Survey Design in Supporting of Product Design and Development: A Case Study

Conference Paper · January 2019

DOI: 10.13031/aim.201900291

2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

An ASABE Meeting Presentation
DOI: https://doi.org/10.13031/aim.201900291
Paper Number: 1900291

Survey Design in Supporting of Product Design and Development: A Case Study

Chenggang Yin, Yiyan Wang, Haiqiang Wang*
Department of Mechanical Design and Manufacture, College of Engineering, China Agricultural University, Beijing, China 100083

Written for presentation at the
2019 ASABE Annual International Meeting
Sponsored by ASABE
Boston, Massachusetts
July 7–10, 2019

ABSTRACT: *Survey design plays a key role for investors to identify proper market opportunities in early stage of business plan, and then to motivate subsequent technical activities in product design and development (PD&D) process. Product design and development (PD&D) process includes a series of stages, such as business plan, concept generation, detail design, prototype & test, production, after-sale service, etc. This paper introduced both product design and development (PD&D) processes and survey methodology in Background section. This research introduced a case study product design and development project that was aiming to developing non-destructive testing robots employed for on-site inspecting flaws in wind turbine blades. With focus on the case study project, the author designed a survey and questionnaire, that was afterwards conducted by 34 year-2 undergraduate students in the College of Engineering, China Agricultural University, under a summer vacation social survey program. The survey investigated 28 wind farms in 12 provinces around north and south part of China. This paper reported full cycle of the survey process, including survey purpose, survey design, conducting survey, analyzing data & information, report & suggestions, etc. Research results showed that high quality of survey design significantly supports early stage of business plan in product design and development processes.*

Keywords: *survey design, survey methodology, product design and development process, wind turbine blades inspection, non-destructive testing robots.*

1. Introduction

Survey design plays a key role for investors to identify proper and seize market opportunities in early stage of business plan, and then to motivate subsequent technical activities in product design and development (PD&D) processes. Product design and development (PD&D) processes include a series of stages, such as business plan, concept development, detail design, prototype & test, production, after-sale service, etc. (Yin and McKay 2018), (Eppinger and Ulrich 2015), (Grieves 2006), which associate complex interdisciplinary subjects. Survey design and methodology (Groves, Fowler Jr et al. 2011), (Rossi, Wright et al. 2013), (Fowler Jr 2013), (Krosnick 1999) is significantly important in the success of product design and development, while often lack of sufficient attention and effective management in practice.

This research used a case study product design and development project that was aiming to design and develop non-destructive testing (NDT) robots for on-site flaws inspection in wind turbine blades. Therefore, the purpose of survey in the case study project was to investigate wind farms operation, wind turbine blades inspection methods, inspection procedure, inspection duration and cost, etc. The survey was designed by the author and conducted by 34 year-2 volunteer students in College of Engineering, China Agricultural University, under a summer vacation social survey program. The 34 students come from five majors: Industrial Design, Mechanical Manufacture & Automation, Vehicle Engineering, Electromechanics, and Agricultural Engineering. The survey covered 28 wind farms within 12 provinces around north and south part of China, which are rich of wind energy.

The rest of the paper is organized as follows. Section 2 introduces research background, i.e. product design and development (PD&D) processes and survey methodology. Section 3 introduces a case study product design and development project. Section 4 demonstrates a survey design with focus on the case study product development project. Section 5 introduces situation of volunteer students conducting the survey questionnaires. Section 6 analyzes data and information collected in the survey, and reports survey results. Section 7 concludes the paper.

2. Research Background

This section introduces two fundamental research areas: product design and development (PD&D) processes and survey methodology, with aim to paving a way for application survey methodology to supporting product design and development in a case study project.

2.1 Product Design and Development (PD&D) Processes

Product design and development process comprises of different stages, through which new products are conceived, designed, manufactured, and finally served for users in market. Product design and development system not only involves technical-related perspectives, but also associates social related aspects, which as a whole, forms a complicated "social-technical" system (Yin 2014). Researchers developed different product design and development (PD&D) procedures in accordance with their scientific research and practice experience (Yin and McKay 2018), (Eppinger and Ulrich 2015), (Grieves 2006). The author developed a product design and development procedure in the process of conducting various product development projects. Figure 1 demonstrates the product design and development procedure.

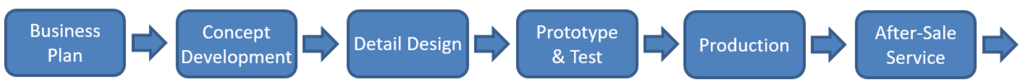

Figure 1. Product Design and Development Procedure

As shown in Figure 1, the product design and development procedure includes 6 stages, i.e. Business Plan, Concept Development, Detail Design, Prototype & Test, Production, and After-Sale Service. Each stage is specified with distinct responsibilities that are implemented by different functional teams. For example, Business Plan team is responsible for market investigation, user survey, product functions definition, proposal writing, etc. Concept Development team designs product concepts that meet users' requirements. Detail Design team makes specifications for product prototype and individual parts. Prototype & Test team constructs the prototype as specified and carries out trial tests for further improvement. Production team builds up supply chain networking and product assembly lines. After-Sale Service provides product and relevant service to users in market.

This research focused on the first stage of Business Plan in the product design and development process. And survey design is highlighted within Business Plan team's duties, in order to support subsequent design and development activities in current stage and thereafter.

2.2 Survey Methodology

Since "ology" is Greek for "the study of", the survey methodology is the study of survey methods (Groves, Fowler Jr et al. 2011). Surveys are fundamentally a matter of asking a sample of people from a population a set of questions and using the answers to describe that population (Fowler Jr 2013). Survey can be applied for many social related and organizational related fields, like economic survey, population survey, birth rate survey, etc. Researchers developed various survey procedures according to their research and practice. The author defined a survey process as shown in Figure 2.

Figure 2. Survey Process

The survey process involves 5 phases, i.e. Survey Purpose, Survey Design, Conducting Survey, Analyzing Data & Information, and Report & Suggestions, which are carried out in a sequential order. Each stage in the process undertakes different responsibilities. For example, Survey Purpose identifies survey aim and objectives, Survey Design designs survey method and survey questionnaire, Conducting Survey stage carries out a series of survey activities, Analyzing Data & Information stage analyzes data and information collected in the survey, and Report and Suggestions stage produces advice and suggestions.

3. Case Study Product Design and Development (PD&D) Project

The Case study used in this research was to design and develop non-destructive testing robots applied for on-site inspecting cracks and flaws in wind turbine blades in wind farms. Figure 3 displays a picture of such wind farms operation scenario (photo comes from internet).

Figure 3. Wind Farm Operation Scenario

Wind turbine blades are important parts of wind turbine. Key features of such wind turbine blades are large dimensions (as long as 30 - 50 meters) and huge weight (as heavy as 10 - 20 tons). While, most of blades failures are due to small cracks and flaws in blade surface, which results in dangerous incident usually together with huge cost for recovery of the wind turbines. Such small flaws may be originally generated in manufacturing process, delivery process, assembly process, etc. Even tiny flaws may expand very fast in extreme conditions, such as heavy load, dynamic load, extreme temperature, etc. Therefore, it is very necessary to detect and fix such flaws in early stage, in order to avoid lose in incidents. Figure 4 displays wind turbine blade delivery by truck (photo comes from internet).

Figure 4. Wind Turbine Blade Delivery

The research motivation is that majority of wind farms carry out blades inspection by humans in China, which results in many disadvantages and dangers, such as long inspection time, high inspection cost, high casualty risk, etc. Figure 5 demonstrates a wind turbine blade human inspection method (photo comes from internet).

Figure 5. Wind Turbine Blade Human Inspection Method

The case study product development project is to design and develop a kind of non-destructive testing robot, which replaces traditional human inspection method. Non-destructive testing robots bring many benefits, such as shortened inspection time, reduced inspection budget, assured inspection quality, etc. In addition, non-destructive testing robots may carry out on-site investigation in wind turbine blades, so that it potentially reduces the cost of shutdown and restart of the wind turbines.

4. Survey Design for the Case Study Product Design and Development (PD&D) Project

As introduced in Section 3, the case study project is going to design non-destructive testing robots employed for detecting flaws in wind turbine blades. The survey purpose is thereafter collecting data and information from wind farm owners, regarding current inspection method, inspection time, inspection cost, inspection procedure, etc.

This paper focused on survey design and conduction in early stages of product design and development process. The aim of the survey was to assessing business opportunity for applying non-destructive testing robots, instead of humans, to detecting flaws in wind turbine blades in wind farms.

The survey objectives are as follows:

- To investigate wind farms distribution in China and their power capacity;
- To investigate wind farms operation situation and ownership status;
- To investigate wind turbine blades life cycle, inspection frequency, and inspection time;
- To investigate current blades inspection methods and inspection cost;
- To understand willingness of wind farm owners to use non-destructive testing robots in future.

The author designed the survey and questionnaire, with aim to implement survey objectives listed above. The survey questionnaire includes 15 questions, covering inspection method, time, frequency, cost, targets, etc. Table 1 demonstrates the full content of the questionnaire.

Table 1. Questionnaire: Wind Turbine Operation and Blades Inspection Situation in Wind Farms

Name of Wind Farm	
Location of Wind Farm	
Time Put into Use	
Interviewee Types	A. Administrative B. Technical Staff C. General Staff D. Others
Method of Survey	A. On Site B. Telephone C. Internet D. Others
Questions:	
1. How many sets of wind turbines in your wind farm? What is the power capacity at full load?	
Answer 1:	Answer 2:
2. What is the ownership of wind farm? (state-owned, private sector, or others)	
Answer:	
3. As a clean energy, do you think wind power will develop fast in China in future? Why?	

Answer 1:	Answer 2:
4. How long does it take to inspect one wind turbine blade under normal working conditions?	
Answer:	
5. What is the blades inspection method? What is the procedure?	
Answer 1:	
Answer 2:	
6. How long does it take to carry out a full inspect of three blades for a wind turbine?	
Answer:	
7. How much does it cost to inspect full three blades of a wind turbine?	
Answer:	
8. What are the common problems regarding the quality of blades? (fracture, crack, delamination, others)	
Answer:	
9. What is the maintenance procedure of blades after severe problems occurring?	
Answer:	
10. When blade breaks down, the wind turbine needs to be shut down for maintenance, which aspect of economic loss does the enterprise most care about?	
Answer:	
11. How long is the blade life span?	
Answer:	
12. Where are suppliers of the blades? When buying blades in batches, what is the price for a single piece?	
Answer 1:	Answer 2:
13. What do you think are the main problems or difficulties in China's wind power industry? (or no problem)	
Answer:	
14. Do you think it is necessary to develop non-destructive testing robots for blades inspection?	
Answer:	
15. If non-destructive testing robot is used, which aspects of safety hazards would you most like the robot to detect?	
Answer:	
Thank you for your time and information!	
Investigator: Class: Student Number: Contact Method: Date:	

5. Conducting Survey for the Case Study Product Design and Development (PD&D) Project

The survey was conducted by 34 year-2 volunteer students in College of Engineering, China Agricultural University, under a summer vacation social survey program. The 34 students come from five majors: Industrial Design, Mechanical Manufacture & Automation, Vehicle Engineering, Electromechanics, and Agricultural Engineering. Table 2 gives details of volunteer students major distribution.

Table 2. Volunteer Students Major Distribution

Major	Number
Industrial Design	1
Mechanical Manufacture and Automation	5
Vehicle Engineering	15
Electromechanics	6
Agricultural Engineering	7
Total	34

The survey investigated 28 wind farms within 12 provinces in north and south part of China, which are rich of wind energy. Figure 6 illustrates the distribution map of such wind farms included in the survey.

Figure 6. Distribution Map of Wind Farms in the Survey

Table 3 illustrates the distribution map of wind farms involved in the survey in a form.

Table 3. Distribution of Wind Farms in the Survey

Distribution of Wind Farms in China	
Provinces	Numbers
Hebei	9
Zhejiang	3
Inner Mongolia	2
Yunnan	1
Guangdong	1
Fujian	1
Qinghai	1
Shandong	2
Gansu	3
Xinjiang	2
Shanxi	2
Jilin	1
Total	28

In the survey, 34 volunteer students investigated 28 wind farms within 12 provinces in north and south part of China, totally completed 57 questionnaire forms.

6. Survey Results Analysis to Support Product Design and Development (PD&D) Activities

The survey was conducted in summer vacation, between July and September 2018. Total 34 volunteer students completed 57 questionnaire forms. Relevant data and information produced in the survey were collected and analyzed by the authors on December 2018. Survey results revealed wind farm operation situation and blade inspection situation in wind farms in China. Details are demonstrated in tables, pie charts, and bar charts in following sections.

Table 4 displays wind farms put into use time. The first wind farm was established in 1988, around 50% wind farms were built up between 2011 and 2015, which means such wind turbines face safety inspection period soon.

Table 4. Wind Farms Time Put into Use

Time Put into Use	Number
2017	1

2016	2
2015	2
2014	3
2013	3
2012	4
2011	2
2010	1
2009	2
2008	4
2007	1
1988	1
n/a	2
Total	28

Table 5 shows different ownership status of such wind farms. Results points out that majority of wind farms are owned by the government, and some private sector joined the wind energy industry recently.

Table 5. Ownership of Wind Farms

Ownership of Wind Farms	Number
state-owned	26
private sector	8
others	2
total	36

Figure 7 demonstrates the ownership map of wind farms involved in the survey using a pie chart. 72 percent of wind farms are owned by the China government. But the private sector invested around 22 percent of wind farms in total 36 wind farms involved in the survey.

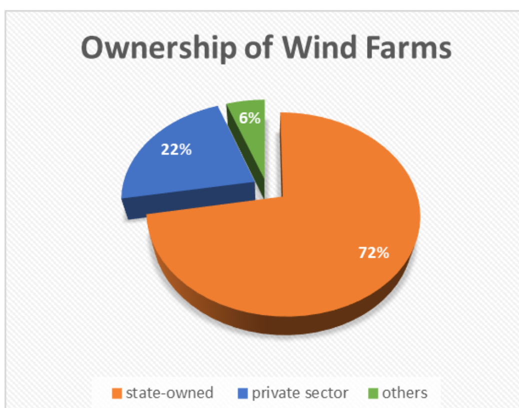

Figure 7. Ownership Percentage of Wind Farms

Table 6 demonstrates wind turbine blades life cycle provided by wind farm owners. Around 60% blades' life cycle is designed as 20 years.

Table 6. Wind Turbine Blades Life Cycle

Wind Turbine Blades Life Cycle (Years)	Number
<20	8
20	18
>20	4
Total	30

Figure 8 shows the wind turbine blades' life cycle specified by blades manufacturer in a bar chart.

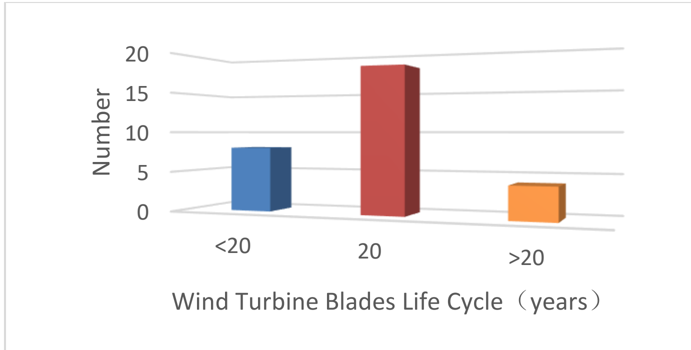

Figure 8. Wind Turbine Blades Life Cycle

Table 7 demonstrates wind turbine blades safety inspection frequency in wind farms involved in the survey. Most of blades suppliers suggested the blade inspection period is 4-6 months.

Table 7. Wind Turbine Blades Inspection Frequency

Inspection Frequency (months)	Number
0~3	4
4~6	18
7~12	11
Total	33

Figure 9 gives a bar chart of wind turbine blades inspection frequency.

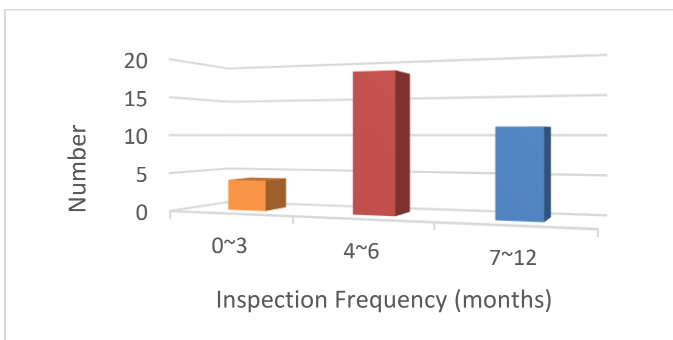

Figure 9. Wind Turbine Blades Inspection Frequency

Table 8 shows wind turbine blades inspection time in wind farms included in the survey. Approximate 55 percent of wind farms use 2-4 hours to complete one single blade safety inspection.

Table 8. Wind Turbine Blades Inspection Time

Inspection Time （hours）	Number
<2 hours	7
2~4 hours	18
>4 hours	8
Total	33

Figure 10 demonstrates wind turbine blades inspection time in different wind farms in a bar chart.

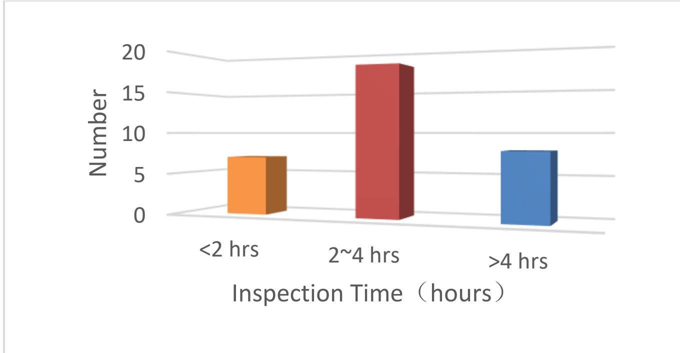

Figure 10. Wind Turbine Blades Inspection Time

Table 9 gives a picture of the cost of wind farm operator inspects a single blade. Most of wind farms provided the answer as "unknown or confidential". While, in the rest of the wind farms, they spend around 2000-5000 (CNY) for detecting a single blade.

Table 9. Wind Turbine Blades Inspection Cost

Inspection Cost (CNY)	Number
<2000	4
2000~5000	8
>5000	2
Unknown or Confidential	22
Total	36

Figure 11 demonstrate the inspection cost survey results in a bar chart.

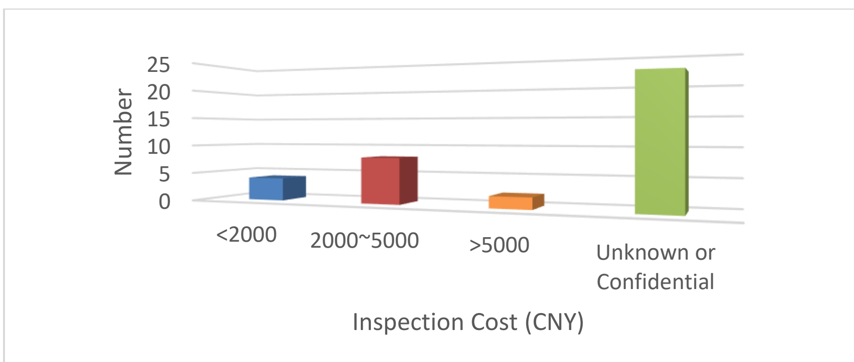

Figure 11. Wind Turbine Blades Inspection Cost

Table 10 displays the willingness of wind farm owners applying non-destructive testing robots to replacing human operation in future.

Table 10. Necessity of Non-Destructive Testing Robots

Necessity of NDT Robots	Number
Yes	32
No	2
N/A	2
Total	36

Figure 12 demonstrate the survey results of necessity of non-destructive testing robots from the wind farm owners in a pie chart. Around 89 percent of wind farm owners expressed the expectation of applying robots to carry out blade inspection in future.

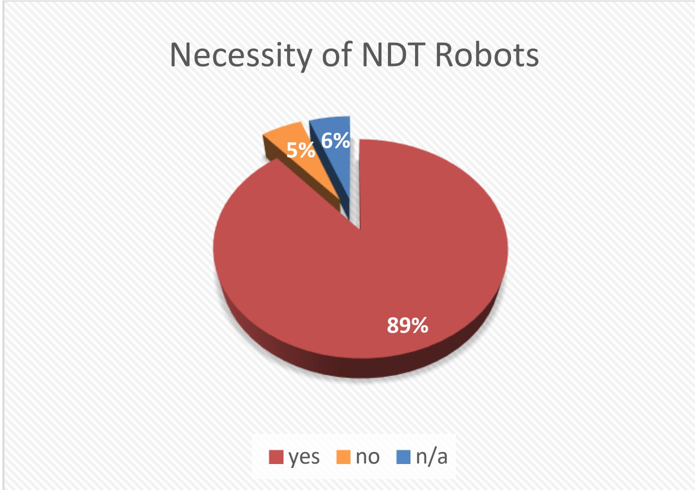

Figure 12. Necessity of Non-Destructive Testing Robots

7. Conclusions

Survey design plays a key role for investors to properly identify market opportunities in early stage of business plan, and then to motivate subsequent technical activities in product design and development (PD&D) processes. Firstly, this paper introduced architecture and characteristics of both product design and development (PD&D) processes and survey methodology.

This research used a case study of product design and development project that was aiming to developing non-destructive testing robots employed for on-site inspecting flaws in wind turbine blades. This research focused on survey design in early stage of business plan in the case study product development project. The survey purpose is to collect data and information from wind farm owners, regarding inspection method, inspection time, inspection cost, inspection procedure, etc. The survey was designed by the author and conducted by 34 Year-2 undergraduate students in the College of Engineering, China Agricultural University, under a summer vacation social survey program. The survey investigated 28 wind farms in 12 provinces around north and south part of China. This paper introduced full cycle of the survey process, including survey purpose, purvey design, conducting survey, analyzing data & information, reports & suggestions, etc.

The survey process was smooth and successful. The survey results showed that most wind turbines face safety inspection period, traditional inspection method are still human inspection operation, inspection time is about 2-4 hours per single blade, inspection cost is around 2000-5000 RMB per single blade. In addition, majority of wind farm owners expressed their expectation to use non-destructive testing robots for blades inspection, which actually brings more advantages, such as shortened inspection time, reduced inspection budget, assured inspection quality, reduced casualty risk, etc. Research results also showed that high quality survey design significantly supports early stage of business plan in product design and development processes.

Acknowledgements

The research is supported by 2019 Counterpart Support Fund for Scientific Research Cooperation (Project No.: 2019TC155).

The survey was conducted by 34 Year-2 undergraduate students in College of Engineering in China Agricultural University. Their names are: Yuanbo Huang, Yu Tian, Zhixue Gong, Yanze Wu, Yuxuan Yi, Haoran Zeng, Haohao Liu, Guangyu Li, Chengxiao Wang, Chengyi Zhou, Haifan Liu, Xiaoci Li, Ziping Xiao, Jingran Huang, Ruofei Ma, Yuying Liang, Jiaxing Li, Hongsheng Li, Lanlan Lv, Xuan Gao, Jingyue Zhang, Jiaxin Zhang, Erwen Song, Jiawei Wu, Yafei Qin, Yujie Wang, Lu Wang, Qizhi Guo, Guohua Li, Limin Gui, Zhuhui Wang, Qiyan Ji, Yiyan Wang, Wentao Li.

References

Eppinger, S., & Ulrich, K. (2015). *Product design and development*. McGraw-Hill Higher Education.

Fowler Jr, F. J. (2013). *Survey research methods*. Sage publications.

Grieves, M. (2006). *Product Lifecycle Management: Driving the next generation of lean thinking*. McGraw-Hill Companies.

Groves, R. M., Fowler Jr, F. J., Couper, M. P., Lepkowski, J. M., Singer, E., & Tourangeau, R. (2011). *Survey methodology*. John Wiley & Sons.

Krosnick, J. A. (1999). Survey research. *Annual review of psychology*, 50(1), 537-567.

Rossi, P. H., Wright, J. D., & Anderson, A. B. (2013). *Handbook of survey research*. Academic Press.

Yin, C-G. (2014). Modelling and simulating vicious circles in new product introduction systems. PhD Dissertation. Leeds, UK: University of Leeds, School of Mechanical Engineering.

Yin, C.-G., & McKay, A. (2018). Agent-Based Simulation New Product Development Processes. *Proceedings of 8th International Symposium on Computational Intelligence and Industrial Applications*. Japan: Fuji Technology Press Ltd.

Yin, C.-G., & McKay, A. (2018). Modeling and Simulating Vicious Circles Problems. *Proceedings of 8th International Symposium on Computational Intelligence and Industrial Applications*. Japan: Fuji Technology Press Ltd.