Training Facility Norms and Standard Equipment Lists
VOLUME 2

MECHATRONICS TECHNOLOGY

Fook Yen Chong and Raymond Tay

NOVEMBER 2019

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6 ADB Avenue, Mandaluyong City, 1550 Metro Manila, Philippines
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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 industry needs. Education and skills development are often unable to keep up with the pace of technological changes, and TVET systems need to adopt new technologies much faster under the fourth industrial revolution. Recent technological developments in the area of artificial intelligence, the Internet of Things, big data analytics, and machine learning have huge implications for TVET. Constant updating of TVET facilities, instructor competencies, and the training system needs to be accelerated.

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. These specifications are indicative, and should be further contextualized based on the actual needs of the TVET institutions. This volume is the second 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 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.

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, Alfredo P. Garcia and Ma. Cristina S. Bardos, SAHS provided administrative assistance. The authors are also grateful for the cooperation of Nanyang Polytechnic International and ITE Education Services in Singapore for taking photos of their training facilities at their campus.

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

ABBREVIATIONS

ADB	Asian Development Bank
ILO	International Labour Organization
PLC	programmable logic controller
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 has been 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 mechatronics technology 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 of equipment-to-student ratio at 1:1, 1:2 or 1:4 based on best practices in different institutions. Depending on the available budget and how well teachers can adapt to different pedagogical approaches, the equipment-to-student ratio needs to be configured differently.

This reference provides broad guidance and should not be mechanically applied to different settings. Users are strongly encouraged to customize these indicative specifications and guidelines according to industry needs, education requirements, budgetary 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.

1 INTRODUCTION

During 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 mechatronics technology.

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 curriculums 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, Pitaniabut 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.

MECHATRONICS TECHNOLOGY

This volume covers mechatronics technology.² The mechatronics technology field of study provides students with multi-disciplinary and/or inter-disciplinary skills and knowledge (mechanical, electrical, electronics, and information technology) in installing, setting up, commissioning, operating, maintaining, and servicing industrial automated production equipment, line, and systems. It provides an advanced skillset to manage process control in production and quality control. Mechatronics technology is a key field of study for supporting modern industrialization, such as food manufacturing, electronics, electrical, and automotive assembly.

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 precision engineering or machining, mechanical technology, and electrical technology, which are also developed as reference guides of training facility norms and standard equipment lists.

The recent proliferation of Industry 4.0 is closely related to mechatronics technology. Sensor technology, robotics, Internet of Things, big data, and data analytics are key advanced technology aspects that are already integrated with mechatronics technology. The industry trend is moving toward automated production facilities that are Industry 4.0-enriched.

Possible occupations associated with mechatronics technology are automation technician, automated equipment maintenance technician, mechatronics technician, robotic technician, etc.

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 work 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-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 need 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 mechatronics technology. Mechatronics technology is largely divided into three areas: (i) electrical and electronics training facilities; (ii) hydraulics and pneumatic training facilities; and (iii) mechatronics training facilities (modular manufacturing system, programmable logic controller, sensor and vision laboratory). 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 electrical and electronics training facilities by electrical laboratory (section 2.1) as well as electronics laboratory (section 2.2). Section 3 introduces hydraulics and pneumatic training facilities by hydraulics laboratory (section 3.1) and pneumatic laboratory (section 3.2). Section 4 explains the mechatronics training facility requirements on modular and/or flexible manufacturing system. Section 5 describes programmable logic controller, sensor, and vision laboratory and Section 6 explains industrial project laboratory.

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

2 BASIC ELECTRICAL AND ELECTRONICS TRAINING LABORATORY

■ **Training.** Students attend a training in basic electrical installation.

2.1 BASIC ELECTRICAL LABORATORY

■ **Domestic and industrial training unit.**
Students learn electrical installation in a station set up like this one.

2.1.1 Training Facility Norms

A. WORKSHOP FLOOR PLAN LAYOUT AND SIZE

Figure 1: Layout of Basic Electrical Technology Laboratory

Table 1: Floor Area Requirement for Basic Electrical Technology Laboratory

S/N	Item	Quantity	Dimensions	Area
1	Practical learning area	1	9.85 m × 8.3 m	82 m ²
2	Electrical technology trainer units	10	—	—
3	Storage cabinet	3	—	—
4	Theory learning area	1	5.17 m × 8.3 m	43 m ²
5	Teacher's table and chair set	1	—	—
6	Students' chairs and table	20	—	—
7	Ceiling projector	1	—	—
8	Projector screen	1	—	—
9	Whiteboard	1	—	—
10	First aid kit	1	—	—
11	Fire extinguisher	2	—	—
12	Storage cabinet	2	—	—

— = not applicable, m = meter, m² = square meter.

Source: Asian Development Bank.

B. TECHNICAL SPECIFICATIONS FOR THE WORKSHOP

Table 2: Laboratory and/or Workshop for Basic Electrical Technology Laboratory

Name of the Laboratory and/or Workshop	BASIC ELECTRICAL TECHNOLOGY LABORATORY
Proposed Student Enrollment Size	20
Applicable Field of Usage	MECHANICAL TECHNOLOGY, MECHATRONICS TECHNOLOGY

Parameter	Norm	Remarks
Size of Laboratory and/or Workshop	15 m × 8.3 m × 4 m (length × width × height)	
Electrical Loading Requirement	Two 16A twin socket electrical outlet should be provided for each computer 12 16A electrical socket outlet should be provided each for general use in the practical area and theory area All electrical installation should comply with local regulations Two emergency stop-buttons should be provided	
Floor Loading Requirement	350 kg/m ²	
Lighting Requirement (Lumen)	Standard ceiling fluorescent lightings at 25 W/m ² Emergency lights	
Flooring Requirement	Raised flooring to facilitate wire cabling from below floor Vinyl composition to reduce dust and improve electrical insulation	
Location of Laboratory and/or Workshop (Floor)	Any floor	
Laboratory and/or Workshop Climatic Condition	Air-conditioned	
Building Safety Code Requirement	Comply with national safety code requirements	
Door Width	At least 1.5 m wide	
First Aid Requirement	Adhering to building safety code	
Storage Area Requirement	One storage cabinet	
Built-in Furniture Requirement	Not applicable	

A = ampere, kg = kilogram, m = meter, m² = square meter, W = watt.

Source: Asian Development Bank.

2.1.2 Standard Equipment List

Table 3: Basic Electrical Technology Workshop Equipment Specification

Name of the Laboratory and/or Workshop	BASIC ELECTRICAL TECHNOLOGY LABORATORY
Proposed Student Enrollment Size	20
Applicable Field of Usage	MECHATRONICS, ELECTRICAL, AUTOMOTIVE

S/N	Name of Item	Description of Item	Quantity	Remarks
A	Training Equipment and/or Machine: \$150,000			
	Electrical Technology Trainer	<p>Fully assembled electrical control panel includes the following:</p> <p>Push-button - Four push-buttons. A green, yellow, and blue momentary push-button and a red maintained mushroom button. Each button has two normally open contacts and two normally closed contacts. The normally open contacts are color-coded green and the normally closed contacts are color coded red on the back of the trainer.</p> <p>Selector switch 2-position - Two 2-position selector switches. It should have an open contact on each selector switch that closes when you turn the switch to the right (clockwise).</p> <p>Selector switch 3-position - Two 3-position selector switches. There is a normally open contact for both the left and right position of the selector switch.</p> <p>Lights - Four lights colored green, yellow, red, and blue.</p> <p>Analog potentiometer and gauge - 10K potentiometer and a 4 to 20 mA analog gauge.</p> <p>Contact relay - One contactor or relay that is an open style. It is a double-pole double-throw, which means it has two sets of contacts with both normally open and normally closed positions.</p> <p>AC drive - AC inverter drive takes 220 VAC single-phase in and creates 240 VAC 3-phase out so this trainer can be used to learn about 3-phase power yet plugs into a standard wall outlet.</p> <p>24V DC power supply - 24V DC 50-watt switching power supply. The trainer should be designed for all switches, lights, relay or contactor, and even the heater to be powered by 24 V DC to make it safer.</p> <p>3-phase motor and/or fan - 3-phase fan.</p> <p>It along with the AC drive allows for 3-phase principles to be taught when only 220 VAC wall outlet power is available.</p> <p>Heater and thermocouple - 24 V DC heater and type J thermocouple. The preceding relay or contactor can be used to switch the heater on and off</p>	10 units	

continued on next page

Table 3 continued

S/N	Name of Item	Description of Item	Quantity	Remarks
		Thermocouple to 4 to 20 mA converter		
		Terminal blocks		
		Programmable logic controller - CPU with 16 I/O's		
		Control panel types and mounting techniques covers:		
		metallic non-metallic (insulated)		
		direct mounting on insulated panels		
		rear connections		
		DIN mounted switchgear		
		strapped harness wiring use of duct to support and		
		channel wiring clearances		
		Labelling and numbering covers:		
		cable labelling or identification		
		component labelling or identification use of terminal		
		strips to assist fault finding		
		Component layout covers:		
		wiring and schematic diagrams		
		placement or layout of power circuit devices and		
		components		
		placement or layout of control circuit devices and		
		components		
		Interconnecting plugs and sockets		
		Choice of switchgear and control gear covers:		
		voltage ratings		
		current ratings		
		overload and fuse settings		
		number of operations		
		Other considerations include:		
		earthing of panels		
		size of power and control circuit conductors		
		effect of high current devices on electromagnetic		
		components or programmable logic controllers		
		effect on electronic components of other devices		
		Trainers' Training should be provided		
B	Tools			
		Set of pliers	10 sets	
		Set of screw drivers	10 sets	
		Set of wire markers	10 sets	
		Wire strippers	10 sets	
		Digital multi-meter	10 sets	
		Wire crimpers	10 sets	
		Clamp ammeter	10 units	
		Mobile tool trolley	10 units	
		Plastic cable tray 1 m × 1.5" × 1.5"	20 pieces	
C	Furniture			
		Table and chair for the trainer	1 sets	
		Students' tables and chairs	20 sets	
		Mobile whiteboard, 1,000 mm × 1,500 mm	1 unit	
		Screen	1 unit	
		Projector (liquid crystal display)	1 unit	

A = ampere, AC = alternating current, DC = direct current, DIN = Deutsches Institut für Normung (German Institute for Standardization), I/O = input/output, K = shorthand for 1,000 ohms, mA = milliamperes, mm = millimeter, VAC = voltage alternating current, VDC = voltage direct current.

Source: Asian Development Bank.

2.1.3 Sample Photos for Electrical Workstation

■ **Basic electrical laboratory.** Photo shows a close-up shot of a domestic electrical training workstation.

■ **Basic electrical laboratory.** Photo shows another angle of a domestic electrical workstation.

■ **Industrial electrical training workstation.** Photo shows a basic electrical laboratory training set-up for industry application.

2.2 ELECTRONICS LABORATORY

■ **Robotics demo.**
Student demonstrating
robotics project.

2.2.1 Training Facility Norms

A. WORKSHOP FLOOR PLAN LAYOUT AND SIZE

Figure 2: Layout of Electronics Laboratory

Table 4: Floor Area Requirement for Electronics Laboratory

S/N	Item	Quantity	Dimensions	Area
1	Student learning area	1	7.5 m × 13 m	97.5 m ²
2	Electronic workbench	20	—	—
3	Low cabinet	2	—	—
4	Network printer	2	—	—
5	Storage cabinet	2	—	—
6	Steel cabinet	2	—	—
7	Instruction area	1	2 m × 9 m	18.0 m ²
8	Teacher's table and chair set	1	—	—
9	Whiteboard	1	—	—
10	Ceiling overhead projector	1	—	—
11	Projector (liquid crystal display)	1	—	—
12	Fire extinguisher	1	—	—

— = not applicable, m = meter, m² = square meter.

Source: Asian Development Bank.

2.2.2 Standard Equipment List

Table 5: Laboratory and/or Workshop for Electronics Laboratory

Name of the Laboratory and/or Workshop	ELECTRONICS LABORATORY
Proposed Student Enrollment Size	20
Applicable Field of Usage	MECHANICAL TECHNOLOGY AND MECHATRONICS TECHNOLOGY

Parameter	Norm	Remarks
Size of Laboratory and/or Workshop	9.5 m × 13 m × 4 m (length × width × height)	
Electrical Loading Requirement	Two 16A twin-socket electrical outlet should be provided for each electronic workstation 12 16A electrical socket outlet should be provided for general use in the laboratory All electrical installation should comply with local regulations Two emergency stop-buttons should be provided	
Floor Loading Requirement	350 kg/m ²	
Lighting Requirement (Lumen)	Standard ceiling fluorescent lightings at 25 W/m ² Emergency lights	
Flooring Requirement	Raised flooring to facilitate wire cabling from below floor Vinyl composition to reduce dust and improve electrical insulation	
Location of Laboratory and/or Workshop (Floor)	Any floor	
Laboratory and/or Workshop Climatic Condition	Air-conditioned	
Building Safety Code Requirement	Comply with national safety code requirements	
Door Width	At least 1.5 m wide	
First Aid Requirement	Adhering to building safety code	
Storage Area Requirement	One storage cabinet	
Built-in Furniture Requirement	Not applicable	

A = ampere, kg = kilogram, m = meter, m² = square meter, W = watt.

Source: Asian Development Bank.

Source: Asian Development Bank.

2.2.3 Sample Photo for Electronics Laboratory

■ **Electronics training equipment.** Signal generator, power supply, and oscilloscope.

3 HYDRAULICS AND PNEUMATIC TRAINING FACILITIES

■ **Training.** Students attending hydraulic training course.

3.1 HYDRAULICS LABORATORY

■ **Training unit.** Front view of hydraulic training unit complete with air compressor.

3.1.1 Training Facility Norms

A. WORKSHOP FLOOR PLAN LAYOUT AND SIZE

Figure 3: Layout of Hydraulic Laboratory

Table 7: Floor Area Requirement for Hydraulic Laboratory

S/N	Item	Quantity	Dimensions	Area
1	Hydraulic training area	1	14 m × 12 m	168 m ²
2	Hydraulic trainer	5	—	—
3	Carrier	5	—	—
4	Students' theory and computer area for hydraulic design and simulation training	1	10 m × 12 m	120 m ²
5	Instruction area	1	2.5 m × 10 m	25 m ²
6	Whiteboard	1	—	—
7	Ceiling projector	1	—	—
8	Screen	1	—	—
9	Fire extinguisher	1	—	—
10	Teacher's table and chair set	1	—	—

— = not applicable, m = meter, m² = square meter.

Source: Asian Development Bank.

B. TECHNICAL SPECIFICATIONS FOR THE WORKSHOP

Table 8: Laboratory and/or Workshop for Hydraulic Laboratory

Name of the Laboratory and/or Workshop	HYDRAULIC LABORATORY	
Proposed Student Enrollment Size	20	
Applicable Field of Usage	MECHANICAL, MECHATRONICS	

Parameter	Norm	Remarks
Size of Laboratory and/or Workshop	26 m × 12 m × 4 m (length × width × height)	
Electrical Loading Requirement	One 16A twin-socket electrical outlet should be provided for each hydraulic trainer One 16A twin-socket electrical outlet should be provided in each computer table 12 16A electrical socket outlet should be provided for general use in the laboratory All electrical installation should comply with local regulations Two emergency stop-buttons should be provided	
Floor Loading Requirement	350 kg/m ²	
Lighting Requirement (Lumen)	Standard ceiling fluorescent lightings at 25 W/m ² Emergency lights	
Flooring Requirement	Raised flooring to facilitate wire cabling from below floor Vinyl composition to reduce dust and improve electrical insulation	
Location of Laboratory and/or Workshop (Floor)	Any floor	
Laboratory and/or Workshop Climatic Condition	Air-conditioned	
Building Safety Code Requirement	Comply with national safety code requirements	
Door Width	At least 1.5 m wide	
First Aid Requirement	Adhering to building safety code	
Storage Area Requirement	5 carriers for storage of parts and components	
Built-in Furniture Requirement	Not applicable	

A = ampere, kg = kilogram, m = meter, m² = square meter, W = watt.

Source: Asian Development Bank.

3.1.2 Standard Equipment List

Table 9: Hydraulic Laboratory Specification

Name of the Laboratory and/or Workshop		HYDRAULICS LABORATORY		
Proposed Student Enrollment Size		20		
Applicable Field of Usage		MECHANICAL, ELECTRICAL, MECHATRONICS, AND AUTOMOTIVE		
S/N	Name of Item	Description of Item	Quantity	Remarks
A	Training Equipment / Machine: \$1,000,000.00			
1	Basic Hydraulics with Troubleshooting Trainer			
		Pressure relief valve	10 units	
		2-way flow control valve	10 units	
		1-way flow control valve	10 units	
		Non-return valve, lockable	10 units	
		Non-return valve, 6 bars opening pressure	10 units	
		4/2-way hand lever valve, spring return	10 units	
		4/3-way hand lever valve, relieving mid-position, detented	10 units	
		4/3-way hand lever valve, closed mid-position, detented	10 units	
		Shut-off valve	10 units	
		Differential cylinder minimum 16/10/200 with cover	10 units	
		Weight, minimum 8 kg for cylinder	10 units	
		Hydraulic motor	10 units	
		T-distributor	10 units	
		4-way distributor with pressure gauge	20 units	
		Pressure gauge	30 units	
		Flow sensor	10 units	
		Workbook: <i>Hydraulics Basic Level</i>	20 units	
		Shut-off valve, defective	10 units	
		1-way flow control valve, defective	10 units	
		Pressure relief valve, defective	10 units	
		2-way flow control valve, defective	10 units	
		1 × 4/3-way hand lever valve, center position, detented	10 units	
		Flow control valve	10 units	
		Differential cylinder minimum 16/10/200, defective	10 units	
		Hose line with quick release couplings, clogged	10 units	
		Design and simulation software	School license	
		Textbook: <i>Basic Principles of Hydraulics and Electro-Hydraulics</i>	20 units	
2	Advanced Hydraulics Trainer			
		Pressure relief valve, compensated	10 units	
		3-way pressure reducing valve	10 units	
		Flow dividing valve	10 units	
		2/2-way stem actuated valve, convertible	10 units	
		Non-return valve, 6 bars opening pressure	30 units	
		Diaphragm accumulator with shut-off block	10 units	
		Differential cylinder minimum 16/10/200 with cover	10 units	
		Mounting kit for cylinders	10 units	
		T-distributor	10 units	
		Workbook: <i>Hydraulics Advanced Level</i>	20 sets	
		Design and simulation software for advanced hydraulics	School license	To be installed in PC room hydraulic

continued on next page

Table 9 continued

S/N	Name of Item	Description of Item	Quantity	Remarks
3	Basic Electro-Hydraulics Trainer with Supplementary Equipment Set and PLC (Electro-Hydraulics)			
		Pressure relief valve	10 units	
		2-way flow control valve	10 units	
		1-way flow control valve	10 units	
		Non-return valve, 6 bars opening pressure	10 units	
		4/2-way solenoid valve, spring return	20 units	
		4/3-way solenoid valve, closed mid-position	20 units	
		4/2-way double solenoid valve, detented	20 units	
		Shut-off valve	10 units	
		Weight, minimum 8 kg, for cylinder	10 units	
		Differential cylinder minimum 16/10/200 with cover	30 units	
		Mounting kit for cylinders	20 units	
		T-distributor	30 units	
		4-way distributor with pressure gauge	20 units	
		Pressure gauge	20 units	
		Pressure switch, electronic	20 units	
		Relay, three-fold	30 units	
		Signal input, electrical	20 units	
		Limit switch, electrical, left-actuated	20 units	
		Limit switch, electrical, right-actuated	20 units	
		Proximity sensor, electronic	30 units	
		Workbook: <i>Electro-Hydraulics Basic Level</i>	20 sets	
		Design and Simulation Software for Electro-Hydraulics (Ladder Logic)	School license	
		Instruction manual for use of the software simulator (in English)	10 units	
		USB port	10 units	
		Quick-fix screw adapter	10 units	
		Universal connection unit, digital	10 units	
		I/O data cable connectors (IEEE 488), minimum 2 m	10 units	
		Instruction manual for use of the PLC programming software	10 units	
		Compact programmable logic controller	10 units	
		Programming software for the above programmable logic controller	10 units	
		Ethernet cable		
4	Advanced Level Electro-Hydraulics Trainer			
		Time relay, two-fold	10 units	
		Relay, three-fold	20 units	
		Preset counter, electronic	10 units	
		Diaphragm accumulator with shut-off block	10 units	
		Hydraulic motor	10 units	
		4/3-way solenoid valve, relieving mid-position	10 units	
		Proximity sensor, inductive, M12	10 units	
		Emergency stop push-button, electrical	10 units	
		T-distributor	10 units	
		Non-return valve, lockable	10 units	
		Pressure relief valve, compensated	10 units	
		Workbook: <i>Electro-Hydraulics Advanced Level</i>	20 units	
		Design and simulation software for electro-hydraulics advanced level	School license	
		Textbook: <i>Basic Principles of Hydraulics and Electro-hydraulics</i>	20 sets	
	Trainers' Training should be provided			
5	Latest Version of Personal Computer			
		i7 Processor or higher	20 units	
		16 GB RAM		
		1 TB HDD		
		Video card latest specification		
		Latest version OS		
		MS Office Suite		
		Network printer	1 unit	

continued on next page

Table 9 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
B	Tools and Accessories			(Included in Hydraulic Trainer Price)
		Mobile workstation with extruded aluminum profile plate (length × width × height): 1,800 × 800 × 1,080 mm	10 units	
		Hydraulic power unit AC 230 V 50/60 Hz - power pack with AC motors, single-phase and start capacitors - flow rate: 2 × 3.4 liter/min	10 units	
		Protective cover for weight	10 units	
		8 pieces hose line with quick release couplings: 600 mm minimum	10 units	
		4 pcs. hose line with quick release couplings: 1,000 mm minimum	10 units	
		2 pcs. hose line with quick release couplings: 1,500 mm minimum	10 units	
		Digital multi-meter	10 units	
		Power supply unit for mounting frame - input voltage: 230 VAC (50–60 Hz) - Output voltage: 24 V DC, short-circuit-proof - output current: 3 A minimum	10 units	
		Power cable connector as per BS 1363 for Great Britain; Hong Kong, China; Ireland; Malaysia; Singapore; Ukraine; and United Arab Emirates or equivalent to country standard	10 units	
		4 mm safety laboratory cables, 120 pieces, red, blue, and black		
		17 pieces, red 50 mm		
		17 pieces, blue 50 mm		
		8 pieces, black 50 mm		
		8 pieces, red 300 mm		
		8 pieces, blue 300 mm		
		18 pieces, black 300 mm		
		8 pieces, red 500 mm		
		8 pieces, blue 500 mm		
		18 pieces, black 500 mm		
		2 pieces, red 1,000 mm		
		3 pieces, blue 1,000 mm		
		2 pieces, black 1,000 mm		
		1 piece, red 1,500 mm		
		1 piece, blue 1,500 mm		
		1 piece, black 1,500 mm		
C	Furniture			
		Teacher's table and chair set	1 unit	
		Computer table and chair set for students	20 sets	To be installed in PC room hydraulic
		Projector (liquid crystal display)	1 unit	
		Whiteboard	1 unit	
		Projector screen	1 unit	

AC = alternating current, BS = British Standard, GB = gigabyte, HDD = hard disk drive, Hz = hertz, IEEE = Institute of Electrical and Electronics Engineers, I/O = input/output, kg = kilogram, M = metric, min = minute, mm = millimeter, MS = Microsoft, OS = operating system, PC = personal computer, PLC = programmable logic controller, TB = terabyte, V = volt, VAC = voltage in alternating current, VDC = voltage direct current.

Source: Asian Development Bank.

3.1.3 Sample Photo for Hydraulic Laboratory

■ **Air compressor.** Lateral view of hydraulic training unit.

3.2 PNEUMATIC LABORATORY

■ **Pneumatic laboratory.**
Various tools and instruments
for student learning.

3.2.1 Training Facility Norms

A. WORKSHOP FLOOR PLAN LAYOUT AND SIZE

Figure 4: Layout of Pneumatic Laboratory

Table 10: Floor Area Requirement for Pneumatic Laboratory

S/N	Item	Quantity	Dimensions	Area
1	Pneumatic training area	1	14 m × 12 m	168 m ²
2	Pneumatic trainer	5	—	—
3	Carrier	5	—	—
4	Students' theory and computer area for pneumatic design and simulation training	1	10 m × 12 m	120 m ²
5	Instruction area	1	2.5 m × 10 m	25 m ²
6	Whiteboard	1	—	—
7	Ceiling projector	1	—	—
8	Projector screen	1	—	—
9	Fire extinguisher	2	—	—
10	Teachers' table and chair set	1	—	—

— = not applicable, m = meter, m² = square meter.

Source: Asian Development Bank.

B. TECHNICAL SPECIFICATIONS FOR THE WORKSHOP

Table 11: Laboratory and/or Workshop for Pneumatic Laboratory

Name of the Laboratory and/or Workshop	PNEUMATIC LABORATORY
Proposed Student Enrollment Size	20
Applicable Field of Usage	MECHANICAL TECHNOLOGY AND MECHATRONICS TECHNOLOGY

Parameter	Norm	Remarks
Size of Laboratory and/or Workshop	26 m × 12 m × 4 m (length × width × height)	
Electrical Loading Requirement	One 16A twin socket electrical outlet should be provided for each pneumatic trainer 12 16A electrical socket outlets should be provided for general use in the laboratory All electrical installation should comply with local regulations Two emergency stop-buttons should be provided	
Floor Loading Requirement	350 kg/m ²	
Lighting Requirement (Lumen)	Standard ceiling fluorescent lightings at 25 W/m ² Emergency lights	
Flooring Requirement	Raised flooring to facilitate wire cabling from below floor Vinyl composition to reduce dust and improve electrical insulation	
Location of Laboratory and/or Workshop (Floor)	Any floor	
Laboratory and/or Workshop Climatic Condition	Air-conditioned	
Building Safety Code Requirement	Comply with national safety code requirements	
Door Width	At least 1.5 m wide	
First Aid Requirement	Adhering to building safety code	
Storage Area Requirement	Five carriers for storage of parts and components	
Built-in Furniture Requirement	Not applicable	

A = ampere, kg = kilogram, m = meter, m² = square meter, W = watt.

Source: Asian Development Bank.

3.2.2 Standard Equipment List

Table 12: Pneumatic Laboratory Equipment Specification

Name of the Laboratory and/or Workshop	PNEUMATIC LABORATORY
Proposed Student Enrolment Size	20
Applicable Field of Usage	MECHATRONICS, MECHANICAL, AUTOMOTIVE, AND ELECTRICAL

S/N	Name of Item	Description of Item	Quantity	Remarks
A	Training Equipment / Machine: \$500,000.00			
1	Basic Pneumatics with Fault - Tracing Trainer			
		3/2-way valve with push-button actuator, normally closed	20 units	
		3/2-way valve with push-button actuator, normally open	10 units	
		5/2-way valve with selector switch	10 units	
		3/2-way valve with selector switch, normally closed	10 units	
		3/2-way roller lever valve, normally closed	20 units	
		Proximity sensor, pneumatic, with cylinder attachment	20 units	
		Pneumatic timer, normally closed	10 units	
		Pneumatic timer, normally open	10 units	
		Pressure sequence valve	10 units	
		3/2-way valve, pneumatically actuated at one end	10 units	
		5/2-way valve, pneumatically actuated at one end	10 units	
		5/2-way double pilot valve, pneumatically actuated at both ends	30 units	
		Shuttle valve (OR)	10 units	
		Dual-pressure valve (AND)	20 units	
		Quick-exhaust valve	10 units	
		1-way flow control valve	20 units	
		Single-acting cylinder	10 units	
		Double-acting cylinder	10 units	
		Start-up valve with filter control valve	10 units	
		Pressure regulator valve with gauge	10 units	
		Pressure gauge	20 units	
		Manifold	20 units	
		Plastic tubing, 4 mm OD blue 20 m	20 units	
		Double-acting cylinder, defective	10 units	
		Pressure gauge, defective	10 units	
		Filter sleeves for on-off valve with filter regulator, clogged	10 units	
		3/2-way valve with push-button actuator, normally closed, defective	10 units	
		5/2-way bi-stable valve, defective	10 units	
		5/3-way valve, mid-position pressurized	10 units	
		Flow control valve	10 units	
		Silencer M5, clogged	20 units	
		Workbook: <i>Pneumatics Basic Level</i>	20 sets	
		Basic pneumatic design and simulation simulator	School license	
		Textbook: <i>Basic Principles of Pneumatics and Electro-Pneumatics</i>	20 sets	
2	Advanced Pneumatics Trainer			
		3/2-way valve with push-button actuator, normally closed	20 units	
		3/2-way valve with mushroom-head emergency switch, normally open	10 units	
		3/2-way roller lever valve with idle return, normally closed	10 units	
		Back pressure valve	10 units	
		3/2-way valve, pneumatically actuated at one end	40 units	
		5/2-way double pilot valve, pneumatically actuated at both ends	20 units	
		Plastic tubing, 4 mm OD blue 20 m	20 units	
		Shuttle valve (OR)	40 units	

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Table 12 continued

S/N	Name of Item	Description of Item	Quantity	Remarks
		Dual-pressure valve (AND)	30 units	
		Pneumatic timer, normally open	10 units	
		Pneumatic pre-set counter	10 units	
		Stepper unit	10 units	
		1-way flow control valve	20 units	
		Non-return valve, lockable	20 units	
		Double-acting cylinder	20 units	
		Workbook: <i>Pneumatics Advanced Level</i>	20 units	
3	Basic Electro-Pneumatics with Integrated PLC Trainer			
		Signal input, electrical	40 units	
		Relay, three-fold	40 units	
		Timer, DPDT	10 units	
		Electronic counter NPN	10 units	
		Electronic counter PNP	10 units	
		Limit switch, electrical, left-actuated	10 units	
		Limit switch, electrical, right-actuated	10 units	
		Indicator unit and distributor, electrical	10 units	
		Emergency push-button twist and turn	10 units	
		Proximity sensor, inductive, M12	40 units	
		Proximity sensor, capacitive, M12	40 units	
		Proximity sensor, optical, M12	40 units	
		Proximity sensor, electronic, with cylinder mounting	80 units	
		2 × 3/2-way solenoid valve with LED, normally closed	20 units	
		5/2-way solenoid valve with LED	20 units	
		5/2-way double solenoid valve with LED	30 units	
		Valve terminal with 4 valves + 1 spare valve	10 units	
		Pressure sensor with display	10 units	
		1-way flow control valve	40 units	
		Non-return valve	10 units	
		Single-acting cylinder	20 units	
		Double-acting cylinder	40 units	
		On/Off valve with filter control valve	20 units	
		Manifold	20 units	
		Plastic tubing, 4 mm OD blue 20 m	20 units	
		Universal connection unit	20 units	
		Workbook: <i>Programmable Logic Controller Basic Level</i>	20 sets	
		Textbook: <i>Programmable Logic Controller Basic Level</i>	20 sets	
		Instruction manual for use of the software simulator (in English)	10 sets	
		USB connector	10 units	
		Quick-fix screw adapter	10 units	
		Universal connection unit, digital	10 units	
		I/O data cable with connectors (IEEE 488), 3 m minimum	10 units	
		Instruction manual for use of the PLC programming software	20 sets	
		Compact programmable logic controller	10 units	
		Programming software for the above programmable logic controller	School license	
		Ethernet cable	10 units	
		Trainers' Training should be provided		
4	Latest Version of Personal Computer			
		i-7 processor or higher	20 units	
		16 GB RAM		
		1 TB HDD		
		Video card, latest specification		
		Latest version OS		
		MS Office Suite		
	Network Printer		1 unit	

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Table 12 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
B	Tools and Accessories			Price included in Pneumatic Trainers
		Mobile workstation with aluminum profile plate (length × width × height): 1,800 × 800 × 1,080 mm	10 units	
		Low noise compressor, at least 45dB, 230 VAC 50/60 Hz	10 units	
		Power supply unit for mounting frame - input voltage: 230 VAC (50–60 Hz) - output voltage: 24 V DC, short-circuit-proof - output current: max. 4 A	10 units	
		Power cable connector as per BS 1363 for Great Britain; Hong Kong, China; Ireland; Malaysia; Singapore; Ukraine; and United Arab Emirates or equivalent country standard	110 sets	
		4 mm safety laboratory cables, 120 pieces, red, blue, and black		
		17 pieces, red 50 mm		
		17 pieces, blue 50 mm		
		8 pieces, black 50 mm		
		8 pieces, red 300 mm		
		8 pieces, blue 300 mm		
		18 pieces, black 300 mm		
		8 pieces, red 500 mm		
		8 pieces, blue 500 mm		
		18 pieces, black 500 mm		
		2 pieces, red 1,000 mm		
		3 pieces, blue 1,000 mm		
		2 pieces, black 1,000 mm		
		1 pieces, red 1,500 mm		
		1 pieces, blue 1,500 mm		
		1 pieces, black 1,500 mm		
C	Furniture			
		Trainer's table and chair set	1 unit	
		Students table and chair sets	20 sets	PC room for pneumatics simulation training
		Projector (liquid crystal display)	1 unit	
		Screen	1 unit	
		Whiteboard	1 unit	

A = ampere, BS = British Standard, dB = decibel, DPDT = double pole double throw, GB = gigabyte, HDD = hard disk drive, Hz = hertz, IEEE = Institute of Electrical and Electronics Engineers, I/O = input/output, LED = light-emitting diode, M = metric, mm = millimeter, MS = Microsoft, NPN = negative-positive-negative, OD = outside diameter, OS = operating system, PC = personal computer, PLC = programmable logic controller, PNP = positive-negative-positive, Pt = platinum, TB = terabyte, VAC = voltage in alternating current, VDC = voltage direct current.

Source: Asian Development Bank.

3.2.3 Sample Photos for Pneumatic Laboratory

■ **Work station.** Pneumatic training.

■ **Training kit.** Programmable logic control.

■ **Training kits.** Components for programmable logic controller.

4

MECHATRONICS TRAINING FACILITIES

■ **Training in the institute.** Students attend practical class in one of the training facilities.

4.1.1 Training Facility Norms

A. WORKSHOP FLOOR PLAN LAYOUT AND SIZE

Figure 5: Layout of Modular Manufacturing System Laboratory

Table 13: Floor Area Requirement for Modular/Flexible Manufacturing System Laboratory

S/N	Item	Quantity	Dimensions	Area
1	Modular manufacturing system training area	1	10.5 m × 10.0 m	105.0 m ²
2	Network printer	2	—	—
3	Storage cabinet	1	—	—
4	Instructional area	1	6.5 m × 3.0 m	19.5 m ²
5	Trainer's table and chair set	1	—	—
6	Ceiling projector	1	—	—
7	Projector screen	1	—	—
8	Whiteboard	1	—	—
9	First aid kit	1	—	—
10	Fire extinguisher	1	—	—

— = not applicable, m = meter, m² = square meter.

Source: Asian Development Bank.

B. TECHNICAL SPECIFICATIONS FOR THE WORKSHOP

Table 14: Laboratory and/or Workshop for Modular/Flexible Manufacturing System Laboratory

Name of the Laboratory and/or Workshop	MODULAR MANUFACTURING SYSTEM LABORATORY	
Proposed Student Enrollment Size	20	
Applicable Field of Usage	MECHANICAL TECHNOLOGY AND MECHATRONICS TECHNOLOGY	

Parameter	Norm	Remarks
Size of Laboratory and/or Workshop (m ²)	10.5 m × 13 m × 4 m (length × width × height)	
Electrical Loading Requirement	Four 16A twin-socket electrical outlet should be provided for each modular manufacturing system 12 16A electrical socket outlet should be provided for general use in the laboratory All electrical installation should comply with local regulations Two emergency stop-buttons should be provided	
Floor Loading Requirement	350 kg/m ²	
Lighting Requirement (Lumen)	Standard ceiling fluorescent lightings at 25 W/m ² Emergency lights	
Flooring Requirement	Raised flooring to facilitate wire cabling from below floor Vinyl composition to reduce dust and improve electrical insulation	
Location of Laboratory and/or Workshop (Floor)	Any floor	
Laboratory and/or Workshop Climatic Condition	Air-conditioned	
Building Safety Code Requirement	Comply with national safety code requirements	
Door Width	At least 1.5 m wide	
First Aid Requirement	Adhering to building safety code	
Storage Area Requirement	One storage cabinet	
Built-in Furniture Requirement	Not applicable	

A = ampere, kg = kilogram, m = meter, m² = square meter, W = watt.

Source: Asian Development Bank.

4.1.2 Standard Equipment List

Table 15: Modular/Flexible Manufacturing System Laboratory Equipment Specification

Name of the Laboratory and/or Workshop	MODULAR MANUFACTURING SYSTEM WITH ROBOTICS LABORATORY
Proposed Student Enrollment Size	20
Applicable Field of Usage	MECHATRONIC, MECHANICAL, ELECTRONICS, AND ELECTRICAL

S/N	Name of Item	Description of Item	Quantity	Remarks
A	Training Equipment / Machine: \$425,000.00			
1	Modular Manufacturing System with Robotics			
		Modular manufacturing system complete with robotics to include the following stations: Distributing with HMI Robot stations with sub-modules Sorting with HMI Topics Covered: Distributing Conveying Detection Robotics Separating Joining	5 sets	
a	Distributing Station			
		Complete with operator interface technical data Operating pressure: (6 bar) Power supply: 24 V DC Square/round workpiece dimensions: minimum 40 mm 6 digital sensors 4 digital actuators Aluminum profile plate, minimum 700 × 350 mm, with cable guide Conveyor module, minimum 350 × 40 mm, DC Stacking magazine module, without workpiece holder Start-up valve with filter control valve Cable holder with hook-and-loop fastener more than 10 sets C-interface Quick-fix clamping adapter Control console	5 units	
		PLC Trainer CPU 314C-2PN/DP 192 KB RAM for program and data Includes MMC Interfaces: at least three Inputs/outputs: 24 digital inputs (24 V DC); 16 digital outputs (24 V DC, 500 mA) 4 analog inputs, 12 bit, 20 ms, (±10 V, 0–10 V, ±20 mA, 0/4–20 mA), 1 Pt100 input 2 analog outputs, (±10 V, 0–10 V, ±20 mA, 0/4–20 mA) I/O data cable connectors (IEEE 488), minimum 2 m Analog cable, parallel, minimum 2 m Safety laboratory cable, minimum 3 m IEC power cable 90° PC adapter, USB Programming software for above PLC	5 units	School license

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Table 15 continued

S/N	Name of Item	Description of Item	Quantity	Remarks
		Digital simulation box	5 units	
		Light barrier with holder and sleeves	5 units	
		5/2-way single solenoid valve, including minimum 1 m valve cable	5 units	
		Textbook: <i>Basic Principles of Pneumatics and Electro-Pneumatics</i>	20 sets	
		Workbook: <i>Conveyor Module Basic Level</i>	20 sets	
		Design and simulation software for PLC and sensors	School license	
b	Robot Station with Module			
		Technical data:		
		Power supply: 230 VAC, 50/60Hz.		
		Operating pressure: 6 bar		
		Maximum workpiece width: minimum 40 mm		
		12 digital inputs		
		5 digital outputs		
		Trolley height (including castors, to bottom edge of profile plate):		
		minimum 750 mm, width: 700 mm, depth: 700 mm		
		Extruded aluminum profile plate minimum 700 × 700 mm		
		Safety housing minimum 700 × 700 mm complete with the safety door is equipped with a safety switch. Supplied as a kit with detailed assembly instructions.		
		Control console allows simpler operation of the multimedia messaging service with robotics station. Fully assembled with operating panel, communication panels, spare panel, and mounting frame with suitable connector		
		Membrane keyboard: Start push-button with LED, stop push-button, reset push-button with LED, 2 flexibly assignable control lamps		
		4 mm safety sockets with LED status display for simple I/O connection. I/O sub-D sockets for connection to PLC		
		Tabletop power supply unit with below specification:		
		Input voltage: 230 VAC (50–60 Hz)		
		Output voltage: 24 V DC, short-circuit-proof		
		Output current: minimum 4 A		
		Robot handling module technical data as below:		
		Power supply: 24 V DC		
		Maximum workpiece width: minimum 40 mm 2 digital inputs		
		Workpiece set “cylinder bodies”		
		Workpiece set “for cylinder assembly”		
		C interface		
		15-pin D-sub cables: plug connector-plug connector		
		I/O data cable with connectors (IEEE 488)		
		Robot assembly module technical data		
		Operating pressure max: 6 bar		
		Power supply: 24 V DC		
		8 digital inputs		
		3 digital outputs		
		Robot interface box - Add-on for robot station. Up to 16 robot controller I/Os can be distributed to 4 sockets with the Robot interface box. The robot interface box is connected to the robot controller's I/O card via a 50-pin centronics connector. On the front panel are LEDs to display the status of the robot I/Os. On the rear panel are 4 sockets for connection to peripherals		
		Graphical operator terminal - The graphical operator terminal allows the robot to be controlled via an intuitive user interface with touchscreen. All screen content of the high-resolution TFT display with 65536 colors is freely programmable using the supplied PC software. An ethernet connection is used for communication with the robot controller		
		Robot - With teachbox and gripper, pneumatic, high-precision, 6-axis articulated arm robot with gear units and brakes on all axes. Complete with control unit, programming cable, battery set, and a standard hand-held terminal.		

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Table 15 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
		Gripper, pneumatic, pneumatic parallel gripper for mounting on the robot arm - complete with gripper jaws, sensor with fiber-optic cable and accessories		
		Start-up valve with filter control valve filter control valve with pressure gauge and start-up valve mounted on adapter with adjustable angle. The start-up valve pressures and/or exhausts the connected pressure zone. Design: sintered filter with water separator and piston regulator. Flowrate: 120 liters/minute Pressure regulation range: (0,5–10 bar) Grade of filtration: 5 µm Fitting: G 1/8 × 6 mm OD		
c	Sorting Station			
		Sorting station with operator interface		
		General technical data:		
		Operating pressure: 6 bar		
		Power supply: 2 × 24 V DC/minimum 4.0 A		
		Square/round workpiece		
		Dimensions: maximum 40 mm		
		5 digital sensors		
		1 digital actuator		
		Textbook: <i>Fundamentals of Stepper Motor Drive Technology</i>	20 sets	
		Design and simulation software for PLC, motors, electro-pneumatics, and drive	School license	
		Control console	5 units	
		PLC Trainer CPU 314C–2PN/DP	5 units	
		192 KB RAM for program and data includes MMC		
		Interfaces: at least three		
		Inputs/outputs: 24 digital inputs (24 V DC), 16 digital outputs (24 V DC, 500 mA)		
		4 analog inputs, 12 bit, 20 ms, (±10 V, 0–10 V, ±20 mA, 0/4–20 mA), 1 Pt100 input		
		2 analog outputs, (±10 V, 0–10 V, ±20 mA, 0/4–20 mA)		
		I/O data cable with connectors (IEEE 488), minimum 2 m		
		Analog cable, parallel, 2 m		
		Safety laboratory cable, 3 m		
		IEC power cable 90°		
		PC adapter, USB		
		PLC programming software	School license	
		Digital simulation box	5 units	
d	Integrated HMI Module			
		Operator interface	20 units	
		Screen diagonal: 9 inches	(10 for	
		Display: TFT widescreen display, 16 million colors	distributing	
		Resolution: 800 × 480 pixels	and 10 for	
		Control elements: Touch screen 10 keys	sorting)	
		Interfaces: Ethernet for profinet, 1 × USB host, 1 × SD slot		
		Protection rating: IP65		
		Power supply for fast reconnection: Maintenance free energy storage with a capacity of up to 5 minutes		
		Drop test: Withstands the shock of a fall up to 1.2 m		
		Safety technology: F-variant with illuminated stop button, 3-step enabling switch with distinct physical advise		

continued on next page

Table 15 continued

S/N	Name of Item	Description of Item	Quantity	Remarks
		Software specification Configuration software: Win CC comfort Messages: 4,000 Message classes: 32 Process screens: 500 Tags: 2,048 Recipes: 300 Archives: 50 Visual basic scripts: 100 Connection cable for power Connection cable to interface to PLC All accessories to make the complete system fully functional such as power supply. Connectors and HMI stand Trainers' Training should be provided		
B	Tools and Accessories			
		Workpiece set	5 sets	
		Battery set for robot	5 sets	
		Workpiece set "for cylinder assembly"	10 sets (with spares)	
		Programming instructions for robot	5 units	
		Technical manual for robot	5 units	
		Compressor: Screw-type, portable, low-noise, 45 db	5 units	
C	Furniture			
		Trainer's table and chair set	1 unit	
		Students' chairs	20 sets	
		Screen	1 unit	
		Whiteboard	1 unit	
		Projector (liquid crystal display)	1 unit	

A = ampere, CPU = central processing unit, dB = decibel, DC = direct current, DP = display port or decentralized peripherals, HMI = human machine interface, Hz = hertz, IEC = International Electrotechnical Commission, IEEE = Institute of Electrical and Electronics Engineers, I/O = input/output, IP = international protection marking, KB = kilobyte, LED = light-emitting diode, m = meter, mA = milliampere, mm = millimeter, μm = micrometer, MMC = multimedia card, OD = outside diameter, PC = personal computer, PLC = programmable logic controller, PN = profinet, Pt = platinum resistance thermometer, SD = secure digital, TFT = thin-film-transistor, V = volt, VAC = voltage in alternating current, VDC = voltage direct current.

Source: Asian Development Bank.

4.1.3 Sample Photos for Mechatronics Laboratory

■ **Robotics laboratory.** Robotics laboratory for practical training.

■ **Flexible manufacturing system.** Pick-and-place warehousing system.

■ **Flexible manufacturing system.** Sorting station.

■ **Flexible manufacturing system.** Complete set of flexible manufacturing system.

5

PROGRAMMABLE LOGIC CONTROLLER, SENSOR, AND VISION LABORATORY

■ **Industry 4.0 demonstration.** Advanced mechatronics laboratory demonstration.

5.1.1 Training Facility Norms

A. WORKSHOP FLOOR PLAN LAYOUT AND SIZE

Figure 6: Layout of Programmable Logic Controller, Sensor, and Vision Laboratory

Table 16: Floor Area Requirement for Programmable Logic Controller, Sensor, and Vision Laboratory

S/N	Item	Quantity	Dimensions	Area
1	Student learning area	1	8.2 m × 10 m	82 m ²
2	Students' workbench with chair	10 or 20	—	—
3	Storage cabinet	5	—	—
4	Instruction area	1	1.8 m × 10 m	18 m ²
5	Teacher's table and chair set	1	—	—
6	Ceiling projector	1	—	—
7	Whiteboard	1	—	—
8	Projector screen	1	—	—
9	Fire extinguisher	1	—	—
10	Network printer	1	—	—

— = not applicable, m = meter, m² = square meter.

Source: Asian Development Bank.

B. TECHNICAL SPECIFICATIONS FOR THE WORKSHOP

Table 17: Laboratory and/or Workshop for Programmable Logic Controller, Sensor, and Vision Laboratory

Name of the Laboratory and/or Workshop	PROGRAMMABLE LOGIC CONTROLLER, SENSOR, AND VISION LABORATORY
Proposed Student Enrollment Size	20
Applicable Field of Usage	MECHANICAL TECHNOLOGY, MECHATRONICS TECHNOLOGY

Parameter	Norm	Remarks
Size of Laboratory and/or Workshop	10 m × 10 m × 4 m (length × width × height)	
Electrical Loading Requirement	Two 16A twin socket electrical outlet should be provided for each computer table 12 16A electrical socket outlets should be provided for general use in the laboratory All electrical installation should comply with local regulations Two emergency stop-buttons should be provided	
Floor Loading Requirement	350 kg/m ²	
Lighting Requirement (Lumen)	Standard ceiling fluorescent lightings at 25 W/m ² Emergency lights	
Flooring Requirement	Raised flooring to facilitate wire cabling from below floor Vinyl composition to reduce dust and improve electrical insulation	
Location of Laboratory and/or Workshop (Floor)	Any floor	
Laboratory and/or Workshop Climatic Condition	Air-conditioned	
Building Safety Code Requirement	Comply with national safety code requirements	
Door Width	At least 1.5 m wide	
First Aid Requirement	Adhering to building safety code	
Storage Area Requirement	Five storage cabinet	
Built-in Furniture Requirement	Not applicable	

A = ampere, kg = kilogram, m = meter, m² = square meter, W = watt.

Source: Asian Development Bank.

5.1.2 Standard Equipment List

Table 18: Programmable Logic Controller, Sensor, and Vision Laboratory Equipment Specification

Name of the Laboratory and/or Workshop		PROGRAMMABLE LOGIC CONTROLLER, SENSOR, AND VISION LABORATORY		
Proposed Student Enrollment Size		20		
Applicable Field of Usage:		MECHATRONICS, ELECTRONICS, ELECTRICAL		

S/N	Name of Item	Description of Item	Quantity	Remarks
A	Training Equipment / Machine: \$600,000.00			
1	PLC Trainer	Modular programmable logic controller with universal analog input and analog output interface cards module, digital output module, and digital input module Modular architecture for future expansion (analog, fieldbus) Program capacity of up to 3 MB/ 60 k steps Retentive data memory capacity up to 0.5 MB Support up to 2,560 I/O points Able to process floating point instruction within 0.86 microseconds Built in USB port × 1 Built-in ethernet/IP port × 1 Tag data links (program-less data exchange) CIP message communication functions Socket services FTP server FTP client Automatic clock synchronization SNMP agent Data base connection function for Internet of Things Microsoft corporation: SQL Server 2008/2008 R2/2012/2014 Oracle corporation: Oracle database 10g /11g /12c MySQL community edition 5.1/5.5/5.6 IBM: DB2 for Linux, UNIX and Windows 9.5/9.7/10.1/10.5 Firebird foundation incorporated: Firebird 2.1/2.5 The PostgreSQL Global Development Group: PostgreSQL 9.2/9.3/9.4 Built-in ethercat port × 1 (For connection to inverters or servo drives) OLE for process control connectivity Support ethercat communication for distributed I/O control Support ladder program, structured text, and function block programming Available function block libraries for communication such as MODBus, TCP/IP Socket, etc.		
a	Analog to Digital Converter Module	To be connected to PLC CPU communication bus directly 4 analog inputs Separate configuration for individual inputs Fully universal inputs: Pt100 JPt 100 Pt 1,000 Type K, J, T, L, R, S, or B thermocouple 4 to 20 mA 0 to 20 mA 1 to 5 V/0 to 5 V/0 to 10 V	20 sets	

continued on next page

Table 18 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
		Accuracy: Platinum resistance thermometer input: $\pm 0.3\%$ of PV or $\pm 0.8^\circ\text{C}$, whichever is larger) ± 1 digit max. Thermocouple input: ($\pm 0.3\%$ of PV or $\pm 1.5^\circ\text{C}$, whichever is larger) ± 1 digit max. Voltage or current input: $\pm 0.3\%$ of F.S. ± 1 digit max. Conversion speed of 250 ms/4 inputs		
b	Digital to Analog Converter Module	To be connected to PLC CPU communication bus directly 4 analog outputs Separate configuration for individual outputs Support analogue signal 4 to 20 mA 0 to 20 mA 1 to 5 V 0 to 10V -10 to 10V Resolution: Up to 1/4,000 conversion period: Up to 250 μs /point	20 sets	
c	Digital Output Module	To be connected to PLC CPU 16 relay contact outputs Maximum switching capacity: 250 VAC/ 24VDC, 2A	20 sets	
d	Digital Input Module	To be connected to PLC CPU 16 Inputs Input voltage: 24 VDC Input current: 10 mA PLC stand The PLC must be mounted onto a standing platform and/or panel The platform should be tilted at an appropriate angle to allow ease of wiring The platform should come with necessary wiring to power up the PLC The platform should come with 24 VDC power supply The 24 VDC power supply should be DIN mounted, with finger guards on the wiring terminals The 24 VDC power supply should not have metal coverings The I/Os of the PLC are to be connected to a terminal block system The terminal block system should be in such a way that 24 VDC power is available at individual digital input and output point Isolation switch must be individual analog input and output Trainers' Training should be provided	20 sets 20 units	
2	Sensor Trainer	Photo electric sensors Proximity sensors Capacitive sensor Strain gauges / load cell Pressure sensor Temperature sensors (RTD, thermocouple) Accelerometer	20 units	
3	Vision System Trainer	High speed controller with integrated LCD, with 1 camera, PNP output, digital CCD/CMOS camera, 5 million pixels, color, image Read time: 38.2 ms	10 units	

continued on next page

Table 18 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
B	Tools and Accessories			
		Bend resistant camera cable 5 m	10 pieces	
		LED monitor cable	10 pieces	
		Parallel I/O cable for connector-terminal conversion unit	10 pieces	
		Connector-terminal block conversion units can be connected		
		Connector-terminal block conversion units, general-purpose devices	10 pieces	
		Desktop controller stand	10 units	
		For installing the LCD integrated-type and attachment		
		Switch hubs ethernet IP	10 units	
		External lighting	10 pieces	
		Lighting controller	10 units	
		Vibrations and shock resistance C mount lens	10 units	
C	Furniture			
		Trainer's table and chair set	1 set	
		Whiteboard 1,500 × 1,000 mm double-sided with castors	1 unit	
		Working table	10 units	
		LCD projector	1 unit	
		Screen	1 unit	

A = ampere, CCD/CMOS = charge-coupled device/complimentary metal-oxide semi-conductor, CIP = common industrial protocol, CPU = central processing unit, DIN = Deutsches Institut fur Normung (German Institute for Standardization), FTP = file transfer protocol, FS = full scale, IBM = International Business Machines, I/O = input/output, IP = internet protocol, JPt = Japan Industrial Standard (JIS) for Platinum Resistance Thermometer, LCD = liquid crystal display, LED = light-emitting diode, m = meter, mA = milliampere, MB = megabyte, ms = millisecond, μ m = micrometer, OLE = object linking and embedding, PLC = programmable logic controller, PNP = positive-negative-positive, Pt = platinum resistance thermometer, PV = present value, RTD = resistance temperature detector, SNMP = simple network management protocol, SQL = standardized query language, TCP/IP = transmission control protocol/internet protocol, UNIX = uniplexed information and computing system, V = volt, VAC = voltage in alternating current, VDC = voltage direct current.

Source: Asian Development Bank.

5.1.3 Sample Photos of Programmable Logic Controller, Sensor, and Vision Laboratory

■ **Program logic control.** Training unit.

■ **Sensor and control.** High-speed process station.

■ **Computer vision.** Training unit.

■ **Modular trainer.** Programmable logic sensor.

6 INDUSTRIAL PROJECT LABORATORY

Robotics. Students demonstrating an industrial project.

6.1.1 Training Facility Norms

A. WORKSHOP FLOOR PLAN LAYOUT AND SIZE

Figure 7: Layout of Industrial Project Laboratory

Table 19: Floor Area Requirement for Industrial Project Laboratory

S/N	Item	Quantity	Dimensions	Area
1	Project work area	1	23.7 m × 15.3 m	362.6 m ²
2	Fitter workbench	20	—	—
3	Machine assembly project	10	—	—
4	Mill machine	2	—	—
5	Turn machine	2	—	—
6	Surface grinder	4	—	—
7	Drill machine and pedestal grinder	4	—	—
8	Discussion area	1	3.6 m × 7.1 m	25.6 m ²
9	Tables and chairs	12	—	—
10	Flip charts	2	—	—
11	3-D manufacturing room	1	3.6 m × 7.1 m	25.6 m ²
12	3-D printer	2	—	—
13	Tables, chairs, and computer	6	—	—
14	Storage area	1	8.1 m × 7.1 m	57.5 m ²
15	Tools crib	6	—	—
16	Storage cabinet	6	—	—
17	Storage shelves (floor-to-ceiling)	1	—	—
18	Fire extinguishers	8	—	—

— = not applicable, m = meter, m² = square meter.

Source: Asian Development Bank.

B. TECHNICAL SPECIFICATIONS FOR THE WORKSHOP

Table 20: Laboratory and/or Workshop for Industrial Project Laboratory

Name of the Laboratory and/or Workshop	INDUSTRIAL PROJECT LABORATORY
Proposed Student Enrollment Size	20
Applicable Field of Usage	MECHANICAL TECHNOLOGY; MECHATRONICS TECHNOLOGY

Parameter	Norm	Remarks
Size of Laboratory and/or Workshop	23.7 m × 15.3 m × 6 m (length × width × height)	
Electrical Loading Requirement	3-phase power supply for conventional mill, turn, grinder Each mill, turn, grind 15 KVA and each machine assembly project station 2 KVA Two 16A twin socket electrical outlet should be provided for each assembly machine project station 20 16A electrical socket outlet should be provided for general use in the workshop, 6 in discussion room, 6 in 3-D printing room All electrical installation should comply with local regulations Three emergency stop-buttons should be provided	
Floor Requirement	Project work and storage area: 12 KN 300 mm concrete 2 coats epoxy industrial paint Discussion and 3-D printing room Raised floor at least 350 kg/m ² Vinyl composition to reduce dust and improve electrical insulation	
Lighting Requirement (Lumen)	Standard ceiling fluorescent lightings at 25 W/m ² Emergency lights	
Location of Laboratory and/or Workshop (Floor)	Any floor	
Laboratory and/or Workshop Climatic Condition	Air-conditioned	
Building Safety Code Requirement	Comply with national safety code requirements	
Door Width	At least 1.5 m wide	
First Aid Requirement	Adhering to building safety code	
Storage Area Requirement	One storage room	
Built-in Furniture Requirement	Floor-to-ceiling shelves	

A = ampere, D = dimensional, kg/m² = kilogram per square meter, KN = kilonewton, kVA = kilo volt ampere, m = meter, mm = millimeter, W/m² = watt per square meter.

Source: Asian Development Bank.

6.1.2 Standard Equipment List

Table 21: Industrial Project Laboratory Equipment Specification

Name of the Laboratory and/or Workshop	INDUSTRIAL PROJECT WORKSHOP
Proposed Student Enrollment Size	20
Applicable Field of Usage:	MECHANICAL, MECHATRONIC, ELECTRICAL

S/N	Name of Item	Description of Item	Quantity	Remarks
A	Training Equipment / Machine: \$ 200,000.00			
1	Machine Assembly Project		10 sets	
		<p>Workbench: (length × width × height) 1,800 × 700 × 825 mm</p> <p>Mechanical drive mechanism – Synchronous belt, chain, gear, rack, worm, crank, connecting rod, cam, groove wheel, friction wheel, ball screw and other transmission mechanism</p> <p>Control system – Compact and portable hybrid measuring and testing system</p> <p>Multiple-speed gearbox, dual 3-speed output, one output shaft with a positive function, at the top of the organic glass door. It mainly consists of box, gear, spline shaft, spacer sleeve, key, angular contact bearing, deep groove ball bearing, circlip, end cover, manual shift mechanism</p> <p>2-dimensional worktable – Linear guide pair, ball screw pair, for installation and adjustment of related bearings, and application of related measuring tools</p> <p>Decelerator: it mainly consists of spur gear, angular contact bearing, deep groove ball bearing, bracket, shaft, end cover, key</p> <p>Intermittent rotary table four groove – Geneva mechanism, worm gear worm, friction wheel, thrust ball bearing, angular contact bearing, tabletop, bracket</p> <p>Crank connecting rod and cam mechanism crank, connecting rod, cam, gear, rack, coupling, bearing seat, bearing, shield, guide rod, stay rod, rail</p> <p>Simulation software for mechanical assembly and adjustment divided into 2 parts: manual assembly part and assembly video demonstration part</p> <p>Three shaft gear decelerator – Spur gear, bevel gear, angular contact bearings, deep groove ball bearing, bracket, shaft, end cover, keys, right angle distributor of single bevel gear chain wheel, bevel gear and gear shaft three piece</p> <p>Power supply, AC motor, speed regulator and power control box, to provide power source for mechanical system</p> <p>Trainers' Training should be provided</p>		
2	Fitter Workbench: \$ 100,000.00			
		Workbench: (length × width × height) 1,500 × 750 × 800 mm	20 units	
		Bench vise: 5 inch	20 units	
		Hacksaw	20 units	
		Circle file: 8–12 inch	20 units	
		Semi-circle file: 8–12 inch	20 units	
		Square file: 8–12 inch	20 units	
		Diamond file: 8–12 inch	20 units	
		Angle file: 8–12 inch	20 units	
		Surface plane: 300 × 400 mm	20 units	
		Hammer	20 units	
		Try square	20 units	
		Steel rule: 150	20 units	

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Table 21 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
		Vernier caliper	20 units	
		Screw tape: M6, 8, 10, 12, 14	20 units	
		Monkey wrench: 10	20 units	
		Hacksaw blade	50 units	
		Straight screwdriver	20 units	
		Cross screwdriver	20 units	
		Tap wrench	20 units	
		Die wrench	20 units	
		Nipper plier	20 units	
		Wire brush	20 units	
3	Lathe Machine with Digital Display		2 units	
	Travel Range	Swing over bed range: 450–470 mm Swing over cross slide: 280–300 mm Distance between center: 1,500 mm		
		Tailstock travel: 150–170 mm Tailstock spindle taper: MT no.4 Feed specification: Longitudinal feed (Z axis): 0.06–0.88 mm/rev Cross feed (X axis): 0.03–0.44 mm/rev Feed motor (X / Z axes): 1.5kW or more		
4	Vertical Milling Machine with Digital Display General Specifications (minimum requirements): \$ 60,000.00		2 units	
	Travel Range	X axis, table: 750 mm Y axis, cross: 380 mm Z axis, vertical knee travel: 380 mm		
	Table Specification	Table size: 1,300 × 300 mm Table loading: 200 kg T slot: 16 mm		
	Ram Specification	Ram travel: 500–600 mm Ram swivel: 360°		
	Spindle Specification	Spindle power: 3.75 kW Spindle speed: 3,500 rpm Spindle taper: NT 40 Quill travel: 140 mm Quill auto feed: 0.035, 0.07, 0.14 Head tilt: +/- 45°		
	Engineering Specification			
		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		
5	Surface Grinding Machine with Digital Display General Specifications (minimum requirements): \$ 50,000.00		2 units	
	Travel Range	X axis (longitudinal): 500–600 mm Y axis (crosswise): 200–220 mm Max grinding area: 500 × 100 mm		
	Table Specification	Size: 200 × 500 mm Longitudinal feed rate: 0.1–20 m/min Maximum table loading: 100 kg		
	Hydraulic Pump	0.75 kW (min)		

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Table 21 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
	Spindle Motor	Speed: 50Hz/2,850 rpm Power: 2 HP/1.5 kW		
	Standard Grinding Wheel	Wheel size: 205 mm (diameter) × 6 mm (width) × 31.75 mm (bore)		
	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 complete with coolant tank		
6	Bench Grinder: \$ 1,400.00 1.5 kW, Voltage 220, Wheel Size: 200 × 25 × 32 mm		4 units	
7	3-D Printer: \$ 9,000.00		2 units	
	Printer and Printing Properties	Technology: Fused filament fabrication Print head: Dual nozzle, with lifting mechanism on 2nd nozzle Easily swappable print cores Build volume: Left nozzle: 215 × 215 × 200 mm Right nozzle: 215 × 215 × 200 mm Dual material: 197 × 215 × 200 mm Filament diameter: 2.85 mm Layer resolution: 0.4 mm Nozzle: 20–200 micron Step accuracy X, Y, Z: 12.5, 12.5, 2.5 micron Print head travel speed: 30–300 mm/s Material flow speed: 0.40: up to 16 mm ³ /s Build plate: Heated glass bed Material types: PLA, PVA, ABS, CPE, nylon Nozzle diameter: 0.4 mm Nozzle temperature: 180–280 °C Build plate temperature: 20–100 °C Nozzle heat up time: < 2 min Build plate heat-up time: < 4 min (20 – > 60 °C) Average operation noise: 50 dBA Nozzle replacement: Easily swappable print cores Filament storage: Open, reel holder including guide for 2 spools of 750 g NFC system to automatically detect material type Connectivity: Wi-Fi, ethernet, stand-alone via USB-drive Bed levelling: Active leveling Camera: Yes Input: 100–240V, 4 A, 50–60 Hz, 221 W maximum Output: 24 V DC, 9.2 A Software: File types: Print direct from Cura via network, stand-alone File transfer: USB drive printing		
8	Latest Version of Personal Computer	i-7 Processor or higher 16 GB RAM 1 TB HDD Video Card latest specification Latest version OS MS Office Suite	6 sets	
	Network Printer		1 unit	

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Table 21 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
B	Tools and Accessories			
1	Machine Assembly Project			
		Assembly and adjustment tools fitter assembly kit, vise, crossed plate, lamar and copper. The kit is mainly consisted of the toolbox, inner six angle wrench, spanner, adjustable wrench, file, compasses, hammer, die, die frame, screwdriver, and pliers	10 sets	
		Measuring instrument: consists of vernier caliper, universal angle ruler, square, dial gauge, and micro-meter	10 sets	
2	Milling			
	Stub Milling Arbor	Diameter × length: 16 × 25 mm	2 units	
		Diameter × length: 22 × 25 mm	2 units	
		Diameter × length: 27 × 25 mm	2 units	
		Diameter × length: 32 × 25 mm	2 units	
	Collet Chuck		2 units	
	Conical Type Collet for Chuck Holders	Diameter: 5 mm	2 units	
		Diameter: 6 mm	2 units	
		Diameter: 8 mm	2 units	
		Diameter: 12 mm	2 units	
		Diameter: 16 mm	2 units	
		Diameter: 20 mm	2 units	
	Drill Chuck		2 units	
	Wrench for Chuck Holder		2 units	
	Fixture for Holder Clamp or Unclamp		2 units	
	Parallel Bar	Parallel bar size: 5 × 10 × 100 mm	4 units	
		Parallel bar size: 10 × 20 × 150 mm	4 units	
		Parallel bar size: 15 × 30 × 150 mm	4 units	
		Parallel bar size: 20 × 40 × 200 mm	4 units	
	Rotary Table	Diameter: 300 mm complete with mounting accessories	2 units	
	Hydraulic Vice Swivel Base	Jaw width: 100 mm complete with mounting accessories	2 units	
	Hydraulic Vice Swivel, Tilt, and Swivel	Jaw width: 100 mm complete with mounting accessories	2 units	
	Cutting Tools	Angular cutter: 90° double equal angle	2 units	
		Twist drill: 1–13 mm diameter	2 units	
		Twist drill: 13.5–23 mm diameter	2 units	
		End mills diameter: 50 mm	2 units	
		Face mill diameter: 50 mm	2 units	
		Gear cutter, pressure angle: 20°, module 3 reamer (taper shank)	2 units	
		Taper shank: 3–14 mm diameter in steps of 1 mm	2 units	
		Shell end mill diameter: 50 mm	2 units	
		Sitting saw diameter: 1.25–3 mm	2 units	
		Slot drills diameter: 3–20 mm	2 units	
		Dovetail cutter 60° diameter 25 mm	2 units	
		T-slot cutter diameter 22 × 8 mm	4 units	
	Splash Guard	Front and rear	2 units	

continued on next page

Table 21 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
3	Grinding Machine			
	Wheel Balancing Unit	Complete with accessories	2 units	
	Creep Feed Grinding Wheel	For steel roughing and finishing	2 units	
	Machine Vices	Opening: 80 mm	2 units	
	Permanent Magnet Table		2 units	
	Compound Angle Vice	Opening: 60 mm	2 units	
	Cleaning Tower with Stand		2 units	
	Tower Rolls		2 units	
	Grinding Wheels	Selection of grinding wheels AB60L8V	2 units	
	Sine Plate	Magnetic type - 10 (L = 170, B = 100, angle adjust up to 60°) Non-magnetic type - 5	2 units 2 units	
	Surface Grinder Dresser		2 units	
	Bench Work Tools	Bench vice with jaw width: 150 mm, approximately	2 units	
4	Lathe			
	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	2 units 2 units 2 units	
	Dog Carriers	Range 10–50 mm	2 units	
	Driving Plate		2 units	
	Center	Dead center Live center Revolving center Half center	2 units 2 units 2 units 2 units	
	Chuck	Drill chuck, keyless - clamping range up to 13 mm diameter Four-jaw chuck Three-jaw self-centering chuck	2 units 2 units 2 units	
	Chuck Guard		2 units	
	Splash Guard	Front and rear	2 units	
	Set of Collets	15 pieces (5 mm to 20 mm in step of 1 mm) Collet holders	2 units 2 units	
	Knurling Tool	Self-centering with 3 grades of diamond knurl Straight knurl	2 units 2 units	
	Test Bar		2 units	
	Tool Holder	Straight turning tool holder Right-hand turning tool holder Left-hand turning tool holder Inserts turning tool holder Parting off tool holder	2 units	
	Quick Change Tool Post	4-way	2 units	

continued on next page

Table 21 *continued*

S/N	Name of Item	Description of Item	Quantity	Remarks
5	Pedestal Grinder with Grinding Wheel: Diameter 200 mm, Approximately		2 units	
6	Bench Drilling Machine			
	Specification	Minimum capacity: 13 mm diameter Table size: 240 × 240 mm, approximately	4 units	
	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 units 2 units	
	Drill Sleeve	MT 1–2 MT 1–3 MT 2–3	2 units 2 units 2 units	
	Reamer Taper Shank		2 units	
	Mandrel	16–30 mm diameter	2 units	
	Workbench Tools	Bench vise with jaw: width 150 mm, approximately	2 units	
C	Furniture: Table and Chair Sets		12 units	
		Teacher's table and chair set	1 set	
		Storage shelf	1 unit	
		Storage cabinet	6 units	
		Flip chart	2 units	

A = ampere, ABS = acrylonitrile butadiene styrene, AC = alternating current, B = breadth, °C = Celsius, CPE = chlorinated polyethylene, dBA = a-weighted decibels, g = gram, GB = gigabyte, HDD = hard disk drive, HP = horsepower, HSS = high speed steel, Hz = Hertz, kg = kilogram, kW = kilowatt, L = length, m = meter, M = metric, mm = millimeter, mm/s = millimeter per second, mm³/s = cubic millimeter per second, MS = Microsoft, MT = Morse taper, NT = National Machine Tool Builder Association, OS = operating system, PLA = polylactic acid, PVA = polyvinyl acetate, rpm = revolution per minute, TB = terabyte, V = volt, VDC = voltage direct current, W = watts.

Source: Asian Development Bank.

6.1.3 Sample Photos for Industrial Project Laboratory

■ **Conventional milling machine.** Set-up in a conventional milling workshop.

■ **Metrology station.** Metrology machine for student use.

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Training Facility Norms and Standard Equipment Lists

Volume 2—Mechatronics Technology

This publication aims to support good practice in establishing facilities for mechatronics technology training programs. It covers equipment specifications aligned with current industry standards.

This volume is the second of four technical specification reference guides on training facility norms and standard equipment lists. 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.

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6 ADB Avenue, Mandaluyong City

1550 Metro Manila, Philippines

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