# Scientific and Technological Innovation Situations of State-Owned Enterprises for Transport Infrastructure Construction in China

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**Abstract.** This study evaluates the scientific and technological innovation situation and investigates factors associated with the outcomes of state-owned transportation enterprises in China. We conducted a cross-sectional, company-based survey on 308 workers of 21 enterprises using company-stratified cluster sampling from September 2019 to July 2020 in Guangxi Province and performed multivariable logistic regression analyses. Results revealed the total technology innovation situation of surveyed enterprises. The differences in the management system, platform development, developing plans, talent team construction, and R&D investment and their achievements are also manifested. Some vital elements, such as platform support and investment proportion, show great correlations with technological innovations.

**Keywords:** Scientific and technological innovation situation · State-owned enterprises · Transport infrastructure construction · Regression analyses · Influencing factors · Suggestions · China

## 1 Introduction

Science, technology and innovation have become the main driving forces for economic growth in the 21st century [1]. To change the previous extensive growth model and enable high-quality development, the Chinese government has issued a series of national strategies, such as policies to strengthen China through science, technology and talents [2]. In the last three decades, the construction of transportation infrastructure has boosted China's economic development by providing a complete and efficient basis for people's travel and economical transportation [3]. As the fastest growing economy in the


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world, the rapid development of China's economy has led to kilometres of highway being ranked first globally, reaching 131,000 km in 2016 [4]. The average passenger and freight road transportation volume reached 91.65 percent and 74.61 percent of the entire transportation industry between 2006 and 2015, respectively. According to China's National Bureau of Statistics (2016), road transportation has become the most important sector in the entire transportation industry.

However, as the traffic construction mileage increases, many problems have also merged successively, such as insufficient technology, quality defects caused by excessive construction speed, environmental pollution and ecological damage during traditional construction [1, 5, 6]. Taking scientific and technological innovation as the engine is an effective way to solve old problems and seek new profit growth sources. As a representative of the innovative Chinese enterprises, Huawei has invested approximately 600 billion yuan in R&D expenses in the past decade, of which 131.7 billion yuan was invested in 2019 [7]. Moreover, DJI became one of the top companies in the drone industry because of its high proportion of R&D investment [8]. For the transportation industry, scientific and technological innovation is also recognised as an important force for creating the modern transportation system and improving the quality of service. In September 2019, the Chinese government vigorously promoted the strategy of strengthening the country in transportation, thus aiming to drive high-quality development of transportation through science, technology and innovation and providing effective advice and help in solving existing development problems. The Ministry of Transport of the People's Republic of China (2020) [9] also promulgated the guidance of promoting the construction of new infrastructure in transportation, which demands strong support in technology innovation for industrial upgrading.

For China, huge state-owned enterprises are still the primary forces and contributors to construction, especially for the transportation field. The development status and technical level of state-owned enterprises represent the current status of China's transportation—such as China Communications Construction, China State Construction and China Railway Construction—and each province's respective transportation construction, design and consulting units. However, because of the pressure of business production, profit growth and constraints of their own system management, most companies have low technology innovation and insufficient transformation rate of achievements, which have seriously affected the development of science and technology [10]. Considering the situation of Guangxi Autonomous Region as an example, the total mileage of roads in Guangxi reaches 127,800 km, intending to connect counties by highway with the rate of 95 percent. Because of the implementation of the 'One Belt One Road' strategy, a group of corporations has been formed to serve transportation infrastructure investment, design, construction, consulting, testing and maintenance. However, most of them lack the creation and upgrade of their own competitive products or technologies. Only a few corporations have thoroughly mastered the core technology of related businesses. Given fiercer market competition pressure and business demand, whether a company can develop high-quality technology determines its survival and development.

Based on the aforementioned situations, the team was commissioned to conduct research on the current situation of technology & science of several state-owned enterprises in Guangxi Province of China. Considering the main factors influencing science, technology and innovation development of enterprises, the clarity of the development plan, platform level, talent team support and stable R&D investment, the questionnaire inquires about a company's policy orientation, incentive and reward system. We also investigated the factors associated with science, technology and innovation among workers in state-owned enterprises. Finally, several reasonable suggestions pointing to existing problems are provided for decision-makers as an effective reference to science, technology and innovation construction.

## 2 Method

### 2.1 Study Design

The study conducted a cross-sectional, company-based survey via company-stratified cluster sampling from September 2019 to November 2019. To compare the intertype differences in enterprise technology innovation outcomes among workers in state-owned enterprises in China, this study stratified the samples by company type (that is, research, design, construction, investment management and consulting company). A total of 21 state-owned subsidiary companies were included in the survey. The survey was approved by the research ethics committee of all corporations. A questionnaire was completed through the face-to-face survey. Moreover, written informed consent was provided by all survey participants before enrolling for the survey. The investigation was anonymous and ensured the confidentiality of information.

### 2.2 Participants

To ensure the results' credibility and universality, we selected the department responsible for conducting scientific and technological innovation from each selected subsidiary company. Moreover, all the workers in these departments were asked to participate in this study. The target sample size of participants was determined using the formula $N = Z\alpha 2P(1 - P)/d2$, where $\alpha = 0.05$ and $Z\alpha = 1.96$. Further, the estimated acceptable margin of error for proportion was 0.1.

### 2.3 Outcomes and Covariates

This study used a self-made technological innovation planning questionnaire, which evaluated all corporations' preparation and provided effective guidance for the technological development of the group's five major business segments: (1) science and technology management system, (2) scientific research platform status, (3) development planning, (4) talent team construction and (5) R&D investment. The self-made technological innovation planning questionnaire comprised questions related to these five segments.

Demographic data, including gender (male or female), age, educational level (technical school or college, undergraduate or postgraduate), technical title (junior, intermediate or senior) and company type (research, design, construction, investment management and consulting company), were self-reported by participants. The different technical titles of respondents refer to the professional titles certified by their companies.

### 2.4 Statistical Analysis

Science and technology management systems, scientific research platform status, development planning, talent team construction and R&D investment are presented as numbers and percentages. To analyse the differences in the aforementioned items among investigated corporations, we applied the nonparametric Mann–Whitney U test and Kruskal–Wallis test. We used multiple logistic regressions to calculate the univariate associations between independent and dependent variables. All tests have a significance level of $p < 0.05$. Statistical analysis was performed using SPSS Statistic 21.0.

## 3 Results

### 3.1 Demographic Characteristics

Of the 596 workers invited to participate in the survey, only 308 respondents (51.7 percent) completed the survey. These respondents belonged to companies in charge of technology research, design, construction, investment and consulting. The specific information of interviewees, including gender, working experience, education degree and technical title, is listed in Table 1.

As shown in Table 1, some differences of interviewees are reflected significantly. Of the total participants, 193 (62.7 percent) were male and 115 (37.3 percent) were female. The male-to-female ratios of interviewees from research, design and consulting companies were higher than those of construction and investment companies. Most of the participants (55.2 percent) had been working for 1–3 years. In particular, most participants had been working for more than 5 years in the design company. Moreover, most participants had an undergraduate education background. However, in the research and design companies, most participants had a postgraduate degree. A total of 138 (44.8 percent) participants had a junior technical title. However, in the design company, 12 (13.9 percent) had an intermediate technical title. Additionally, the state-owned enterprises were dominated by undergraduates and senior title accounts by less than 30 percent. A significant difference exists in demographic characteristics of interviewees, such as gender, working experience, educational background, technical title and other characteristics, which might determine the level of technological innovation and development differences between companies. More details are analysed in the following sections.

### 3.2 Familiarity Analysis

For interviewees, the familiarity with policy development, companies' technology innovation orientation and situation is not related to their own innovation abilities; however, it reflects the survey feedback results. Table 2 presents the familiarity analysis results.

Most interviewees are familiar with national, industrial and provincial policy, group and companies' development orientation and goals, platform construction and development and innovation achievements, which indicates the validity of the survey design and credibility of the results. However, the result difference between each subsidiary company is also significant. To investigate the relationship between demographic characteristics and familiarity results for respondents, we conducted a correlation analysis.

**Table 1.** Demographic characteristics of respondents (Self drawn by the author)

| | N(N = 308) | R(N = 30) | D(N = 20) | C(N = 106) | I(N = 142) | Z(N = 10) | P |
|---|---|---|---|---|---|---|---|
| Gender | | | | | | | |
| Male | 193(62.7) | 22(6.5) | 14(4.5) | 65(21.1) | 85(27.6) | 7(2.3) | < 0.001 |
| Female | 115(37.3) | 8(2.6) | 6(1.9) | 41(13.3) | 57(18.5) | 3(0.9) | |
| Working experience | | | | | | | |
| 1–3 years | 170(55.2) | 13(4.2) | 4(1.3) | 65(21.1) | 80(26.0) | 8(2.6) | <0.001 |
| 3–5 years | 45(14.6) | 5(1.6) | 4(1.3) | 20(6.5) | 16(5.2) | 0 | |
| More than 5 years | 93(30.2) | 12(3.9) | 12(3.9) | 21(6.8) | 46(14.9) | 2(0.6) | |
| Education | | | | | | | |
| Technical school or college | 16(5.2) | 0 | 0 | 7(2.3) | 9(2.9) | 0 | <0.001 |
| Undergraduate | 172(55.8) | 10(3.2) | 2(0.6) | 63(20.5) | 92(29.9) | 5(1.6) | |
| Postgraduate | 120(39.0) | 20(6.5) | 18(5.8) | 36(11.7) | 41(13.3) | 5(1.6) | |
| Technical title | | | | | | | |
| Junior | 138(44.8) | 13(4.2) | 1(0.3) | 61(19.8) | 56(18.1) | 7(2.3) | <0.001 |
| Intermediate | 115(37.3) | 11(3.5) | 12(3.9) | 36(11.7) | 54(17.5) | 2(0.6) | |
| Senior | 55(17.9) | 6(1.9) | 7(2.2) | 9(2.9) | 32(10.4) | 1(0.3) | |
| Participation in projects | | | | | | | |
| Yes | 89(28.9) | 13(4.2) | 15(4.8) | 28(9.0) | 28(73.7) | 5(1.6) | <0.001 |
| No | 219(71.1) | 17(5.5) | 5(1.6) | 78(25.3) | 114(37.0) | 5(1.6) | |
| Publication of papers or patents | | | | | | | |
| Yes | 157(50.1) | 15(4.8) | 15(4.8) | 47(15.3) | 74(24) | 6(1.9) | <0.001 |
| No | 138(44.8) | 15(4.8) | 4(1.2) | 54(17.5) | 62(20.0) | 3(0.9) | |
| doing | 13(4.2) | 0 | 1(0.3) | 5(1.6) | 6(1.9) | 1(0.3) | |
| Technological innovation | | | | | | | |
| Yes | 177(57.5) | 24(7.8) | 16(5.2) | 44(14.3) | 86(27.9) | 7(2.3) | 0.009 |
| No | 131(42.5) | 6(1.9) | 4(1.2) | 62(20.1) | 56(18.2) | 3(0.9) | |
| Training times/year | | | | | | | |
| No training | 107(34.7) | 12(3.9) | 1(0.3) | 42(13.6) | 50(16.2) | 2(0.6) | 0.004 |
| Less than twice a year | 124(40.3) | 9(2.9) | 12(3.9) | 46(14.9) | 52(16.9) | 5(3.2) | |

(*continued*)

**Table 1.** (*continued*)

| | N(N = 308) | R(N = 30) | D(N = 20) | C(N = 106) | I(N = 142) | Z(N = 10) | P |
|---|---|---|---|---|---|---|---|
| More than twice a year | 77(25) | 9(2.9) | 7(2.3) | 18(5.8) | 40(13.0) | 3(0.9) | |

**Table 2.** Familiarity survey (Self drawn by the author)

| | **N (N = 308)** | **R (N = 30)** | **D (N = 20)** | **C (N = 106)** | **I (N = 142)** | **Z (N = 10)** | **P** |
|---|---|---|---|---|---|---|---|
| **National, industrial and provincial policy** | | | | | | | |
| Familiar | 20(6.5) | 4(1.3) | 5(1.6) | 6(1.9) | 5(1.6) | 0 | **<0.001** |
| Basic | 187(60.7) | 19(6.2) | 11(3.6) | 63(20.5) | 87(28.2) | 7(2.3) | |
| Unfamiliar | 101(32.8) | 7(2.2) | 4(1.3) | 37(11.3) | 50(16.2) | 3(0.9) | |
| **Groups and companies' development orientation and goals** | | | | | | | |
| Familiar | 12(3.9) | 1(0.3) | 0 | 7(2.2) | 3(0.9) | 1(0.3) | **<0.001** |
| Basic | 232(75.3) | 24(7.8) | 18(5.8) | 68(22.1) | 114(37.0) | 8(2.6) | |
| Unfamiliar | 64(20.8) | 5(1.6) | 2(0.6) | 31(10.0) | 25(8.1) | 1(0.3) | |
| **Platform construction and development** | | | | | | | |
| Familiar | 58(18.8) | 5(1.6) | 4(1.3) | 17(5.5) | 30(9.7) | 2(0.6) | **<0.001** |
| Basic | 220(71.4) | 23(7.5) | 16(5.2) | 72(23.4) | 102(33.1) | 7(2.2) | |
| Unfamiliar | 30(9.7) | 2(0.6) | 0 | 17(5.5) | 10(3.2) | 1(0.3) | |
| **Innovation achievements** | | | | | | | |
| Familiar | 29(9.4) | 1(0.3) | 1(0.3) | 11(3.6) | 12(3.9) | 4(1.3) | **<0.001** |
| Basic | 202(65.6) | 20(6.5) | 15(4.9) | 64(20.8) | 97(31.5) | 6(1.9) | |
| Unfamiliar | 77(25) | 9(2.9) | 4(1.3) | 31(10.1) | 33(10.7) | 0 | |

As shown in Table 3, most demographic characteristics except technical title show strong correlations with familiarity items. In terms of gender, men are more familiar with survey contents than women, especially in national, industrial and provincial policies, and the development of their groups or companies' orientation and goals. The same evident correlation results include the items of publishing papers or patents, technological innovation and training frequency. The experience of participating in technology innovation and skill training greatly influences familiarity. However, participating in the project shows a weak correlation with group and companies' development orientation and goals. For respondents working more than three years, they are more familiar and sensitive with their groups or companies' development plan and situation. Meanwhile, for education, the interviewees with a bachelor's degree or above are more concerned about

**Table 3.** The correlation analysis result of demographic characteristics and familiarity results for respondents (Self drawn by the author)

| Familiarity items | National, industrial and provincial policy | Groups and companies' development orientation and goals | Platform construction and development | Innovation achievements |
|---|---|---|---|---|
| Gender | **−0.215**** | **−0.206**** | **−0.186**** | **−0.155**** |
| Working experience | 0.88 | **−0.128*** | 0.103 | **0.158**** |
| Education | **0.231**** | **−0.196**** | 0.084 | −0.042 |
| Technical title | 0.035 | −0.041 | −0.080 | 0.035 |
| Participation in projects | **−0.348**** | −0.114 | **−0.244**** | **−0.126*** |
| Publication of papers or patents | **0.203**** | **−0.262**** | **−0.291**** | **0.168**** |
| Technological innovation | **0.244**** | **−0.118*** | **0.272**** | **0.262**** |
| Training times/year | **0.265**** | **0.291**** | **0.186**** | **0.261**** |

the national, industrial and provincial policies as well as the development orientation of groups.

### 3.3 Situation of Science and Technology Development

According to investment, contribution and achievements in the whole process of technology research, Table 4 summarises the situation of science and technology development of corporations.

As shown in Table 4, most respondents (96.1 percent) believe that the implementation of scientific and technological innovation is fully and partly conducted. By the standards of company revenues, 249 (80.8 percent) consider that their companies were regional leaders, and 175 of them believe that they have reached the national and provincial standard, accounting for 56.8 percent of the total participants. Compared with level and status, more participants insist that the current state of key technology science must be improved, accounting for 53.6 percent of the participants. Especially in construction and investment companies, the proportions are up to 59.4 percent and 56.3 percent, respectively. This phenomenon may be related to the aspects of talent, platform, investment support, achievement proportions and so on. For example, although the talent team of each corporation is established, industry experts are still deemed to be scarce. For the R&D investment, 71.8 percent consider the annual investment to be less than 2.0 percent of the total income. Moreover, 86.7 percent and 80 percent of participants from the research and consulting company deem that the proportion exceeded 2 percent. As

**Table 4.** Characteristics of science and technology system (Self drawn by the author)

| | N (N = 308) | R (N = 30) | D (N = 20) | C (N = 106) | I (N = 142) | Z (N = 10) | P |
|---|---|---|---|---|---|---|---|
| Level and status | | | | | | | |
| Leading in domestic | 6(1.9) | 0 | 0 | 1(0.3) | 5(1.6) | 0 | <0.001 |
| Leading in province | 169(54.9) | 18(5.8) | 12(3.9) | 50(16.2) | 84(27.3) | 5(1.6) | |
| Leading in city | 74(24.0) | 7(2.3) | 3(0.9) | 33(10.7) | 29(9.4) | 2(0.6) | |
| Need to improve | 59(19.2) | 5(1.6) | 5(1.6) | 22(7.1) | 24(7.8) | 3(0.9) | |
| Industry experts | | | | | | | |
| Yes | 118(38.3) | 15(4.9) | 13(4.2) | 38(12.3) | 43(14.0) | 9(2.9) | < 0.001 |
| No | 190(61.7) | 15(4.9) | 7(2.3) | 68(22.1) | 99(32.1) | 1(0.3) | |
| Distribution of education and technical title | | | | | | | |
| Postgraduate predominantly | 125(40.6) | 30(9.4) | 20(6.5) | 38(12.3) | 32(10.4) | 5(1.6) | 0.003 |
| Undergraduate predominantly | 183(59.4) | 0 | 0 | 68(22.1) | 110(35.7) | 5(1.6) | |
| Senior title account for more than 30 percent | 138(44.8) | 11(3.6) | 12(3.9) | 46(14.9) | 67(21.8) | 2(0.6) | |
| Senior title account for less than 30 percent | 170(55.2) | 19(6.2) | 8(2.6) | 60(19.5) | 75(24.4) | 8(2.6) | |
| Scientific research platform | | | | | | | |
| Very complete | 10(3.2) | 0 | 0 | 6(1.9) | 3(0.9) | 1(0.3) | <0.001 |
| Basic complete | 174(56.5) | 17(5.5) | 16(5.2) | 59(19.2) | 74(24.0) | 8(2.6) | |
| None complete | 124(40.3) | 13(4.2) | 4(1.3) | 41(13.3) | 65(21.1) | 1(0.3) | |
| Proportion of investment in scientific research | | | | | | | |
| < 0.5 percent | 134(43.5) | 1(0.3) | 0 | 77(25) | 54(17.5) | 2(0.6) | <0.001 |
| 0.5–1.0 percent | 29(9.4) | 0 | 0 | 6(1.9) | 23(7.5) | 0 | |
| 1.0–1.5 percent | 41(13.3) | 3(0.9) | 16(5.2) | 0 | 22(7.1) | 0 | |
| 1.5–2.0 percent | 15(4.9) | 0 | 0 | 2(0.6) | 13(4.2) | 0 | |
| >2.0 percent | 87(28.2) | 26(8.4) | 4(1.3) | 21(6.8) | 30(9.7) | 8(2.2) | |
| Transformation of achievements in scientific research | | | | | | | |

(*continued*)

**Table 4.** (*continued*)

| | N (N = 308) | R (N = 30) | D (N = 20) | C (N = 106) | I (N = 142) | Z (N = 10) | P |
|---|---|---|---|---|---|---|---|
| Effective | 151(49.0) | 11(3.6) | 1(0.3) | 55(17.9) | 82(26.6) | 2(0.6) | <0.001 |
| Noneffective | 157(50.9) | 19(6.2) | 19(6.2) | 51(16.6) | 60(19.5) | 8(2.6) | |
| Current state of Key technology | | | | | | | |
| National industry key technology | 33(10.7) | 4(1.3) | 3(0.9) | 13(4.2) | 11(3.6) | 2(0.6) | <0.001 |
| City industry key technology | 110(35.7) | 12(3.9) | 13(4.2) | 30(9.7) | 51(16.6) | 4(1.3) | |
| Need improvement | 165(53.6) | 14(4.5) | 4(1.3) | 63(20.5) | 80(26.0) | 4(1.3) | |
| Implementation of scientific and technological innovation | | | | | | | |
| Fully implement | 73(23.7) | 5(1.6) | 3(0.9) | 21(6.8) | 41(13.3) | 3(0.9) | <0.001 |
| Part implement | 223(72.4) | 24(7.8) | 17(5.5) | 80(26.0) | 95(30.8) | 7(2.2) | |
| Unable to implement | 12(3.9) | 1(0.3) | 0 | 5(1.6) | 6(1.9) | 0 | |

the most important assessment indicator of technological innovation, achievement transformation is always the concern of managers and decision-makers. More than 50 percent suppose that the current transformation is ineffective, especially for design and investment companies. To discuss the factors affecting science and technology development and support effective measures for decision-makers, we conducted a correlation analysis (Table 6).

As shown in Table 5, the implementation of scientific and technological innovation shows great correlations with elements of science and technology innovation, except for the distribution of education and technical title. Meanwhile, the current state of key technology is strongly correlated with the situation of platform, talents and the development of companies. This means that more effort in platform, talents and investment can bring more returns in technical innovations or key technology. However, contrary to our expectations, the correlations between the proportion of investment, transformation of achievements and current state of key technology are weak. The analysis result of the distribution of education and technical titles should also be noted. A more balanced distribution in education and titles of corporations reflect better achievements. The aforementioned phenomenon may be related to the characteristics of each corporation, including personnel composition, business type and development planning.

**Table 5.** The correlation analysis results of the situation of science and technology development (Self drawn by the author)

| | Current state of key technology | Implementation of scientific and technological innovation |
|---|---|---|
| Distribution of education and technical title | −0.215** | −0.13 |
| Scientific research platform | 0.494** | 0.426** |
| Proportion of investment in scientific research | 0.032 | 0.139** |
| Transformation of achievements in scientific research | 0.013 | 0.329** |
| Level and status | 0.222** | 0.135* |
| Industry experts | 0.148** | 0.182** |

# 4 Discussion

## 4.1 The Situation of Scientific R&D

The survey results on the current situation of science and technology of each company match the actual situation that we collected. For example, several participants are leaders in the domestic and local province. Their presentative key technology in developing new road materials, bridge construction and inspection technology has been recognised and rewarded by national and professional supervisors. Moreover, most companies' scientific research situation is good or under construction, showing the efficiency and excellence of the Chinese government and decision-makers. However, some problems reflected in the survey cannot be ignored. For instance, (1) the scientific research situation imbalance of different types of companies is obvious. The actual achievements (for example, scientific achievements, platform construction and key technology level) of research (R), design (D) and construction (C) companies are far better than other types of companies, which is not reflected in the survey results. Further, the requirements of their recruiters include higher education and experience. Additionally, the number of platforms, such as national, local key laboratory and engineering and technology (ET) centres, is far larger too. Meanwhile, the platforms of investment (I) and consulting (Z) companies are mostly co-constructed with outer units, leading to a lower level and less property right of key technology. Another problem is that (2) the number of professional leaders is small. Compared with industrial experts, the leaders need possess more solid theoretical knowledges and practical experience. They are characterised as national or provincial talents or outstanding professional engineers with authorised certification. Even in the research and design companies with the strongest talents, there are still deficiencies in training

**Table 6.** Independent correlation of achievement transformation by multiple logistic regression analysis (Self drawn by the author)

| Variable | Multiple logistic regression analysis | | |
|---|---|---|---|
| | P | OR | 95 percent CI |
| Current state of key technology | | | |
| National industry key technology | – | 1.0 | – |
| City industry key technology | 0.689 | 1.174 | 0.535–2.578 |
| Need improvement | 0.325 | 0.529 | 0.149–1.878 |
| Implementation of scientific and technological innovation | | | |
| Full implementation | – | 1.0 | – |
| Partial implementation | 0.556 | 0.662 | 0.168–2.609 |
| Unable to implement | 0.001 | 21.901 | 3.501–137.017 |
| Proportion of investment in scientific research | | | |
| <0.5 percent | – | 1.0 | – |
| 0.5–1.0 percent | 0.432 | 1.401 | 0.604–3.246 |
| 1.0–1.5 percent | 0.663 | 1.538 | 0.222–10.676 |
| 1.5–2.0 percent | 0.467 | 0.412 | 0.038–4.497 |
| >2.0 percent | 0.001 | 0.154 | 0.053–0.445 |
| National, industrial and provincial policy | | | |
| Familiar | – | 1.0 | – |
| Basic | 0.035 | 2.319 | 1.063–5.061 |
| Unfamiliar | 0.002 | 0.036 | 0.004–0.301 |
| Groups and companies' development orientation and goals | | | |
| Familiar | – | 1.0 | – |
| Basic | 0.01 | 0.357 | 0.163–0.781 |
| Unfamiliar | 0.068 | 2.125 | 0.945–4.780 |

professional leaders. (3) The proportion of investment in scientific research is insufficient. The index of 6 percent of the proportion of investment in scientific research is the evaluation criterion for the title of 'high-tech enterprise' in China. The most surveyed are the research (R) and design (D) companies; a few construction (C) companies had obtained this certification by the end of 2020. The technological development problems caused by investment are significant, which indicates the current investment proportion that most companies must continue to increase.

### 4.2 Correlation Analysis

In Tables 3 and 5, some results are interesting and beyond our expectation. After a deeper investigation, the following findings were obtained. (1) Males show more familiarity in scientific research than females, which is related to their self-interest and responsibility. Some female interviewees believe that their potential family responsibility affects their attention to these aspects. (2) Moreover, the item of technical title shows a weak correlation with the familiarity of scientific research elements. The difference in the technical title is not reflected in the results, which might be attributed to work arrangement. For most companies, the management of scientific research tasks is centrally headed by a small number of people who are exposed to the same amount of information. Thus, a more extensive sample selection survey may make the result more accurate. (3) Additionally, investment is the most fundamental driving force of scientific activities [11, 12]. The proportion of achievement investment in scientific research shows a weak correlation with the status of key technology. This phenomenon is mainly because of the conception of effective investment. For some companies, some expenses that cannot translate into effective scientific and technological activities are coordinated and summarised as research investment, which leads to an invalid high investment. Moreover, a few companies made mistakes in investing in scientific research cooperation, thereby resulting in a low-efficiency ratio and deficiency of key technology.

For the situation of science and technology development, achievement transformation is an important index for evaluating the effectiveness of a company. A total of 157 (50.9 percent) interviewees consider that the work of their companies is ineffective, which supports little attribution for constructing key technology from Table 5 results. To discuss factors that may increase the achievement transformation, we conducted a multiple logistic regression analysis after combining the relevant factors affecting the conversion rate of scientific research results. As shown, supervisor policies and the goals of companies play important roles in transforming achievements. Additionally, high investment (>2 percent) and the implementation of scientific and technological innovation are also unignored factors.

### 4.3 Suggestions for Decision-Makers

To guide decision-makers, we conducted a survey on suggestions of science and technology development. Considering factors potentially affecting innovation abilities of the staff [13, 14], questions such as 'What kind of help do you want the company to provide?' and 'Which factors do you think the company must solve urgently for its current technological innovation?' were designed. A total of 960 opinions and suggestions were collected, which can be divided into five aspects (shown in Fig. 1). The specific statistics of suggestions are listed in Figs. 2 and 4.

In Fig. 1, the highest number of suggestions is for cooperation and training, which accounts for 29.6 percent. The policy support of companies is another concerning issue answered by most interviewees (26.4 percent), which is followed by investment (18.4 percent), the culture of innovation (16.3 percent) and other aspects (9.3 percent). A total

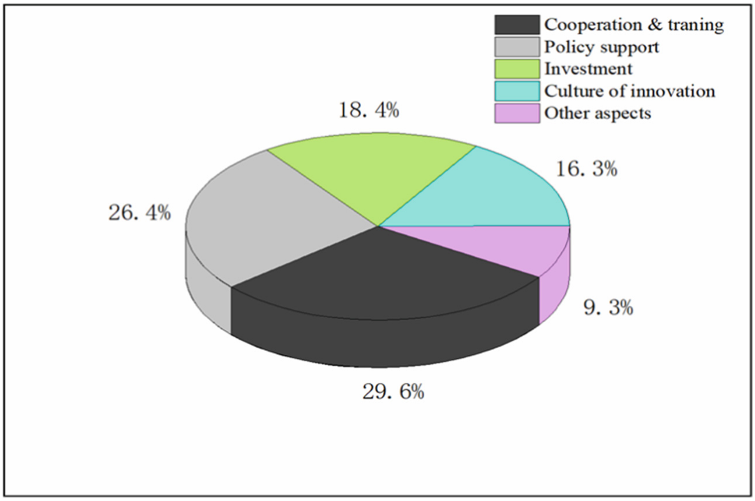


**Fig. 1.** Survey suggestions of science and technology development (Self drawn by the author)

of 284 suggestions for cooperation and training, including development and promotion of technology, talent exchange, training and skill upgrading and resource sharing, were provided. Most employees show a strong willingness to improve their personal capabilities by increasing training frequency and exchanging opportunities. Moreover, policy support is another concern of the interviewees. A total of 98 suggestions hope to obtain policy support and guidance from the top-level management of companies. The number of suggestions for personal motivation and R&D supporting measures is 79 and 76, respectively. For investment, 167 suggestions related to R&D input, investment channels, external funding, platform construction and individual reward are mentioned. Other aspects suggesting the development of science and technology, such as improving science and technology management mechanism, enhancing publicity and strengthening the self-ability of companies, are also collected.

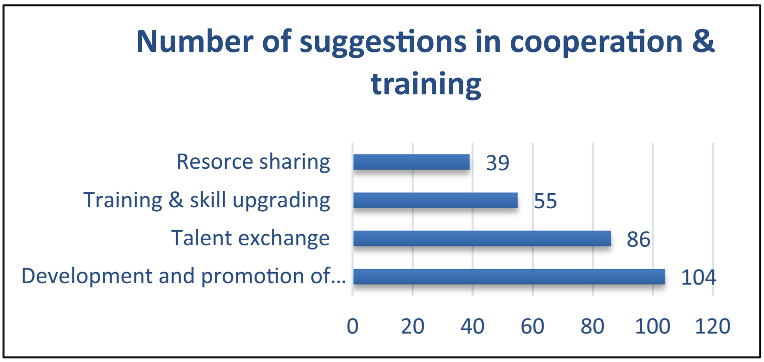


**Fig. 2.** Number of suggestions in cooperation and training (Self drawn by the author)

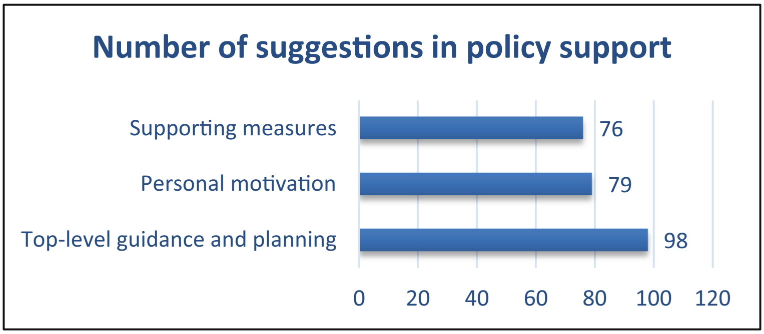


**Fig. 3.** Number of suggestions in policy support (Self drawn by the author)

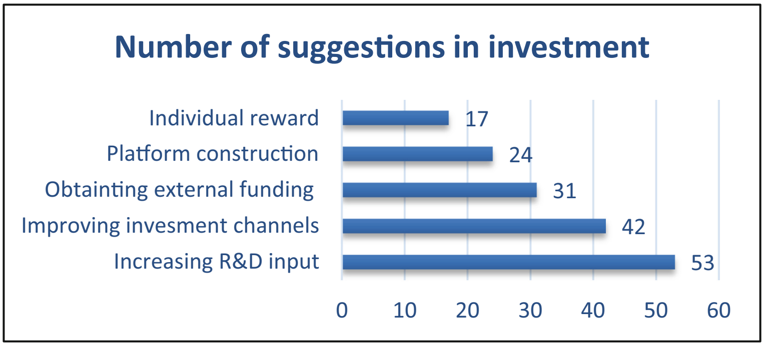


**Fig. 4.** Number of suggestions in investment (Self drawn by the author)

## 5 Conclusions

This study surveys several state-owned transportation enterprises in Guangxi Autonomous Region of China to investigate the scientific and technological innovation of each company. An in-depth analysis of the research results and factors affecting innovation activities was conducted. Furthermore, the following valuable conclusions and suggestions based on the results are provided for scientific and technological innovation work.

(1) The design of the questionnaire is reasonable, and the results are credible. The differences in the interviewees' own demographic characteristics lead to differences in understanding companies' technological status and policies. However, it reflects companies' technological innovation familiarity and work effectiveness.
(2) Regarding surveyed state-owned enterprises in China, all of them actively conducted scientific and technological innovation, which responded to the policies and requirements of the state and local administrations. However, the technological innovation situations of companies are different because of their business-type and development-level differences. Taking the platform conditions, talents, key technology, R&D investment and technological achievements, research (R) and design

(D) companies have better scientific and technological development followed by construction (C) and consulting (Z) companies.

(3) The implementation of scientific and technological innovations shows great correlations with the elements of a scientific research platform, investment proportion, achievements transformation, experts and level and status of the company. Meanwhile, the current status of key technology also strongly correlates with basic elements of technological innovation, except investment proportion and achievements transformation. This can be attributed to the low effective investment and achievements transformation. Moreover, the demand for increased investment is reflected in the suggestions, including R&D input, investment channels, external funding, platform construction and individual reward.

(4) For state-owned enterprises, cooperation with high-level scientific research institutes and universities can directly improve companies' business technology capabilities, cultivate intentional technology and gradually form a mutually beneficial and win-win situation. The specific suggestions collected from interviewees include development and promotion of technical products, resource sharing and talent exchange and training. Additionally, most interviewees show strong desires for personal training and ability improvement. Therefore, companies should pay attention to improve the ability of their staff and cultivate a group of influential industry experts or leaders with a high-tech innovation level.

In conclusion, our study describes the technology innovation situation of transportation state-owned enterprises in China. We discovered the inadaptability of technological innovation and business development. The results can provide valuable information for enhancing technological innovation and contributing to China's transportation development.

## 6 Limitation

The survey focused on the technological innovation situation and evaluated some factors associated with the outcome. However, the different aspects of technology innovation level and the relationship of each factor cannot be fully estimated. In the future, we plan to improve the survey and analyse in depth the differences between enterprises' technological innovation and their causes.

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