameter in steps of 1 mm	2 sets 2 sets	
19	Bench work tools	Bench vise swivel base with jaw – width: 150 mm, approximately	10 units	
20	Common hand tools	Hand files V-blocks Taps and tap wrenches Try square Spring dividers Letter punches and number punches Hammers Hacksaws Scriber	10 sets	
21	Tool pre-setter	Tool length pre-setter for BT 40 and Hsk 63 (combination)	1 unit	
	Measuring Tools			
1	Caliper	Vernier caliper: 0–150 mm Dial Vernier caliper: 0–150 mm Digital Vernier caliper: 0–150 mm	10 units 5 units 5 units	

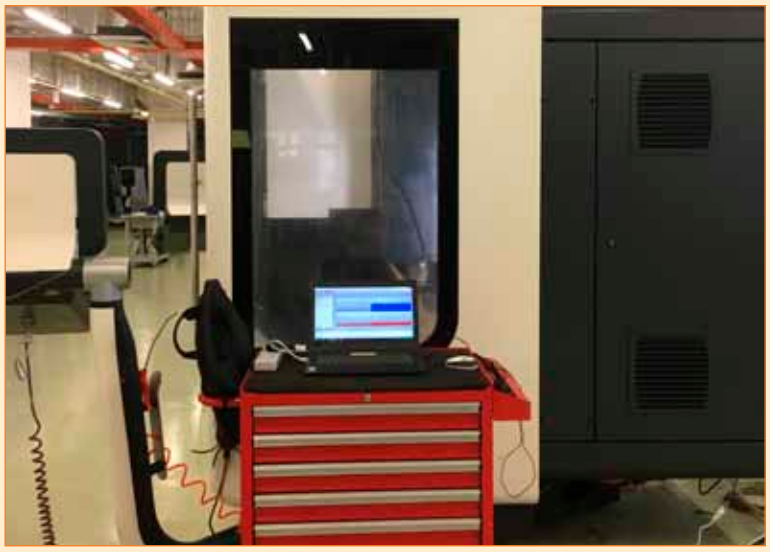
continued on next page

Table 12 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
2	Indicator	Dial indicator c/w accessories and magnetic stand, range: 015 mm, reading: 0.01 mm Dial test indicator c/w accessories and magnetic stand, range: 0–0.8 mm, reading: 0.001 mm	10 sets 5 sets	
3	Micrometer	Depth micrometer: 0.01 mm Inside micrometer: 0.01 mm, caliper type • 5–30 mm • 25–50 mm • 50–75 mm	5 sets 10 sets 10 sets 5 sets	
4	Gauge	Dial bore gauge of measuring range 6–60 mm Feeler gauge Radius gauge (concave and convex)	2 units 2 units 2 units	
C	**Furniture: $50,000–$70,000**			
1	Wooden workbench	1.5 × 1.2 × 0.8, approximately Heavy duty industrial grade thickness: 50 mm	6 units	5 in Machining Area; 1 in Small Measurement Room
2	Heavy duty tool cabinet	1.8 × 1.2 × 1.8 m	2 units	Material Preparation and Storage Room; Material and Tool Dispatch Storeroom
3	Tool crib cabinet	0.75 × 0.75 × 1 m	2 units	Material and Tool Dispatch Storeroom
4	Hydraulic table lift	Load capacity: 600 kg	1 unit	
5	Trainer table and chair		1 set	
6	Whiteboard	1.5 × 1.0 m double- sided with castor wheels Wall mounting recommended	2 units	CAD/CAM Room and Briefing Room
7	Tool cart and work center	0.7 × 0.37 × 0.84 m	10 units	Material Preparation and Storage Room
8	Automatic tool dispenser	0.875 × 0.62 × 1.2 m	1 unit	Optional
9	Tool holder cabinet	Capacity 150 holder slots/cabinet (at tool crib)	2 units	Material Preparation and Storage Room
10	Flip side table and chair. Instructor table and chair		20 units 1 unit	Briefing/Training Room
11	Table and chair for trainer and staff		4 sets	Trainer Office Cubicle
12	Library shelf	According to user's needs	1 unit	Technical Room Cum Library
13	Display shelf	According to user's needs	1 unit	Sample and Display Room
14	Granite surface table	Industry grade with stand and levelling device of 600 × 450 × 130 mm	1 unit	Small Measurement Room
15	Computer tables and chairs		11 sets	CNC Programming Training Room

BT = blade turn, CNC = computer numerical control, Hsk = hollow-shank taper, kg = kilograms, kW = kilowatt, LCD = liquid crystal display, m = meter, mm = millimeter, MT = Morse Taper, rpm = revolutions per minute, µm = micrometer.
Source: Asian Development Bank.

3.1.3 Sample Photos for CNC Milling Room



CNC machine. CNC machine with internet of things enabled function.

Tools and accessories holder. A tools and accessories holder.

CNC controller. For a CNC milling room.

CNC milling machine. CNC milling machine setup.

Machine tools and accessories cabinet. Sample photo of machine tools and accessories cabinets in a CNC milling workshop.

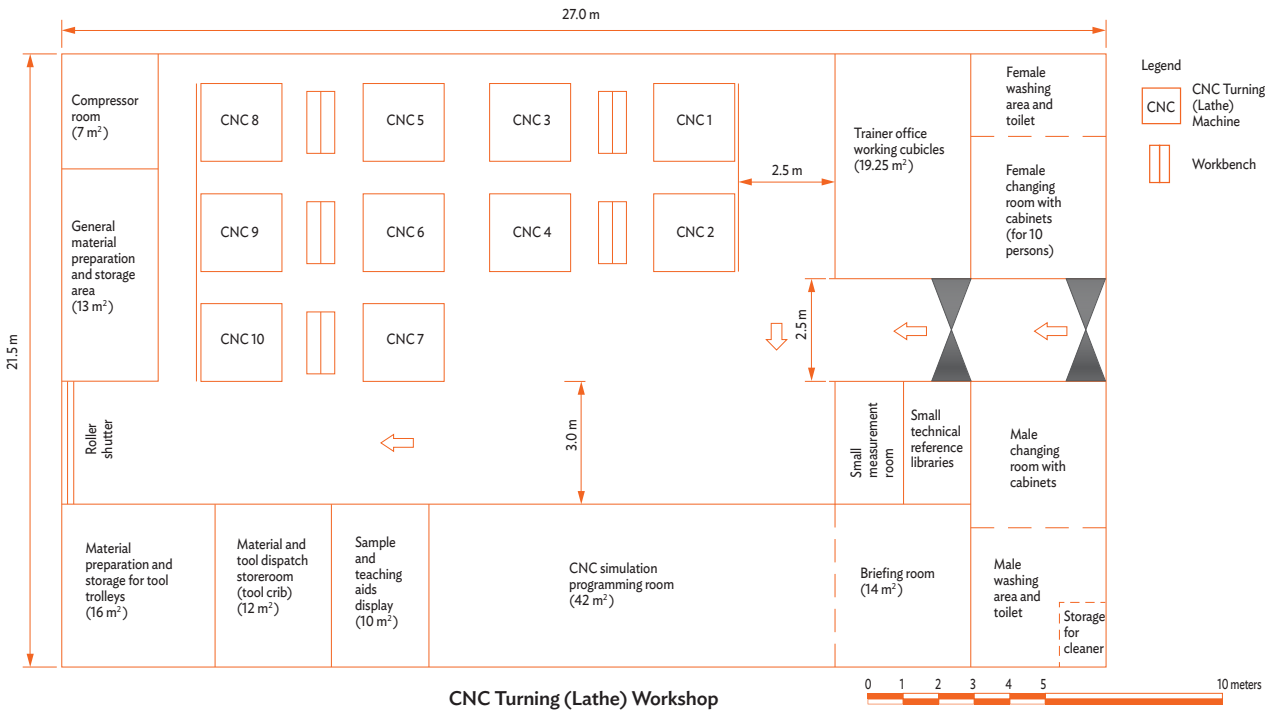
3-in-1 milling machine. Close-up photo of a 3-in-1 milling machine located in manufacturing company.

3.2 CNC TURNING (LATHE) AND CNC SIMULATION TRAINING ROOM

3.2.1 Training Facility Norms

A. WORKSHOP FLOOR PLAN LAYOUT AND SIZE

Figure 5: Computer Numerical Control Turning (Lathe) Workshop Floor Plan



CNC = computer numeric control machine, m= meter, m² = square meter.
Source: Asian Development Bank.

Table 13: Floor Area Requirement for CNC Turning (Lathe) Machine Workshop

S/N	Area	Size (m²)	Remarks
1	CNC milling machine area	220	
2	Compressor room	7	
3	Material preparation and storage (for two trolleys)	16	
4	Material and tool dispatch storeroom	12	
5	Samples and teaching aids display	10	
6	CAD Room	42	
7	Briefing room	14	
8	Small technical reference library	5.25	
9	Small measurement room	5.25	
10	Trainer office working cubicles	19.25	
11	General material preparation and storage room	13	

CAD = computer-aided design, CNC = computer numerical control, m² = square meter.
Source: Asian Development Bank.

B. TECHNICAL SPECIFICATIONS FOR THE WORKSHOP

Table 14: Laboratory and/or Workshop for CNC Turning (Lathe) Machine Workshop

Proposed Student Enrollment Size	**20**
Applicable Field of Usage	**PARTS AND COMPONENTS: AUTOMOTIVE, MEDICAL DEVICE, AEROSPACE, AND ELECTRONICS**

Parameter	Norm	Remarks
Size of Laboratory and/or Workshop	**400 m²**	
Electrical loading requirement	3-phase supply 220V, 60 Hz with voltage stabilizer with surge suppressor in each machine location Each machine: 15 kVA, 60 Amp outlet, total 10 Each workbench: 4 × 13 Amp outlets Wiring type: For machine and workbenches – overhead, for room conceal in wall Type of socket outlet: Universal outlet CNC programing simulation room: 20 × 13 Amp outlets for computers etc. Small measurement room: 6 × 13 Amp outlets Library: 10 × 13 Amp outlets Briefing room: 6 × 13 Amp outlets Display area: 6 × 13 Amp outlets Material and tool dispatch storeroom: 6 × 13 Amp outlets Material preparation and storage room: 6 × 13 Amp outlets Staff office: 10 × 13 Amp outlets General storage area: 5 × 13 Amp outlets Compressor room: 1 × 3-phase and 2 × 15 Amp outlets	
Floor loading requirement	Machine location: 12–15 kN/m², 400 mm deep concrete Others area: 4–6 kN/m²	
Lighting requirement (Lumen)	LED type lighting tube spread above machine and appropriate places in the room • On/off switch: one in each room • Emergency lighting: At emergency exit, along the walking path to the workshop	
Flooring requirement	Machine area: Industrial epoxy paint (hardened type with 2 coatings)	
Location of laboratory and/or workshop (floor)	Ground	
Laboratory and/or workshop climatic condition	Air-conditioned with 5–6 meter of floor to ceiling height If no air-conditioners at machine area, should select big-bladed fan of diameter 4 m–5 m, the height has to be 6–7 meters to the fan base. The ceiling has to be insulated and the air flow has to be good to prevent overheating of the machine	
Building safety code requirement	Local building, safety, and fire code	
Fire fighting equipment	At least 6–8 fire extinguishers	
First aid requirement	Standard first aid box with basic medication installed in a conspicuous position and readily available	
Storage area requirement	28 m²	
Built-in furniture requirement	By design	
Communication	Wired type - LAN cables Wi-Fi router	
Compressor type	Screw type compressor	
Other requirements	Shuttle door opening for machine move-in: minimum 3.5 m wide × 4 m high	

Amp = ampere, CNC = computer numerical control, Hz = hertz, kN = kilonewton, kVA = kilovolt-ampere, m² = square meter, mm = millimeter, LAN = local area network, V = volt.
Source: Asian Development Bank.

3.2.2 Standard Equipment List

Table 15: CNC Turning/Lathe Workshop Equipment Specification

Name of the Laboratory and/or Workshop	**COMPUTER NUMERICAL CONTROL (CNC) LATHE WORKSHOP**
Proposed Student Enrollment Size	**20**
Applicable Field of Usage	**PARTS AND COMPONENTS: AUTOMOTIVE, MEDICAL DEVICE, AEROSPACE, AND ELECTRONICS**

S/N	Name of Item	Description of Item	Quantity	Remarks
A	**Training Equipment and/or Machine: $75,000**			
1	***CNC Lathe***		10 units	Machine Area
a	Travel range	Swing range: 550–600 mm Cutting diameter range: 350–350 mm Cutting length: 300–500 mm		
b	Spindle specification	Spindle noose: A2–6 Spindle motor, minimum: 11/7 kW Maximum spindle speed: 5,000–6,000 rpm Spindle bore, diameter: 60 mm or more		
c	Turret specification	Number of stations: 12 Turning tool shank size × length: 25 × 150 mm Turret indexing time: 0.15–0.2 sec/step		
d	Feed Specification	Rapid traverse rate (X axis): 36 or more m/min Rapid traverse rate (Z axis): 37 or more m/min Feed motor (X/Y axes): 1.5 or more kW		
e	Controller	Programming system: EIA codes Graph display simulation: preferred		
2	***CNC Turning Simulation:* $10,000 for Licenses**			
a	Microcomputer	Configuration suitable to run CNC turning simulator	11 units	CNC Programming Training Room
b	CNC milling simulation software	For students to practice CNC turning programming	11 licenses	
c	LCD projector	4,000 lumens	1	
B	**Tools and Accessories: 30% of Equipment Cost**			
1	Programmable tailstock	MT No. 4		
2	Signal lamp	3 layers		
3	Tool-holder	For external and internal cutter to suit the CNC turret	10 units	
4	Internal threading tool	Insert type	5 units	
5	Reamer	Straight shank 3–4 mm diameter in steps of 1 mm Straight shank 15–22 mm diameter in steps of 1 mm	5 units	
6	Parting tool	Insert type	5	
7	Drill	Counter drill: 3–25 mm diameter Twister drill: 1–13 mm diameter in steps of 0.5 mm Twist drill: 13–23 mm diameter in steps of 0.5 mm U drill: 16 mm diameter U drill: 18 mm diameter U drill (insert type): 20 mm diameter U drill (insert type): 25 mm diameter	5 sets	
8	External grooving tool	Insert type	5 units	

continued on next page

Table 15 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
9	External profiling tool	Insert type	5 units	
10	External roughing tool	Insert type	5 units	
11	External threading tool	Insert type	5 units	
12	Insert	For grooving For parting off For profiling turning For rough turning For threading	50 each	
13	Internal grooving tool	Insert type	5 units	
14	Internal profiling tool	Insert type	5 units	
15	Internal roughing tool	Insert type	5 units	
16	Slot drill	3–20 mm in steps of 1 mm	5	
17	Machine tap	Course tap, M3–M12 in steps of 1 mm Fine tap, M3–M12 in steps of 1 mm	5	
18	Bench work tools	Bench vise with jaw - width: 150 mm, approximately	10 units	
19	Common hand tools	Hand files V-blocks Taps and tap wrenches Tri-square Spring dividers Letter punches and number punches Hammers Hacksaws Scriber	10 sets	
	Measuring Tools			
20	Measuring tools	Caliper • Vernier caliper: 0–150 mm • Dial Vernier caliper: 0–150 mm • Digital Vernier caliper: 0–150 mm	 10 units 5 units 5 units	
21	Gauge	Radius gauge concave and convex Screw pitch gauge round base Surface gauge and ring gauge Dial bore gauge with measuring range of 6–60 mm, reading 0.001 mm with accessories Feeler gauge Vernier height gauge: 300 mm	5 units 5 units 10 units 2 units 20 units 5 units	
22	Indicator	Dial indicator c/w accessories and magnetic stand, range: 0.15 mm, reading: 0.01 mm Dial test indicator c/w accessories and magnetic stand, range: 0–0.8 mm, reading: 0.001 mm	10 units 4 units	
23	Micrometer	Depth micrometer (0.01 mm) Inside micrometer (0.01 mm), caliper type • 5–30 mm • 25–50 mm • 50–75 mm	4 units 10 units 10 units 5 units	
C	**Furniture: $50,000–$70,000**			
1	Wooden workbench	1.5 × 1.2 × 0.8 m, approximately Heavy duty industrial grade workbench: 50 mm	6 units	
2	Heavy duty tool cabinet	1.8 × 1.2 × 1.8 m	2 units	Material Preparation and Storage Room; and Material and Tool Dispatch Storeroom

continued on next page

Table 15 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
3	Tool crib cabinet	0.75 × 0.75 × 1 m	2 units	Material and Tool Dispatch Storeroom
4	Hydraulic table lift	Load capacity 600 kg	1 unit	
5	Trainer table and chair		1 set	
6	Whiteboard	1.5 × 1.0 m double-sided with castor wheels	2 units	CAD/CAM Room and Briefing Room
7	Tool cart and work center	0.7 × 0.37 × 0.84 m	20 units	Material Preparation and Storage Room
8	Automatic tool dispenser	0.875 × 0.62 × 1.2 m	1 unit	(Optional)
9	Tool holder cabinet	Capacity 150 holder slots/cabinet (at tool crib)	2 units	Material Preparation and Storage Room
10	Flip side table and chair; Instructor table and chair		20 units 1 unit	Briefing and Training Room
11	Table and chair for trainer and staff		4 sets	Trainer Office Cubicle
12	Library shelf	According to user's needs	1 unit	Technical Room cum Library
13	Display shelf	According to user's needs	1 unit	Sample and Display Room
14	Granite surface table	Industry grade with stand and levelling devices: 600 × 450 × 130 mm	1 unit	Small Measurement Room
15	Computer tables and chairs		21 sets	CNC Programming Training Room
16	Ceiling-mounted LCD projector with remote switch for main power	4,000 lumens	1 unit	CAD/CAM Room
D	**Start-up, Operating, and Maintenance Consumables**			
1	Oils	SSU 335 at 100°F	6 liters	
2	Lubricants	According to machine maker recommendation		

°F = degree Fahrenheit, CAD = computer-aided design, CAM = computer-aided manufacturing, CNC = computer numerical control, EIA = environmental impact assessment, kg = kilogram, kW = kilowatt, LCD = liquid crystal display, m = meter, min = minute, mm = millimeter, MT = Morse Taper, rpm = revolutions per minute, sec = second, SSU = Sabolt Seconds Universal.
Source: Asian Development Bank.

3.2.3 Sample Photos for CNC Turning (Lathe) Room

CNC turning (lathe) machine. CNC turning (lathe) machine in a CNC turning (lathe) workshop.

CNC turning (lathe) machine. Close-up photo of a CNC turning (lathe) machine in operation.

CNC controller. Close-up photo of a CNC turning (lathe) controller.

Machine tools and accessories cabinet. Sample photo of machine tools and accessories cabinets in a CNC turning (lathe) workshop.

Workbench. Sample workbench with vise.

4 MACHINING CENTER AND METROLOGY LABORATORY

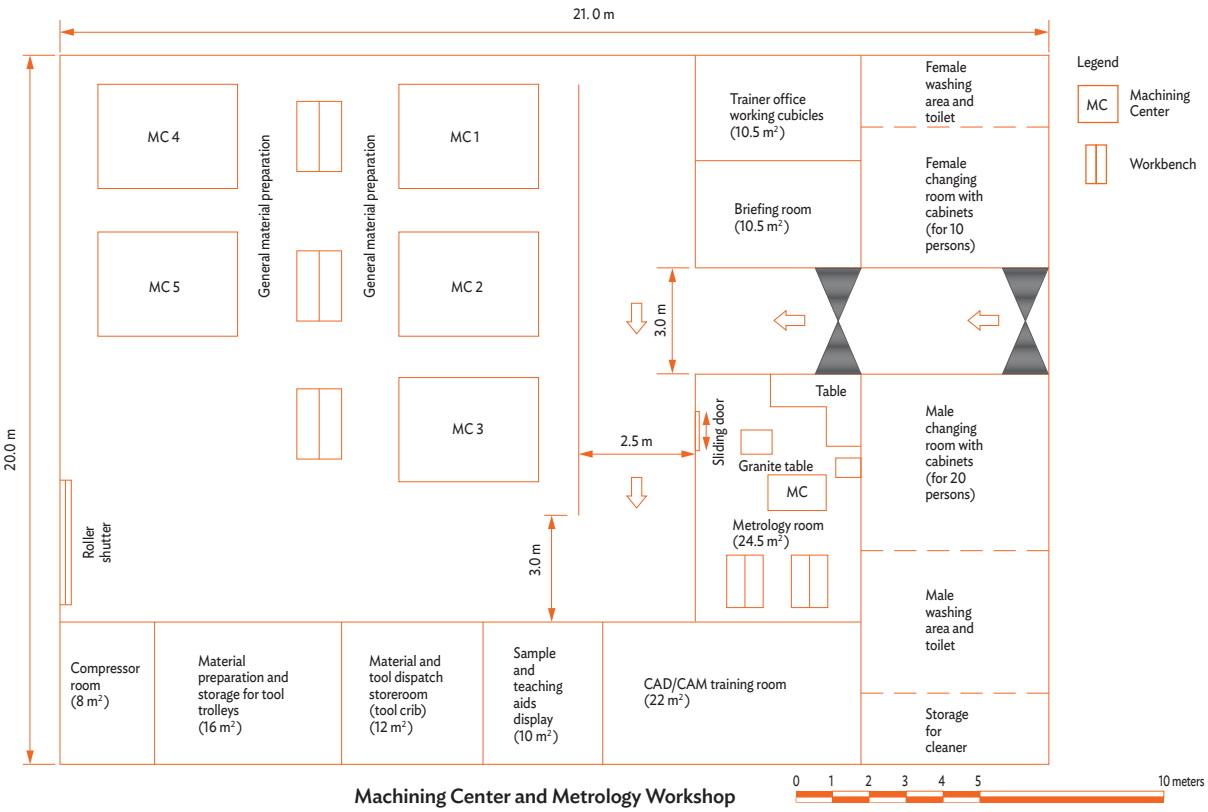
Student in action. Students operate conventional milling machine.

4.1 MACHINING CENTER

4.1.1 Training Facility Norms

A. WORKSHOP FLOOR PLAN LAYOUT AND SIZE

Figure 6: Machining Center and Metrology Laboratory Floor Plan



MC = machining center, m= meter, m² = square meter.
Source: Asian Development Bank.

Table 16: Floor Area Requirement for Machining Center and Metrology Laboratory and/or Workshop

S/N	Area	Size (m²)	Remarks
1	Machining center area	180	
2	Compressor room	8	
3	Material preparation and storage (for tool trolleys)	16	
4	Material and tool dispatch storeroom	12	
5	Samples and teaching aids display	10	
6	CAD/CAM room	22	
7	Briefing room	10.5	
8	Metrology room	24.5	
9	Trainer office working cubicles	10.5	

CAD = computer-aided design, CAM = computer-aided manufacturing, m² = square meter.
Source: Asian Development Bank.

B. TECHNICAL SPECIFICATIONS FOR THE WORKSHOP

Table 17: Machining Center and Metrology Laboratory and/or Workshop

Proposed Student Enrollment Size	**20**
Applicable Field of Usage	**PARTS AND COMPONENTS: AUTOMOTIVE, MEDICAL DEVICE, AEROSPACE, AND ELECTRONICS**

Parameter	Norm	Remarks
Size of Laboratory and/or Workshop	**420 m²**	
Electrical loading requirement	3-phase supply 220V, 60 Hz with voltage stabilizer with surge suppressor in each machine location Vertical machine center: 38 kVA, 60 Amp outlet, total 3 EDM wirecut: 12–15 kVA, 60 Amp outlet, total 2 Each workbench: 4 × 13 Amp outlets Wiring type: For machine and workbenches – overhead, for room–conceal in wall Type of socket outlet: Universal outlet CAD/CAM room: 12 × 13 Amp outlets for computers etc. Metrology room: 10 × 13 Amp outlets Library: 10 × 13 Amp outlets Briefing room: 6 × 13 Amp outlets Display area: 6 × 13 Amp outlets Material and tool dispatch storeroom: 6 × 13 Amp outlets Material preparation and storage area: 6 × 13 Amp outlets Staff office: 10 × 13 Amp outlets Compressor room: 1 × 3-phase and 2 × 15 Amp outlets	
Floor loading requirement	Machine location: 12–15 kN/m², 400 mm deep concrete Others area: 4–6 kN/m²	
Lighting requirement (lumen)	LED type lighting tube spread above machine and appropriate places in the room • On/off switch: one in each room • Emergency lighting: At emergency exits, along the walking path to the workshop	
Flooring requirement	Machine area: Industrial epoxy paint (hardened type with 2 coatings)	
Location of laboratory and/or workshop (floor)	Ground	
Laboratory and/or workshop climatic condition	Air-conditioned	
Building safety code requirement	Local building, safety, and fire code	
Fire fighting equipment	6–8 fire extinguishers	
First aid requirement	Standard first aid box with basic medication installed in a conspicuous position and readily available	
Built-in furniture requirement	According to design	
Communication	Wired type - LAN cables Wi-Fi router	
Compressor type	Screw type compressor	
Other requirements	Shuttle door opening for machine move-in: minimum 3.5 m wide × 4 m high	

Amp = ampere, CAD = computer-aided design, CAM = computer-aided manufacturing, EDM = electrical discharge machining, Hz = hertz, kN/m² = kilonewton per square meter, kVA = kilovolt-ampere, LAN = local-area network, LED = light-emitting diode, m = meter, m² = square meter, V = volts.
Source: Asian Development Bank.

4.1.2 Standard Equipment List

Table 18: Machining Center and Metrology Laboratory and/or Workshop Equipment Specification

Name of the Laboratory and/or Workshop	**MACHINING CENTER AND METROLOGY LABORATORY WORKSHOP**
Proposed Student Enrollment Size	**20**
Applicable Field of Usage	**PARTS AND COMPONENTS: AUTOMOTIVE, MEDICAL DEVICE, AEROSPACE, AND ELECTRONICS**

S/N	Name of Item	Description of Item	Quantity	Remarks
A	**Training Equipment/Machine**			
1	***Machining Center General Specification (Minimum Requirement)***			
a	Travel range: $130,000 each	X axis: 650–700 mm Y axis: 500–550 mm Z axis: 450–460 mm	2 units	Two machine centers with this requirement
b	$180,000 each	X axis: 650–700 mm Y axis: 500–550 mm Z axis: 450–460 mm Z column extension: 150 mm 4th rotary axis NC rotary table: diameter 250 mm	1 units	One machine center with this requirement (for high precision use to manufacture aerospace parts and components)
c	Table specification	Table size: 950 × 500–1000 × 550 mm Maximum table loading: 500–800 mm		
d	Spindle specification	Maximum spindle range: 50–14,000 rpm		
		Spindle taper type: Hsk 63		
		Spindle power and rating at 30 min and continuous: 25/18 Kw (continuous)		
		Design type: Integrated spindle		
e	Automatic tool change	Total storage capacity: 30 tools Maximum tool diameter: 75 mm Maximum tool weight: 8 kg		
f	Feed control	Rapid feed rate: 30 or more m/min Auto feed rate: 0–30 m/min or more		
		Least increment in all axes: 0.001		
		Position display: • Showing work coordinate • Showing machine current position		
g	Air supply system	Pressure: 0.6–0.8 mPa Consumption: 600 L/min		
h	Accuracy	Positioning without feedback scale: within 2.5 µm Repeatability without feedback scale: within 2.0 µm		
i	Engineering specifications	Integral spindle-motor technology Quick acceleration and deceleration Spindle bearing diameter inner/outer: 85 mm/130 mm Good rigidity for better performance Longer spindle life Coolant flow control and chip management: Coolant and chip flush to the back of the machine column Cooling tank capacity: 320 liters Axes guideway type: LM guide, size 45 mm or larger Axis screw cooling technology: By automatic lubricant greasing system Ball screw size: Diameter 45 mm or larger Axis telescopic cover system: Sensor linkage with replaceable wiper Power failure monitoring and brake system Spindle collision prevention devices		

continued on next page

Table 18 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
2	***Wirecut EDM General Specification (Minimum Requirements)***			
a	Travel range: $160,000 each	X axis: 370 mm or more Y axis: 270 mm or more Z axis: 220 mm U axis: +– 50 mm V axis: +– 50 mm	2 units	
b	Table specification	Maximum working area: 630 × 460 mm Maximum workpiece size: 770 × 590 × 220 mm Maximum Table Loading: 600 kg		
c	Wire specification	Wire electrode: diameter 0.01 mm, 0.2 mm, 0.25 mm Automatic wire threading Wire guide: Precision round, Pico grade Maximum taper angle: +/– 15 degress/100 m Dielectric fluid tank capacity: 580 liters		
d	Engineering specifications	Fixed table design Precision table movable cross-bar along X “One click” lower guide removal for maintenance 4-filter arrangement Dual high pressure flush pump, independently digital controlled High energy applied technology for thick work-piece application Dielectric cooling tank as an integrated part of the bed casting Smart controller, with hypercut machining technology, Industry 4.0-compliant Gesture type screen specification like smart phone Antirust technology without adding chemical Power failure recovery system		
3	***Metrology Laboratory General Specification (Minimum Requirements): $125,000***			
a	Coordinate measuring machine	500 × 580 × 500 mm	1 unit	
b	Granite table	Industry grade with stand and levelling devices (600 × 450 × 130 mm)	1 unit	
c	Bench center	Industrial grade	1 unit	
4	***2D and 3D Modelling***			
a	Micro computer	Configuration suitable to run the solid modelling (Parasolid) design software	11 units	
b	2D and 3D modelling software. Parasolid based 2D and 3D	For example: AutoCAD, solid work, Unigraphic	11	Education licenses
B	**Tools and Accessories (Machine Center): 30% of Equipment Cost**			
1	Heavy duty end mill holder	Application: End mills, drills, reamers, and solid taps	3 units	
2	Collet chuck			
3	Face mill arbor	(Diameter 50 and 63 facemill), with 2 inserted carbide	5 units	
4	Drill chuck	Drills and taps	3 units	
5	Straight collet for heavy duty chuck holder	Diameter 12 Diameter 16 Diameter 20 Diameter 25	3 sets	
6	Spring collet for small holder	Diameter 3 Diameter 4 Diameter 6 Diameter 8 Diameter 10	3 sets	
7	Spring collet for large holder	Diameter 10 Diameter 12 Diameter 20	3 sets	
8	Wrench for heavy duty chuck holder		3 units	

continued on next page

Table 18 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
9	Wrench for small chuck holder		3 units	
10	Wrench for large chuck holder		3 units	
11	Pull stud		10 units	
12	Fixture for holder clamp/ unclamp		3 units	
13	Tool pre-setter	Tool length pre-setter for Hsk 63 and BT 40 (combination)	1 unit	
	Tools and Accessories (EDM Wire Cut): 30% of Equipment Cost			
1	Tooling clamping and work holding	Fix base B	4 units	
		Clamping head B–100	2 units	
		Clamping head B–45R	2 units	
		Clamping head B–45L	2 units	
		Clamping head B–70	2 units	
		Clamping head B–62	2 units	
		Zero vise B–100–15	2 units	
2	Energizing plate	Sufficient quantity for 1 year	24 units	
3	Jet nozzle	1.2 mm	6 units	
4	Thermal cutter		5 units	
5	Dielectric fluid filter	Sufficient for 1 year	32 units	
6	Jet filter	Sufficient for 1 year	5 units	
7	De-ionizing resin	(5 liters each) for 6 month	8 units	
8	I-roller		5 units	
9	Felt pad	H axes	20 units	
		I axes		
		B axes	20 units	
		Front	20 units	
		Rear	20 units	
10	Nozzle	upper	10 units	
		lower	10 units	
11	Wire diameter	0.25 mm 5 kg each spool 10 to 12–month supply	20 units	
12	Wire diameter	0.2 mm 5 kg each spool 10 to 12–month supply	20 units	
13	V-guide	Long	6 units	
		Short	6 units	
14	Wire diameter	0.1 mm 3 kg each spool 10 to 12-month supply	6 units	
	Measuring Tools			
15	Caliper	Vernier caliper: 0–150 mm Digital Vernier caliper: 0–150 mm Dial Vernier caliper: 0–150 mm Dial Vernier caliper: 0–50 mm	10 units 10 units 10 units 10 units	
16	Gauge	Radius gauge concave and convex Screw pitch gauge round base	3 units 3 units	
17	Indicator	Dial indicator c/w accessories and magnetic stand, range 0–10 mm, reading 0.01 mm Dial test indicator c/w accessories and magnetic stand, range 0–0.8 mm, reading 0.001 mm	10 units 10 units	

continued on next page

Table 18 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
18	Micrometer	Depth micrometer (0.01 mm) Inside micrometer (0.01 mm), caliper type • 5–30 mm • 25–50 mm • 50–75 mm	 10 units 10 units 10 units	
	Tools and Accessories (Metrology Center): 15% of Metrology Equipment Cost			
1	Optical scope		1 unit	
2	Roundness tester		1 unit	
3	Height gauge		1 unit	
4	Digital Vernier caliper		5 units	
5	Micrometer		5 units	
6	Dial indicator		5 units	
7	Surface roughness center		1 unit	
8	Optical comparator		1 unit	
9	Granite stand		2 units	
C	**Furniture: $50,000–$70,000**			
1	Wooden workbench	1.5 × 1.2 × 0.8 m, approximately	5 units	3 in Machining Area; 2 in Metrology Room
2	Heavy duty tool cabinet	1.8 × 1.2 × 1.8 m	2 units	Material Preparation and Storage Room; Material and Tool Dispatch Storeroom
3	Tool crib cabinet	0.75 × 0.75 × 1 m	2 units	Material and Tool Dispatch Storeroom
4	Hydraulic table lift	Load capacity 600 kg	1 unit	
5	Trainer table and chair		1 set	
6	Whiteboard	1.5 × 1.0 m double- sided with castor wheels	2 units	CAD/CAM Room and Briefing Room
7	Tool cart work center	0.7 × 0.37 × 0.84 m	6 units	Material Preparation and Storage Room
8	Automatic tool dispenser	0.875 × 0.62 × 1.2 m	1 unit	Optional
9	Tool holder cabinet	Capacity 150 holder slots/cabinet (at tool crib)	2 units	Material Preparation and Storage Room
10	Table and chair for trainer and staff		4 sets	Trainer Office cubicle
11	Library shelf	According to user's needs	1 unit	Technical Room cum Library
12	Display shelf	According to user's needs	1 unit	Sample and Display Room
13	Granite surface table	Industry grade with stand and levelling device of 600 × 450 × 130 mm	1 unit	Small Measurement Room
14	Computer tables and chairs		11 sets	CAD/CAM Training Room
15	LCD projector	4,000 lumens	1 unit	CAD/CAM Room

2D = two dimensional, 3D = three dimensional, Amp = ampere, BT = blade turn, CAD = computer-aided design, CAM = computer-aided manufacturing, EDM = electrical discharge machining, Hsk = hollow-shank taper, Hz = hertz, kg = kilogram, kN/m^2 = kilonewton per square meter, kVA = kilovolt-ampere, LAN = local-area network, LCD = liquid crystal display, LED = light-emitting diode, m = meter, m^2 = square meter, mPa = million pascals, m/min = meter/minute, µm = micrometer, V = volts.
Source: Asian Development Bank.

4.1.3 Sample Photos for Machining Center

Machining center. Close-up photo of a machining center.

Tooling cabinet. Proper labeling and arrangement of tools in a tooling cabinet.

Tool holder. Close-up photo of a tool holder.

Machine tools and accessories cabinet. Sample of a machine tools and accessories cabinet in a machining center.

Workbench. Photo of a workbench designed to facilitate group discussion and group work.

Tool trolley. A tool trolley to store machining tools.

REFERENCES

Drummey Rosane Anderson, Inc., J. Macaluso, D. J. Lewek, and B. C. Murphy. 2004. *Building and Renovating Schools: Design, Construction Management, Cost Control*. Rockland: RSMeans.

Government of Australia, Department of Education, Employment and Workplace Relations. 2012. *MEM07006C Perform Lathe Operations*. Canberra.

International Labour Organization. 1978. *Environment Planning Guide for Vocational and Technical Training and Education Programmes. Refrigeration and Air Conditioning*. Geneva.

_____. 1986. *Environment Planning Guide for Vocational and Technical Training and Education Programmes. Learning Stations and Layouts for Workshops. Part 1: Machining/Fitting, Tool and Die Making, Sheet Metal, Automotive, Plumbing/Pipe Fitting, Carpentry/Joinery, Masonry, Refrigeration/Airconditioning*. Geneva.

R. Leach and S. T. Smith. 2018. *Basic of Precision Engineering*. Boca Raton: CRC Press.

National Institute of Building Sciences. 2017. Training Facility. https://www.wbdg.org/building-types/education-facilities/training-facility (accessed 19 September 2018).

A. Pitanilabut. 1979. Guideline for Planning of Facilities for Technical and Vocational Education. Bangkok: UNESCO Regional Office for Education in Asia and Oceania.

K. Schwab. 2016. *The Fourth Industrial Revolution*. Geneva: World Economic Forum.

C. K. Tanner and J. A. Lackney. 2006. *Educational Facilities Planning: Leadership, Architect, and Management*. London: Pearson.

United Nations Educational, Scientific and Cultural Organization (UNESCO). 1979. *Prototype Workshops and Laboratories for Technical Education and Vocational Education. Part 1: Proposed Planning Methods*. Paris.

_____. 1989. *UNESCO's Educational Buildings and Furniture Programme*. Newsletter. Paris.

Training Facility Norms and Standard Equipment Lists

Volume 1—Precision Engineering or Machining

This publication aims to support good practice in establishing facilities for precision engineering training programs. It is the first of four technical specification reference guides on training facility norms and standard equipment lists. This volume includes equipment specifications aligned with current industry standards. Designed for technical and vocational education and training practitioners and policymakers, the series covers the following strategic manufacturing trades: (i) precision engineering or machining, (ii) mechatronics technology, (iii) mechanical technology, and (iv) electrical technology.

About the Asian Development Bank

ADB is committed to achieving a prosperous, inclusive, resilient, and sustainable Asia and the Pacific, while sustaining its efforts to eradicate extreme poverty. Established in 1966, it is owned by 67 members—48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

ADB

ASIAN DEVELOPMENT BANK
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org