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System Dynamics Modeling and Simulation of Enterprise Patent Management Optimization

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ABSTRACT Taking the perspective of cybernetics theory, enterprise patent management can be described as a controllable information system which includes various activities and performances. This paper aims to analysis the relationship between enterprise patent activities and patent performance, and to help convert technological innovation achievements into patent rights more effectively and consolidate technology superiority. This paper uses System Dynamics method to construct a multiscale nonlinear enterprise patent management model. Validity of this model is tested, simulation is conducted in VENSIM, sensitivity analysis of this model shows that: Technology Disclosure Sufficiency does not have much influence on patent application quantity, but it has strongly positive effect on patent grant rate and patent portfolio diversity, it can also lower the risk of patent circumvention. Simulation shows that technology disclosure sufficiency is a key determinant to reduce information loss and improve output efficiency of enterprise patent management system. Collaboration of R&D personnel, patent engineers and patent agencies should be enhanced to improve TDS, so as to promote enterprise patent management efficiency. This SD model provides a foundation for future research in patent management optimization.

INDEX TERMS System analysis and design, multiscale nonlinear system, patent management, computer simulation.

I. INTRODUCTION

In the era of knowledge economy and globalization, patent legal system has become an international rule with universal binding force. Patent system provides patentee a force to legally monopolize the technology within the term of patent right. Therefore, as a special strategic resource, patent right ownership has become the key to business success especially for high-tech enterprises. To ensure that R&D achievements are effectively under protection has been the core mission of enterprise patent management, as well as a practical challenge for enterprise leader and patent manager.

Current research on enterprise patent management can involve many aspects, including the research on patent filing strategies [1], [2], function and writing skills of patent claim [3], [4], function and standards of patent examination [5], [6], patent quality analysis [7], [8], strategies and effects of patent disclosure [9], [10], patent

transfer [11], [12], patent portfolio [13], [14], patent infringement risk identification [15], relationship between patent and market [16], relationship between patent management and technology innovation performance [17], and so on.

Since the goal of enterprise patent management is to transform the R&D achievements into patent rights timely and efficiently, in this angel of view, enterprise patent management can be described as a progress of converting technology innovation achievements into patent rights ownership. The transmission progress requires multiple participators to complete. At the same time, it is influenced by many factors. Therefore, enterprise patent management can be a case of system engineering, and it is suitable to conduct research on enterprise patent management from a perspective of system science. Thus, this paper aims to stablish a system simulation model which could reproduce the actual behavior of enterprise patent management and fill the gap in system engineering research.

Building a system simulation model often comes with two major contributions:

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(1) It can give researchers and decision-makers a full view of complex causal relations in the process and help better understand the whole system. In this study, building SD model can help enterprise managers understand the process of patent management with a systematic view from both qualitative and quantitative aspects.

(2) Conducting computer simulation experiments with this model can help optimize management. Model simulation and sensitivity analysis can help better understand the key variables and how the output of the system is influenced. In this study, building SD model can help convert technological innovation achievements into patent rights more effectively.

The construction of this study includes conceptualization, modellization and simulation. Firstly, we analysis the object and problem in enterprise patent management and build a conceptualization model, so as to define the boundary of this study. Secondly, causes and effects in enterprise management are analysed and shown in a causal model, and a stock-flow model is established. Thirdly, the validity of the model is tested by compare the simulate data to the actual data of the sample enterprise, and the sensitivity of main parameters in the SD model are analysed, enterprise patent management suggestions are promoted in the end of this paper. The construction of this study is as shown in Figure 1.

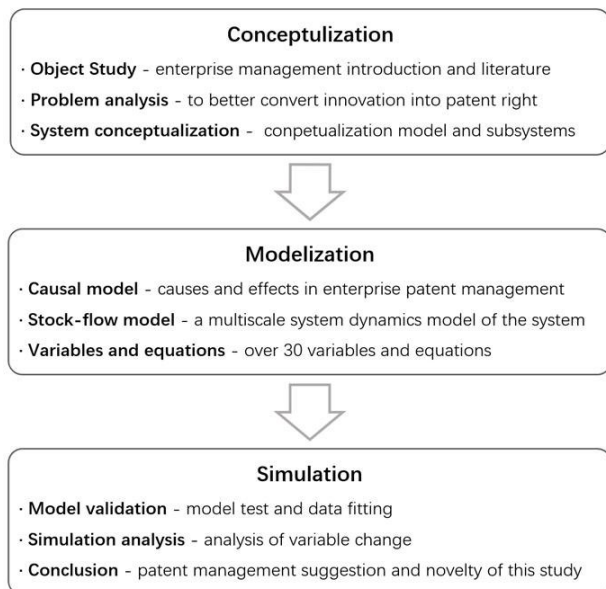


FIGURE 1. Structure and research process of this study.

II. METHODS

The method of System Dynamics (SD) is adopted in this study, which can restore operating status of the system and historical data of enterprise's patent performance from both qualitative and quantitative aspects [18], [19]. SD aims to study overall behaviour of the whole system by analysing the feedback structure relationship between various variables in the social and economic system, its application scope lies in:

(1) SD is suitable for dealing with long-term and cyclical problems. For example, ecological balance in nature, human life cycle and economic crisis in social problems all show periodic laws and need to be observed through a long historical stage. Many system dynamics models have made scientific explanations for their mechanisms.

(2) It is suitable for study of insufficient data. The problem of insufficient data or difficulty to quantify is often encountered in social and economic modelling research. The causal relationship between various elements of the system dynamic school record and the limited data and certain structure can still be calculated and analysed.

(3) It is suitable for dealing with complex social and economic problems with lower accuracy requirements than physical science. Social and economic systems are usually multiscale nonlinear dynamic systems, it is difficult to describe those systems using general mathematical methods, while can still be reproduced by means of computer simulation.

(4) SD model can be used to conduct conditional prediction. This method emphasizes the conditions that produce the results. Run the model in VENSIM, it can provide results of sensitivity analysis and scenario analysis, so as to help decision-making in system optimization under changing environment.

SD method was also used in researches on patent licensing and patent pool in the past [20], [21]. In this study, our purpose is to describe the dynamic behaviours of enterprise patent management system, so as to help enterprise decision-makers better understand the complexity in patent management, so that to convert technological innovation achievements into patent rights more effectively and consolidate technology superiority. Therefore, it is appropriate and necessary to adopt SD method in the study.

III. CONCEPTUALIZATION

Taking the perspective of cybernetics theory [22], we treat the research object as a whole and regard the enterprise patent management as a controllable information system. The first step is to set boundary of the system. Since the purpose of this study is to help convert technology innovation achievements into patent rights more effectively, the patent management system in this study is mainly about the activities and performance of enterprise R&D department, enterprise patent department and patent office. First of all, R&D department carries out R&D projects to the meet the enterprise's need of technological innovation; Secondly, patent department is responsible for patent drafting and patent application, this process could be done by either enterprise's own patent engineering or patent agent. Thirdly, applications are submitted to Patent Office for examination, those that meet the requirements of the patent eligibility criteria will be granted, and those that do not meet the requirements will be rejected. Valid patent grant gives a legal force to stop others from using the same technology and help consolidate enterprise's technology superiority.

Conceptualization of enterprise patent management in this study is as shown in Figure 2.

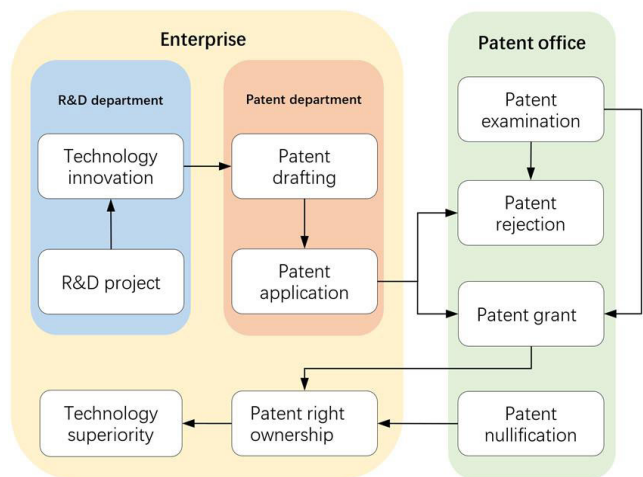


FIGURE 2. Conceptualization of enterprise patent management in this study. Source: Own work.

IV. MODELLIZATION

A. CAUSAL MODEL

A causal model is a qualitative analysis method to understand relationship between different variables in the system. In this study, Causal loop diagram is used to describe enterprise patent management clearly from the qualitative point of view, and to analysis the causes and effects in the system. The interactive relationship among various factors is connected with arrows. If the result of the effect is positive, it is indicated by a plus (+) sign, and if it is negative, it is indicated by a minus (-) sign.

There are two important issues in the process of enterprise patent management. One issue is patent quantity. It takes efforts to convert technology innovation achievements into patent application productivity, these efforts include technology disclosure, patent mining, patent drafting, patent portfolio and patent fling. The other issue is patent quality. On the premise of the creativity, practicability and novelty of the technical achievements, patent drafting quality determines whether the application is granted or rejected, and whether it is validated or nullified in patent reviews filed by competitors. There are also risks in the process of enterprise management, including technology leak risk, novelty loss risk, patent claim risk.

Base on this, a causal model of enterprise patent management in this study is built and as shown in Figure 3. As shown in Figure 3, causal model of enterprise patent management contains 27 factors, covering the process of R&D activity, technology innovation, patent activity and patent performance. In the following paragraphs, we will analysis the cause-tree and use-tree in the model to demonstrate the causal relationship and explain the factors more clearly.

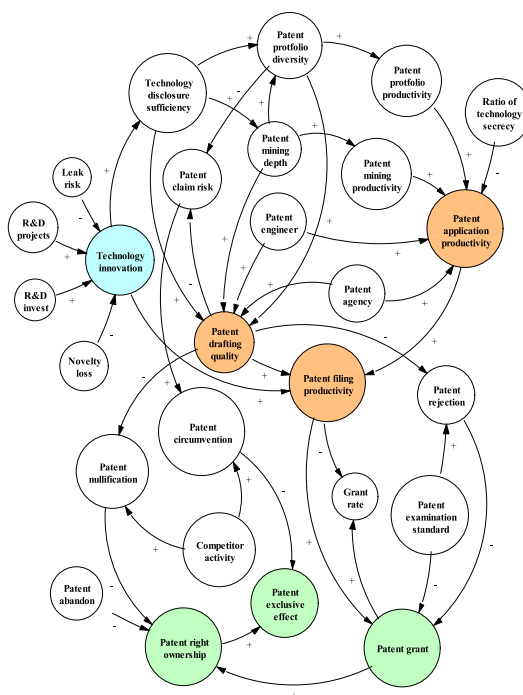


FIGURE 3. Causes and effects in patent management. Source: Own work.

It is necessary to explain why and how key variables in this model changes the output of the system in this section. As shown in Figure 3, there are complex causal relationship in enterprise patent management system, each factor of enterprise activity will have influence on enterprise patent performance. However, there are still some key relationships in this model. They will be analyzed in the form of cause tree and use tree in the following paragraphs.

1) CAUSE TREE ANALYSIS OF PATENT FILING PRODUCTIVITY

As shown in Figure 4, patent filing productivity has three causes, and each cause is influenced by 4 to 5 factors. A substantial amount of patent data is freely and publicly available, with proper method, patent mining can discover and extract knowledge from patent repositories [23], [24]. The discovered knowledge by patent mining can not only provide preliminary estimation of technology innovativeness [25], product information [26], technology trends [27], but also help with recognition of competitors and strategy construction for patent application [15], [28]. Patent portfolio strategy leads to not only more patent applications, but also significant promotion of patent drafting quality, so as to maximize value of the patents [13], [14], [29].

There are also risks to control in technology innovation and patent application, including leak risk and novelty loss risk. Novelty, creativity and practicability are the required by patent eligibility criteria, applications that do not conform to the criteria will be rejected by patent office. If the enterprise does not drift and file the patent timely, the creativity of technology might reduce along with time until competitors

surpass. There is a bigger chance of technology leak if it takes too long to draft and file a patent.

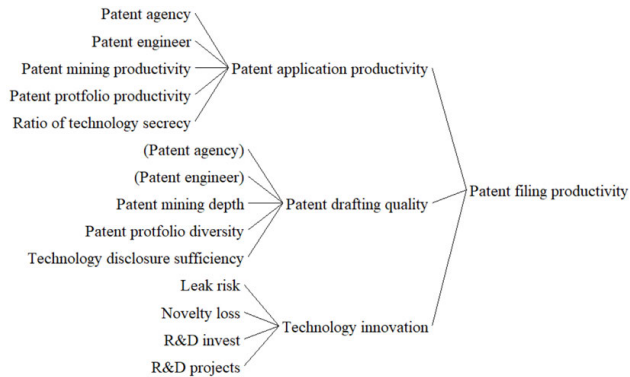


FIGURE 4. Cause tree of patent filing productivity.

2) CAUSE TREE ANALYSIS OF PATENT RIGHT OWNERSHIP

As shown in Figure 5, patent right ownership has three causes, and each of the last two causes is influenced by 2 to 3 factors. It is not a hundred percent stable for a patent after it got granted, any patent that has been granted may face validation review filed by any civil subject in the future, if the patent is not in line with the legal standards, it will be nullified. Enterprises usually tend to abandon old patents that are considered useless after new patents are granted, so as to cut down unnecessary patent renewal fee expense.

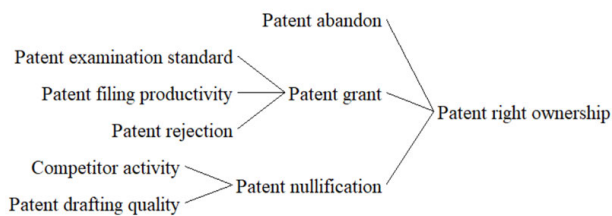


FIGURE 5. Cause tree of patent right ownership.

3) CAUSE TREE ANALYSIS OF PATENT EXCLUSIVE EFFECT

As shown in Figure 6, patent exclusive effect has two causes, and each cause is influenced by 2 to 3 factors. Patent claim amendment is an important part of patent drafting, it provides not only patent eligibility, but also provides legal basis to exclude others, because the technology that a patentee can own is as far as what is described in the patent claim amendments [3], [4], [10], [30], [31]. In other words, badly-drafted patent claim amendments will reduce the quality of the patent, and it will provide a bigger chance for competitor to find a way and circumvent the patent even the patent right is still valid.

4) USE TREE ANALYSIS OF TECHNOLOGY DISCLOSURE SUFFICIENCY

As shown in Figure 7, technology disclosure sufficiency has three uses, and each use influences 3 to 4 factors. Technology

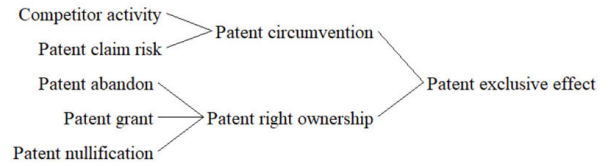


FIGURE 6. Cause tree of patent exclusive effect.

disclosure is a task of knowledge transmission which requires cooperation and efforts of patent inventors, patent engineers and patent agents. In this progress, the inventors should expound the technical items, technical effect and technical background entirely and detailly, so that patent engineers and agents could absorb the knowledge as needed.

Technology disclosure is a very important factor of patent management and yet normally ignored. It will promote patent engineer’s understanding of creativity, practicality and novelty of the technology, which is the foundation of patent drafting, patent mining and patent portfolio. For example, sufficient technology disclosure will help pinpoint the essential technical features accurately in patent claim writing, and define clearly and concisely the scope of the requested protection. Technology disclosure sufficiency is also to meet the disclosure requirement of patent examination [32]. The disclosure requirement in patent law is designed to reveal knowledge regarding a patented invention to allow proper understanding and utilization of that invention [33]. Patent applications with insufficient disclosure are not in compliance with patent law requirements, and has a high risk of being rejected or nullified [34]. Sufficient technology disclosure inside the enterprise will also markedly improve draft quality of patent claim amendments [35], [36], and allow enterprise to form better patent strategies [1], [29], [37], [38].

In brief, technology disclosure sufficiency is a key determinant to reduce information loss and improve output efficiency of the system. The following use tree demonstrates the importance of technology disclosure sufficiency in the process of enterprise patent management.

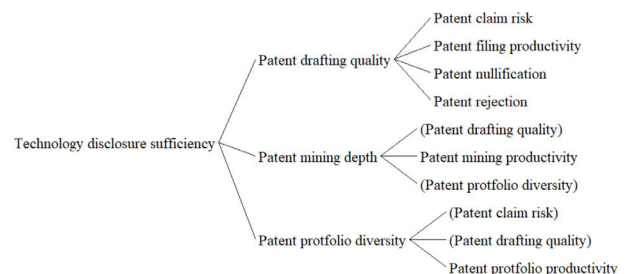


FIGURE 7. Use tree of technology disclosure sufficiency.

B. STOCK-FLOW MODEL

Based on the causal model, a stock-flow model of enterprise patent management system is built. This model contains

40 variables and 42 equations. Mathematical relations between variables are shown with arrows.

This model aims to demonstrate the process of enterprise patent activities and performance including R&D, technology innovation, patent mining, patent drafting, patent portfolio, patent application, patent examination, patent authorization, patent rejection, patent nullification and patent circumvention. Stock-flow model of enterprise patent management system is as shown in Figure 8.

C. VARIABLES

Variable selection criteria are representativeness, data comprehension, comparative objectivity, repeatability and simplicity. Model variable name, attribute, initial value and unit are set as in Table 1.

D. EQUATIONS

In this study, VENSIM is used as a computer software platform for SD modellization and simulation. Although system theory is relatively abstruse, VENSIM has provided specialized DYNAMO language, which makes it more convenient and efficient for researchers to establish mathematical relationships between variables and describe the whole system quantitatively. DYNAMO equations in this SD model are as shown in Table 2.

Using SPSS to analysis data of the sample company from 2014 June to 2021 March, equations of this SD model are finally built. This SD model contains 42 equations which are directly exporting from VENSIM. In order to present in a more readable form, we de divided these equations into three categories, including input with initial value, input equations and output equations, as shown as follows:

1) INPUT INITIAL VALUE

- (01) INITIAL TIME = 0
- (02) FINAL TIME = 81
- (03) SAVEPER = TIME STEP
- (04) TIME STEP = 1
- (05) Mining period = 3
- (06) Leak risk = RANDOM UNIFORM (0, 0.009, 0)
- (07) R&D period = RANDOM UNIFORM (2, 5, 1)
- (08) R&D project growth rate = RANDOM UNIFORM (0.08, 0.172, 0)
- (09) R&D project decrease rate = 0.093
- (10) Ratio of secrecy = RANDOM UNIFORM (0, 0.104, 0)
- (11) Patent mining effort = 7
- (12) novelty risk = RANDOM UNIFORM (0.02, 0.03, 0)
- (13) Technology disclosure sufficiency = 0.3
- (14) Project novelty = RANDOM UNIFORM (6, 10, 1)
- (15) Patent portfolio efforts = RANDOM UNIFORM (0, 0.03, 0)

2) INPUT EQUATION

- (16) Application efficiency = 0.1*Drafting productivity*(1-ratio of secrecy) + Patent portfolio diversity

TABLE 1. Variable name, attribute and initial value.

Variable name	Attribute	Initial value (Unit)
On-going R&D project	Level	1(Project)
Technology innovation stock	Level	0(Innovation points)
Patent application cumulant	Level	0(Cases)
Patent ownership	Level	0(Patents)
R&D project initiation	Rate	0.085(Dmnl)
R&D project conclusion	Rate	0.092(Dmnl)
innovation increment	Rate	0(Dmnl)
Novelty loss	Rate	0(Dmnl)
Leak	Rate	0(Dmnl)
Patent filing	Rate	0(Cases)
Patent grant	Rate	0(Cases)
Patent rejection	Rate	0(Cases)
Patent abandon	Rate	0(Cases)
Patent nullification	Rate	0(Cases)
R&D project growth rate	Exogenous	0.085(Dmnl)
R&D project decrease rate	Exogenous	0.093(Dmnl)
R&D personnel	Exogenous	9(People)
Mining period	Exogenous	3(Month)
Drafting productivity	Auxiliary	0(Cases/Month)
Technology disclosure sufficiency	Exogenous	0.3(Dmnl)
Patent mining depth	Auxiliary	0.43(Dmnl)
R&D capability	Auxiliary	8.54(Dmnl)
Patent per project planned	Auxiliary	32(Patents)
Patent mining effort	Exogenous	7(Workload)
novelty risk	Exogenous	0.03(Dmnl)
Leak risk	Exogenous	0.009(Dmnl)
Ratio of secrecy	Exogenous	0.002(Dmnl)
Application efficiency	Auxiliary	0.123(Cases/Month)
Application period	Exogenous	0.5(Month)
Patent portfolio efforts	Exogenous	0.027(Workload)
Patent portfolio diversity	Auxiliary	0.121(Dmnl)
Patent drafting quality	Auxiliary	0.332(Dmnl)
Grant rate	Auxiliary	0(Dmnl)
Patent circumvented risk	Auxiliary	0.277(Dmnl)
Patent exclusive effect	Auxiliary	0(Dmnl)
Examination period	Auxiliary	15.8(month)
Nullification rate	Auxiliary	0(Dmnl)
Competitor activity	Exogenous	0(Patent disputes encountered)
Rejection rate	Auxiliary	0(Dmnl)
Patent claim risk	Exogenous	0.11(Dmnl)

(17) Drafting productivity = PULSE TRAIN (Mining period, 1, Mining period + 1, 500) *RANDOM UNIFORM (Patent mining effort-1, Patent mining effort + 1, 0)

(18) Examination period = RANDOM UNIFORM (6, 28-15.2*Patent drafting quality, 0)

(19) R&D project initiation = R&D project growth rate*On-going R&D project

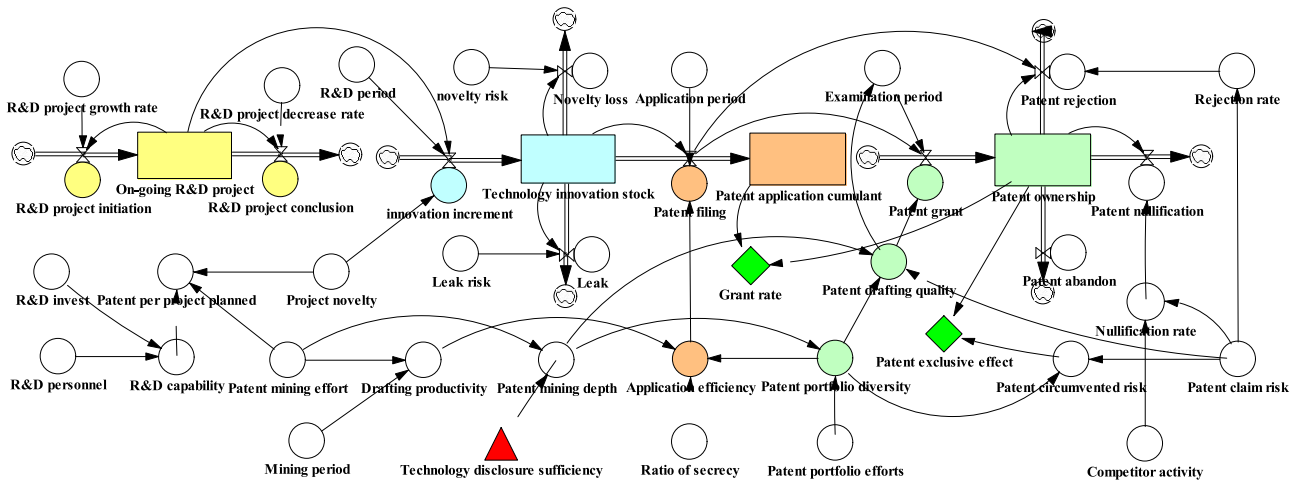


FIGURE 8. Stock-flow model of enterprise patent management system. Source: Own work.

TABLE 2. Dynamo equation and function.

DYNAMO equation	Function
INTEG (A-B, O)	Provides an integral function where A is input flow, B is output flow, O is initial value
PULSE TRAIN (S, W, T, E)	Provides a pulse train function where S is start time, W is interval width, T is pattern repeat time, E is end time
RANDOM UNIFORM (M, X, S)	Provides a uniform distribution where M is minimum value, X is maximum value, S is stream ID for distribution (noise seed)
IF THEN ELSE (C, T, F)	Provides a conditional function where C is condition, T is true value, F is false value
DELAY (A, T)	Provides a delay function where A is input, T is delay time
MAX (A, B)	Maximum of two alternatives

(20) Technology innovation stock = INTEG ((innovation increment - Leak - Novelty loss - Patent filing), 0)

(21) Innovation increment = PULSE TRAIN (“R&D period”, 1, “R&D period” + 1, 100) * “On-going R&D project” * Project novelty

(22) Leak = IF THEN ELSE (Technology innovation stock > 1, Technology innovation stock * Leak risk, 0)

(23) Novelty loss = IF THEN ELSE (Technology innovation stock > 1, novelty risk * Technology innovation stock, 0)

(24) On-going R&D project = INTEG (R&D project initiation - R&D project conclusion, 1)

(25) Patent application cumulant = INTEG (SMOOTH (Patent filing, 3), 0)

(26) Patent circumvented risk = MAX (0.3 + Patent claim risk - Patent portfolio diversity, 0)

(27) Patent drafting quality = 0.18 + 0.42 * Patent mining depth + 0.32 * Patent portfolio diversity - 0.68 * Patent claim risk

(28) Patent filing = PULSE TRAIN (Application period, 1, Application period + 1, 100) * IF THEN ELSE (Technology innovation stock - Technology innovation stock * Application efficiency > 0, Technology innovation stock * Application efficiency, 0)

(29) Patent mining depth = MIN (1, 0.18 * Patent mining effort * Technology disclosure sufficiency)

(30) Patent nullification = Patent ownership * Nullification rate

(31) Patent ownership = INTEG (Patent grant - Patent nullification - Patent abandon - Patent rejection, 0)

(32) Patent per project planned = RANDOM UNIFORM (5.32 * (0.5 * “R&D capability” + 0.5 * Project novelty) * Patent mining effort - 12, 5.32 * (0.5 * “R&D capability” + 0.5 * Project novelty) * Patent mining effort + 12, 0)

(33) R&D project conclusion = On-going R&D project * R&D project decrease rate

(34) Patent portfolio diversity = 0.38 * (0.27 * Patent portfolio efforts + 0.73 * Patent mining depth)

(35) Patent rejection = IF THEN ELSE (Patent ownership > 0, Patent filing * Rejection rate, 0)

(36) R&D capability = 0.5 * “R&D invest” + 0.5 * “R&D personnel”

3) OUTPUT EQUATION

(37) Grant rate = IF THEN ELSE (Patent ownership > 0, Patent ownership / Patent application cumulant, 0)

(38) Nullification rate = Patent claim risk * Competitor activity

(39) Patent grant = DELAY1 (SMOOTH (Patent filing, 3) * Patent drafting quality, Examination period)

(40) Patent ownership = INTEG (Patent grant - Patent nullification - Patent abandon - Patent rejection, 0)

(41) Rejection rate = $RANDOM\ UNIFORM(0, 0.1 * Patent\ claim\ risk, 0)$

(42) Patent exclusive effect = $Patent\ ownership * (1 - Patent\ circumvented\ risk)$

V. SIMULATION

A. MODEL VALIDATION

SD model testing methods usually include structure evaluation test, extreme case test, behavior reproduction test and so on. According to the structural behavior test method proposed by Barlas [39], whether the model structure is composed of factors related to real system is tested through structural verification and extreme case analysis. The behavior of each structural factor is tracked over time, and the amplitude and trend under extreme condition are analyzed, and the abnormal behavior is rescheduled.

The objectivity of the model is verified by comparing the model simulation results with actual data. simulation time was set as 81 months, starting from 2014 June to 2021 March, and the step length was 1 month. Zhuhai Da Hengqin Science and Technology Development Co., Ltd. was chosen as the sample company, which is a state-invested Hi-Tech startup company. Data related to the sample enterprise’s patent performance are retrieved through the National Patent Database and IncoPat patent database platform. Data related to the enterprise’s patent activities are mainly collected through field investigation according to real situation. Data related to enterprise’s patent abilities and risks are obtained through expert consultation, statistical estimation. VENSIM software was used to run the model. Since the purpose of this model is to simulate enterprise’s patent activities and performances, data smoothing method is used to modify the value of R&D projects.

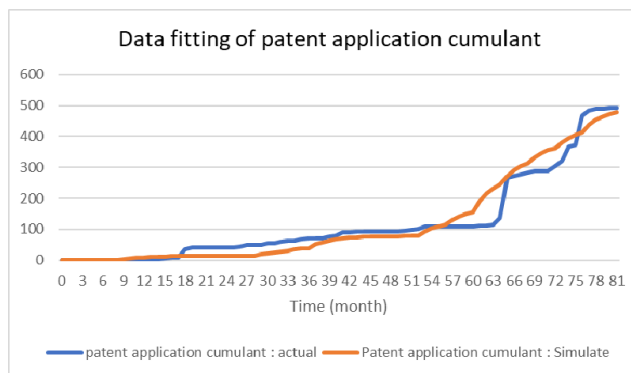


FIGURE 10. Data fitting diagram of Patent application cumulant.

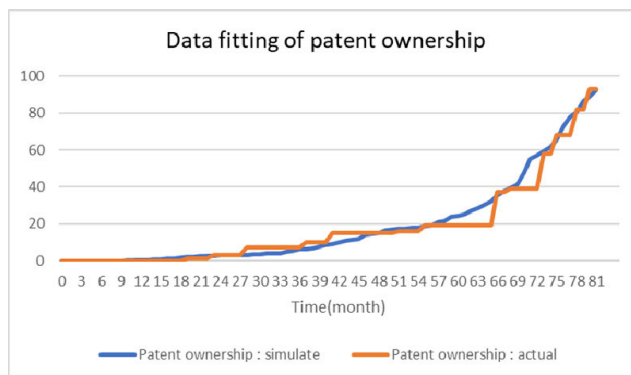


FIGURE 11. Data fitting diagram of Patent ownership.

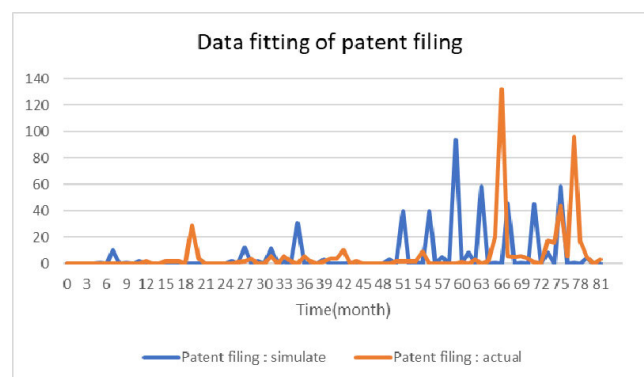


FIGURE 9. Data fitting diagram of Patent filing.

As shown in Figure 9, Figure 10 and Figure 11, patent filing, patent application cumulant and patent ownership is chosen as the data fitting variables. This SD model can simulate the behavior pattern of enterprise’s patent filing. We haven’t considered situations like employee vacancy, coronavirus epidemic, work stagnation in this model, and also due to the randomness of periods and data smoothing

method used in the system, the simulated patent filling curve does not need to be exactly identical with the actual patent application curve, but to reflect the pattern of patent filing activity. Despite some limited randomness of patent filing curve, this SD model still fits well with real data of patent application cumulant and patent ownership. In general, data fitting accuracy of true value and simulate value shows that this model is of validity and objectivity, and it is able to reproduce the activities and performance of enterprise patent management.

B. SENSITIVITY ANALYSIS

The sensitivity of main parameters in this model is analyzed in this section. There are some important variables in this SD model that have big influence on enterprise patent performance, which are analyzed in Section IV and shown in Figure 4, Figure 5, Figure 6 and Figure 7. Among them, Technology Disclosure Sufficiency (TDS) is a key determinant of reducing information loss and improving output efficiency in enterprise patent management system and yet often ignored. Adjust the value of TDS to 30%, 60% and 90% and run the model in VENSIM, the results are shown as follows:

As shown in figure 12, patent application cumulant of the enterprise is not quite sensitive to the change of TDS, which is reasonable because the purpose of technology disclosure

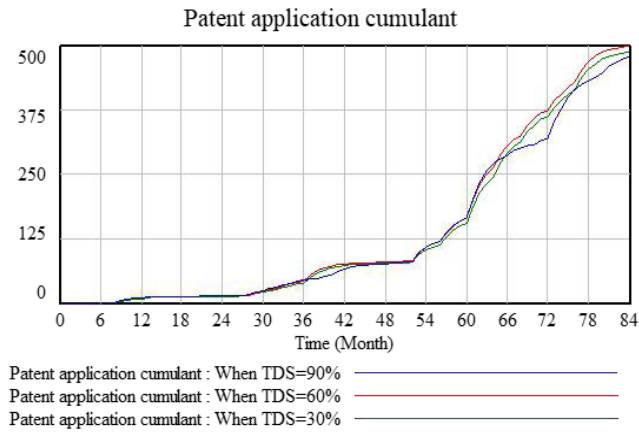


FIGURE 12. Sensitivity analysis result diagram of patent application cumulant.

is not to promote the quantity but to improve quality of the patent.

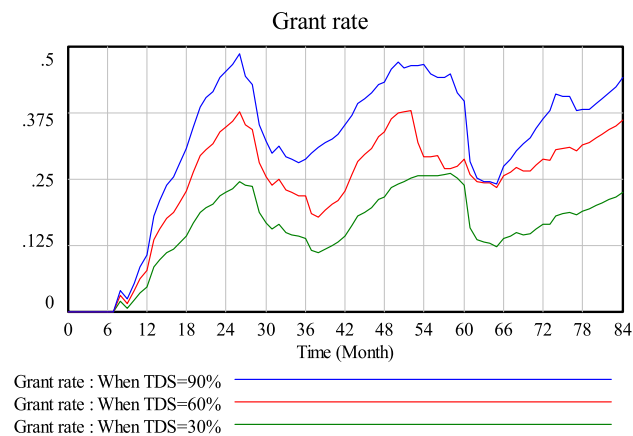


FIGURE 13. Sensitivity analysis result diagram of enterprise patent grant rate.

As shown in Figure 13, patent grant rate of the enterprise is quite sensitive to the change of TDS, which is reasonable because TDS will make significant improvement of patent drafting quality. At the same time, good drafting quality will make it easier for patent office to examine the patent application files, so that patent examination period will be shortened. Therefore, higher TDS will increase enterprise's patent grant rate.

As shown in Figure 14, patent ownership of the enterprise is sensitive to the change of TDS. This result is reasonable because higher TDS will increase grant rate of the enterprise, which leads to less under-examination patents, less rejected patents and more granted patents, so that enterprise's patent ownership will be increasing.

As shown in Figure 15, patent portfolio diversity of the enterprise is sensitive to the change of TDS. This result accords with reality because higher TDS will allow patent

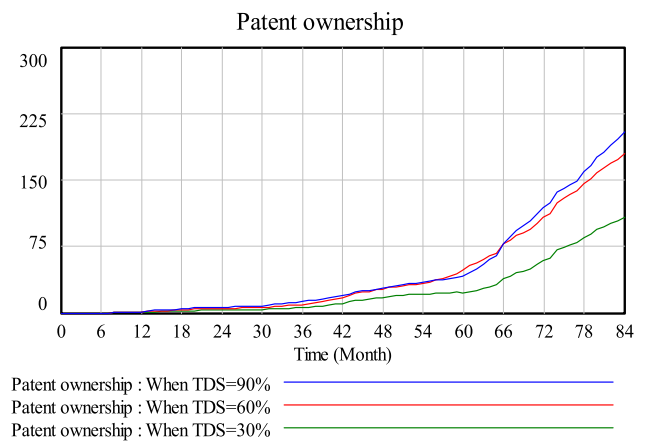


FIGURE 14. Sensitivity analysis result diagram of enterprise patent ownership.

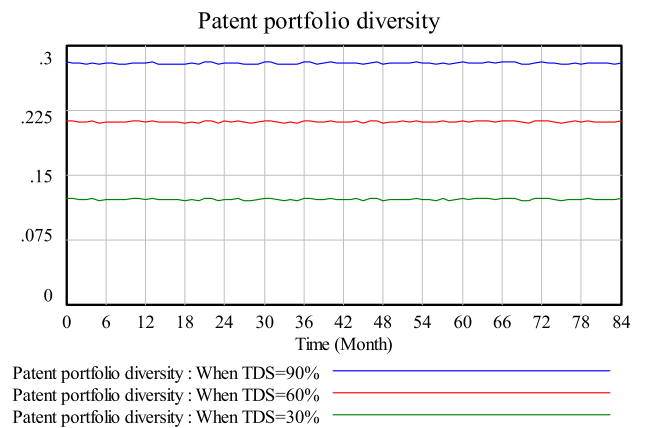


FIGURE 15. Sensitivity analysis result diagram of patent portfolio diversity.

engineer and patent agent to do a more thorough work in patent mining, and get more information about current technologies, potential competitors, so as to make a better patent portfolio strategy.

As shown in Figure 16, patent exclusive effect of the enterprise is sensitive to the change of TDS, and become more and more sensitive along with time. This result is reasonable because higher TDS will improve patent drafting quality and better support the content of patent claim amendments, which makes competitors much harder to find a loophole or come up with a substitute technical solution to circumvent the legal force of enterprise's patent rights. A higher TDS will also allow enterprise to form better patent portfolio strategies, which could maximize the exclusive effect of enterprise's patent rights.

As shown in Figure 17, patent circumvented risk of the enterprise is sensitive to the change of TDS. This result is reasonable because higher TDS will allow enterprise to form a better patent strategy including patent drafting, filing and portfolio, so as to cut down the risk of patent circumvention.

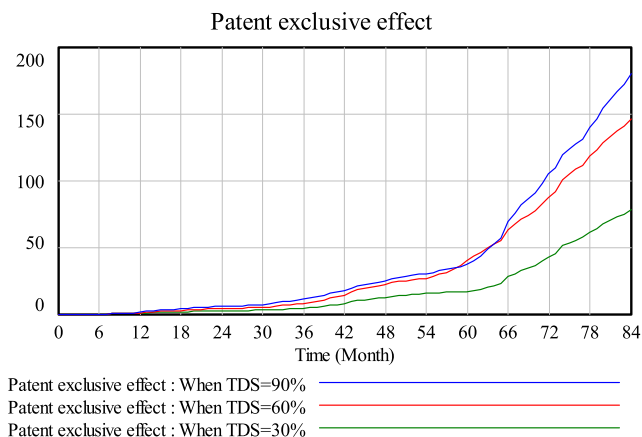


FIGURE 16. Sensitivity analysis result diagram of enterprise patent exclusive effect.

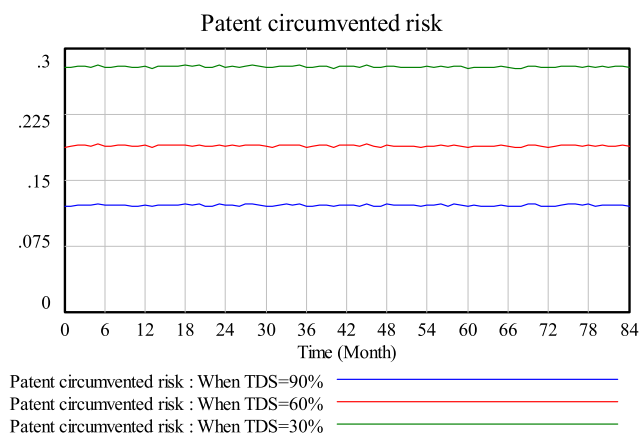


FIGURE 17. Sensitivity analysis result diagram of patent circumvented risk.

VI. CONCLUSION

The novelty of this research can be described as follows:

(1) This study established a valid SD model of enterprise patent management. This model includes 40 variables and 42 equations, can simulate activities of R&D, technology innovation, patent mining, patent drafting, patent portfolio, patent application, patent examination, patent authorization, and can reproduce performance of patent ownership, patent rejection, patent nullification and patent circumvention. Data fitting accuracy of the model is good.

(2) This study analyzed the importance and effects of TDS in enterprise patent management. Simulation of the model shows that TDS does not have much influence on patent application quantity, but it has strongly positive effect on patent grant rate and patent portfolio diversity. It can also lower the risk of patent circumvention and maximize the exclusive effect of enterprise’s patent rights. Collaboration of R&D personnel, patent engineers and patent agencies should be enhanced to improve TDS, so as to promote enterprise patent management efficiency.

With other regulatory factors, this SD model can be used to conduct more simulation experiments and support enterprise patent management optimization. This SD model also

provides a foundation for future research in enterprise patent management and decision-making.

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