Research Article

An Exploratory Pledging Framework of Crowdfunding for Utilities Tunnel Engineering Project

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This paper gives an exploratory mathematical framework for crowdfunding pledging of utilities tunnel engineering project. For two typical types of “All-or-Nothing” and “Keep-it-All” platforms, it analyzes the crowdfunding process how to operate on the platforms for the project. There are four types of crowdfunding modes, and a utilities tunnel project can flexibly choose one or several crowdfunding types analyzed in this paper to improve project construction according to the status of the project. Debt crowdfunding should design rational interest payment mechanism and Macaulay duration, and equity crowdfunding should consider the backers may get dividend and capital revenue for a utilities tunnel project. Simulation analyses of debt crowdfunding and equity crowdfunding give some cases for project fulfillment. The founder of reward crowdfunding can give free or low price energy products to the backers, while the backers of donation crowdfunding are completely philanthropic to supply the pledged capital.

1. Introduction

Utilities tunnel engineering projects have been built in many countries in the world now, which make up an important part for the construction of urban underground space. For the construction of utilities tunnel, electric power, water supply and drainage, gas, telecommunication, and waste pipelines are laid inside the tunnel, which transport many types of energy for the city. Canto-Perello, Curiel-Esparza, and Calvo [1] point out that a utilities tunnel is an underground structure containing one or more utilities, permitting the installation, maintenance, and removal of the systems without the necessity of making street cuts or excavations.

A utilities tunnel has many advantages comparing with traditional “open-cut” style. Under traditional “open-cut” style, electric power, water supply and drainage, gas, telecommunication, and waste pipelines are usually laid underground separately. The roads need to be dug many times to complete the construction of all kinds of pipelines. When there are obstacles for the pipeline to be maintained, the roads must be dug to find the pipeline with obstacle to repair or replace with new pipeline. So, the roads are usually dug many times for “open-cut” operation, which create traffic problem and waste of time and cost. On the contrary, all kinds of pipelines are gathered into the utilities tunnel, and the roads only need to be dug once to construct the tunnel. When there are obstacles for the pipelines, the maintenance worker will enter into the tunnel and easily find the pipelines with obstacles to repair or replace with new pipelines.

To construct a utilities tunnel project, the ground is usually dug deeply to build up one-way, two-way, or multi-way tunnels to lay all kinds of pipelines [2–4]. The lighting, ventilation, and supervision devices need to be set up in the tunnel, so the construction cost for a utilities tunnel is usually high. It is very important to design rational pledging style and pledging procedure for construction funds of a utilities tunnel to successfully fulfill the project.

For a utilities tunnel project, many kinds of funding modes besides traditional debt funding and equity funding
should be flexibly adopted to broaden funding sources
according to the character of the project. Crowdfunding is
an emerging project funding mode. The utilities tunnel
project can make the advantage of crowdfunding mode to
strengthen funding management and construction process.

In crowdfunding mode, the founder posts project in-
truction on the crowdfunding platform, and the backer
browses and chooses suitable project on the platform and
supplies pledged capital during pledged period of the project
[5–7]. Mollick [8] indicates that crowdfunding refers to the
efforts by entrepreneurial individuals and groups (cultural,
social, and for-profit) to fund their ventures by drawing on
relatively small contribution from a relatively large number
of individuals using the Internet, without standard financial
intermediaries.

Now crowdfunding mode has been used in many
countries in the world, and numerous crowdfunding plat-
forms have been built up [9–11]. The founder can choose
suitable crowdfunding platform to fulfill the crowdfunding
project. Kickstarter platform in the US is the largest
crowdfunding platform, which permits the founder to pose
crowdfunding project to pledge the fund from 2009.

Now the project categories on Kickstarter platform
mainly include Games, Design, Technology, Film & Video,
Music, Publishing, Fashion, Food, Art, Comics, Photogra-
phy, Theater, Crafts, Journalism, and Dance. Figure 1 lists
the numbers of crowdfunding projects of all the categories
on Kickstarter platform until December, 2021, and the mean
of launched projects is 36,271. The maximum of launched
projects is Film & Video projects, which arrives at 79,054.
The minimum of launched projects is Dance projects, which
arrives at 4,383. The maximum of successfully pledged
projects is 32,958 for Music projects. The minimum of
successfully pledged projects is 1,408 for Journalism
projects.

Figure 2 lists the numbers of total pledged capital of all
the crowdfunding categories on Kickstarter platform until
December, 2021, and the mean of total pledging dollars is
419.5 million dollars. The maximum of total pledging dollars
is Games projects, which arrives at 1.79 billion dollars. The
minimum of total pledging dollars is Dance projects, which
arrives at 15.56 million dollars.

For the management of crowdfunding project on the
platform, now the mainstream modes include “All-or-
Nothing” and “Keep-it-All” according to the pledged status
of the founder. Under “All-or-Nothing” mode, only if the
pledged fund is more than pledged goal during the regulated
pledging period, the founder can get the pledged fund. If the
pledged fund is less than pledged goal during the regulated
pledging period, the backer need not supply the fund and the
founder cannot get any pledged fund. The platform mode
used by Kickstarter is “All-or-Nothing”. Under “Keep-it-
All” mode, whether or not the pledged fund arrives at
pledged goal during the regulated pledging period, the
backer must supply the fund and the founder can get the
pledged fund. The platform mode used by famous Indiegogo
is “Keep-it-All”. The choice between these two platform
modes may affect the result and successful rate for the
crowdfunding projects. Veuger [12] uses platform size, the
degree of regulation and the funding models including “All-
or-Nothing” and “Keep-it-All” to analyze their effect on the
overall platform success rate.

Crowdfunding mode has not been used with big scale in
engineering field now. But because crowdfunding mode has
the character of low cost and convenience, it can be flexibly
used in engineering field with big scale to broaden the
construction fund source for the engineering project. The
first crowdfunding engineering project (Mosaic Solar House
Roof) in US was built in 2011, which had 18 MW volumes
and pledged 600 thousand dollars. The first photovoltaic
power station for crowdfunding in China was built in early
2014, which had 1 MW volume and pledged 1.57 million
dollars.

During the construction process for utilities tunnel
project, the construction fund with big scale is needed to
timely construct the project. To improve project construc-
tion, many kinds of funding modes can be designed and
their advantages can be used. Crowdfunding mode is a new
type funding mode which can be used for utilities tunnel.
Now crowdfunding mode has not been used for utilities
tunnel project, for example, there is not crowdfunding for
utilities tunnel project among fifteen categories on Kickstarter platform. Crowdfunding mode can be used for
utilities tunnel project in the future. The experience of
engineering project which has used crowdfunding can be
referred by utilities tunnel. The advantage of crowdfunding
mode can be used to improve utilities tunnel construction.
In the early stage crowdfunding mode can be used in small
and middle-sized utilities tunnel project, and it can be
gradually used in large utilities tunnel project in the future.

This paper gives an exploratory crowdfunding pledging
framework for fulfillment of utilities tunnel. It analyzes four
types of crowdfunding modes for utilities tunnel including
debt crowdfunding, equity crowdfunding, reward crowd-
funding and donation crowdfunding. For two typical types
of “All-or-Nothing” and “Keep-it-All” platforms, it analyzes
the crowdfunding process how to operate on the platforms
for utilities tunnel project. It gives simulation analyses of
crowdfunding based on debt and crowdfunding based on
equity under this framework. Existing literature papers
about crowdfunding mainly analyze the influence factors
of crowdfunding operation, but do not give the analysis on how
to operate crowdfunding for utilities tunnel project. To the
best of the authors’ knowledge, this paper is the first to create
a crowdfunding framework to analyze utilities tunnel
funding.

Just as mentioned in this paper, every crowdfunding type
has its own character, which can be used to improve the
construction of utilities tunnel project. Debt crowdfunding
gives some interest for the capital supply of the backer, and
the founder need not give management vote right of utilities
tunnel project to the backer. For equity crowdfunding, the
founder does not have the duty to repay the pledged capital,
while may give certain amount dividend to the backer. The
founder of reward crowdfunding can give some free or low
price energy products conveyed by utilities tunnel project to
the backer as reward. The backer of donation crowdfunding
is completely philanthropic to supply the pledged capital to
the utilities tunnel project for the improvement of social welfare. The utilities tunnel project can flexibly choose one or several above crowdfunding types to acquire project fund according to the status of the project. Using the mathematical framework of four types of crowdfunding analyzed in this paper, the founder and the backer can get a full understanding for the process and procedure of a utilities tunnel funding, which will promote the construction and operation for the utilities tunnel engineering project.

The rest of this paper is structured as follows: Section 2 analyzes debt crowdfunding for “All-or-Nothing” and “Keep-it-All” platforms, and the duration and convexity management for the utilities tunnel project. It also gives simulation analysis of crowdfunding based on debt. Section 3 analyzes equity crowdfunding with dividend and equity crowdfunding with dividend and capital revenue for utilities tunnel, and it gives simulation analysis of crowdfunding based on equity. Crowdfunding mode based on reward and crowdfunding mode based on donation are analyzed in Section 4. Section 5 concludes this paper.

2. Analysis of Crowdfunding Mode Based on Debt for the Utilities Tunnel Project

For a utilities tunnel project, the corridor is built at some depth underground in which water supply and drainage, electric power, telecommunication, gas, rubbish, and other pipelines are laid. The utilities tunnel is given to pipeline using units to use after project construction. So, the utilities tunnel project is a complicated integrated engineering project [13–16]. For different utilities tunnel projects, the main differences are investment amount, project scale, pipeline kinds, engineering condition, etc. The scales of utilities tunnel projects in the world are greatly different. There are some small-scale utilities tunnel projects, such as utilities tunnel of Shanghai Taopu Science and Technology Intelligence City in China whose investment is about 7.85 million dollars. There are also some utilities tunnel projects with big scale whose investments are from several hundreds of millions dollars to several billions dollars, such as the utilities tunnel project of Tokyo in Japan whose construction capital is 3.2 billion dollars. According to construction scale, project condition, operation, and other factors, suitable crowdfunding modes can be chosen to pledge capital for the utilities tunnel project. Crowdfunding modes can be flexibly used to pledge construction capital in small- and middle-sized utilities tunnel projects now.

When the utilities tunnel project uses crowdfunding to pledge capital, according to the modes given by crowdfunding backers to the project, there are mainly four types of crowdfunding that can be used for the utilities tunnel funding. Comparisons among these four types of crowdfunding using the framework can improve the funding process and fulfillment effects for the utilities tunnel project.

2.1. Crowdfunding Based on Debt for “All-or-Nothing” and “Keep-It-All” Platforms. The first type is crowdfunding based on debt for the utilities tunnel project. Project backers
supply investment capital to utilities tunnel crowdfunding, and they can get repayment of investment with certain amount interest or without interest from project revenue after the project is delivered. In some cases, the backers are interested in not only debt interest but also reputation from the project, so they admit to receive repayment of investment without interest.

The crowdfunding founders of the utilities tunnel project may be organizations or individuals, while crowdfunding backers of utilities tunnel project are usually individuals. Assume during construction period, the financial capital is from \( j \) \((j = 1, 2, \ldots, n)\) individuals. No. \( j \) individual invests \( I_S \), to utilities tunnel project, and the total pledged capital is

\[
I_S = \sum_{j=1}^{n} I_S. \tag{1}
\]

For utilities tunnel crowdfunding on the platform, backers usually supply pledged capital by basic units. One basic unit of pledged capital is often from several dollars to several tens of dollars. Assume one backer supplies \( Q_S \) number of basic unit \( \varphi \), and then, all the backers supply total pledged capital

\[
I_S = \sum_{j=1}^{n} \varphi Q_S. \tag{2}
\]

For a utilities tunnel project, there is usually certain pledged period for backers to supply pledged capital. The pledged period is usually between zero and three months. When founder of utilities tunnel project poses one project on the crowdfunding platform, the backers enter into the crowdfunding platform and look at the videos, photos, and words introduction for the utilities tunnel project. Wonderful videos and photos about the utilities tunnel project will attract more backers to supply the pledged capital. At the early stage of crowdfunding posing, which is usually from several days to several weeks, many backers who are interested in the utilities tunnel project will supply pledged capital. These backers often include many Tweets friends of the founder and many people who are familiar with the utilities tunnel project or very interested in the utilities tunnel project. At the next stage of crowdfunding posing, there are not usually many backers supplying the pledged capital. At the near-end stage of pledged period, there will be many backers who supply pledged capital to the utilities tunnel project again. One reason of this phenomenon is that total pledged capital at this time is usually near pledged goal, and many backers supply pledged capital for the successful fulfillment of the utilities tunnel project. Rakesh et al. [17] analyze this phenomenon of pledged capital for crowdfunding mode based on empirical data on Kickstarter platform. Kim et al. [18] find that potential donors are more likely to donate to projects, which are closer to their funding goal.

For crowdfunding platform of the utilities tunnel project with “All-or-Nothing” type, if pledged capital surpasses pledged goal \( K \), the crowdfunding of utilities tunnel will be successful. The founder of utilities tunnel crowdfunding can get pledged capital if \( \sum_{j=1}^{n} \varphi Q_S \geq K \). On the contrary, the founder cannot get pledged capital if \( \sum_{j=1}^{n} \varphi Q_S < K \). While for crowdfunding platform of the utilities tunnel project with “Keep-it-All” type, the founder can get pledged capital whether or not \( \sum_{j=1}^{n} \varphi Q_S \) surpasses pledged goal \( K \).

The crowdfunding platform for utilities tunnel project will manage the crowdfunding process and pledged fund between the founder and the backers. The crowdfunding platform usually charges usage fee from crowdfunding founder. In “All-or-Nothing” type, the usage fee rate paid to platform is \( \eta \) to let founder of utilities tunnel crowdfunding fulfill the project. In “Keep-it-All” type, the usage fee rate paid to platform is \( \eta_1 \) if pledged capital does not surpass pledged goal, whereas the usage fee rate paid to platform is \( \eta_2 \) if pledged capital surpasses pledged goal, and it is often \( \eta_1 \geq \eta_2 \).

The platform for utilities tunnel crowdfunding with “All-or-Nothing” type can get usage fee

\[
F_K = \sum_{j=1}^{n} \varphi Q_S \eta. \tag{3}
\]

The founder for utilities tunnel crowdfunding can get pledged capital \( \sum_{j=1}^{n} \varphi Q_S (1 - \eta) \).

The usage fee paid to platform for utilities tunnel project with “Keep-it-All” type is as follows:

\[
F_K = \sum_{j=1}^{n} \varphi Q_S (\eta_1 - \eta_2) I \left( \sum_{j=1}^{n} \varphi Q_S \geq K \right). \tag{4}
\]

The founder for utilities tunnel crowdfunding can get pledged capital \( \sum_{j=1}^{n} \varphi Q_S (1 - \eta_1) + \sum_{j=1}^{n} \varphi Q_S (\eta_1 - \eta_2) I \left( \sum_{j=1}^{n} \varphi Q_S \geq K \right). I(\bullet) \) is indicator function. The function value is 1 if the condition \( \sum_{j=1}^{n} \varphi Q_S \geq K \) is satisfied, while the value is 0 if the condition is not satisfied.

The backers of utilities tunnel crowdfunding give pledged capital with hope of refunding the investment with some interest or without interest. The bond founder of utilities tunnel crowdfunding is usually organizations. The total value of utilities tunnel crowdfunding at \( T_j \) period with bond interest rate \( R_{f_j} \) of continuous period for “All-or-Nothing” type is as follows:

\[
K_j = \sum_{j=1}^{n} \varphi Q_S (1 - \eta) e^{R_{f_j} T_j}. \tag{5}
\]

The investment revenue rate of backers for utilities tunnel crowdfunding is as follows:

\[
H_S = \frac{\sum_{j=1}^{n} \varphi Q_S (1 - \eta) e^{R_{f_j} T_j}}{\sum_{j=1}^{n} \varphi Q_S}. \tag{6}
\]

The investment revenue rate of backers for “Keep-it-All” type is as follows:
After the founder for utilities tunnel crowdfunding gets the pledged capital, the utilities tunnel project will be delivered at $T_{j \text{yp}}$ period. The founder of utilities tunnel crowdfunding will pay bond interest based on par value $U$ to backers according to the predetermined annual interest rate $C_r$. Assume term to maturity is a years, maturity revenue rate is $R_{T_j}$, and $R_{T_{jyp}}$ is delivery date discount rate.

For utilities tunnel crowdfunding with “All-or-Nothing” type, the interest discount is $(\forall U, C_r > 0, \exists \Phi_1)$:

$$\Phi_1 = C_r \frac{1 - 1(1 + R_{T_j})^n}{R_{T_j}}.$$  

(8)

The end value discount for utilities tunnel crowdfunding is as follows:

$$\Phi_2 = \left(1 + R_{T_j}\right)^{-n}.$$  

(9)

The founder can get capital from the backers of crowdfunding

$$\Phi_3 = \varphi Q_j (1 - \eta).$$  

(10)

The delivery date discount of crowdfunding bond for utilities tunnel project is as follows:

$$H_{S_j} = \frac{\left\{\sum_{j=1}^{n} \varphi Q_j (1 - \eta_1) + \sum_{j=1}^{n} \varphi Q_j (\eta_1 - \eta_2) I\left(\sum_{j=1}^{n} \varphi Q_j \geq K\right)\right\} e^{R_{T_j} T_j}}{\sum_{j=1}^{n} \varphi Q_j}.$$  

(7)

$$F_{S_j} = \frac{\sum_{j=1}^{n} \Phi_3 (\Phi_1 + \Phi_2)}{1 + R_{T_{jyp}}}.$$  

(11)

The investment revenue rate for bond crowdfunding of utilities tunnel project is as follows:

$$H_{S_j} = \frac{\sum_{j=1}^{n} \Phi_3 (\Phi_1 + \Phi_2)}{1 + R_{T_{jyp}}}.$$  

(12)

If backers of utilities tunnel crowdfunding supply pledged capital to buy bonds without interest, the delivery date discount of crowdfunding bond becomes

$$F_{S_j} = \frac{\sum_{j=1}^{n} \Phi_3 (\Phi_1 + \Phi_2)}{1 + R_{T_{jyp}}}.$$  

(13)

The investment revenue rate for bond crowdfunding of utilities tunnel project becomes

$$H_{S_j} = \frac{\sum_{j=1}^{n} \Phi_3 (\Phi_1 + \Phi_2)}{1 + R_{T_{jyp}}}.$$  

(14)

For utilities tunnel crowdfunding with “Keep-it-All” type, the investment revenue rate is as follows:

$$H_{S_j} = \frac{\sum_{j=1}^{n} \Phi_3 (\Phi_1 + \Phi_2)}{1 + R_{T_{jyp}}}.$$  

(15)

$$H_{S_j} = \frac{\sum_{j=1}^{n} \Phi_3 (\Phi_1 + \Phi_2)}{1 + R_{T_{jyp}}}.$$  

(16)

When crowdfunding founder fulfills bond crowdfunding, it is necessary to take some measures to increase the investment confidence of backers [19–22]. Because backers search the Internet platform to find suitable investment projects from many platform projects, the introduction posed by founder of bond crowdfunding for the utilities tunnel project is important. Excellent videos, photos, and words will attract more backers in short time and increase the confidence of backers to acquire $C_r$ of bond crowdfunding for the utilities tunnel project. Zhou et al. [23] find that the length, readability, and tone from the content of project descriptions and past experience and past expertise are all significantly associated with crowdfunding success.

After the delivery of the utilities tunnel project, all kinds of pipeline using units will transport energy through the tunnel, and they need pay usage fee to the project, which is the main revenue of the project. In addition, in many cases the utilities tunnel project belongs to public city
infrastructure goods, and the government will give certain bonus to the project. The founder of bond crowdfunding should pay interest rate \( C_r \) and guarantee the backers can get \( H_S \) from project revenue and get refund of investment \( \sum_{j=1}^{n} \varphi Q_S \). Good reputation of fulfillment of bond crowdfunding for one utilities tunnel will benefit the founder more chances to fulfill other utilities tunnel crowdfunding in the future.

2.2. The Duration and Convexity for Crowdfunding Based on Debt. Assume bond interest for the utilities tunnel project is paid \( V \) times in one year with time period \( T_m \), and \( \theta \) is the variable to count the payment times in \( n \) years.

The duration investment period discount of bond crowdfunding for par value is as follows:

\[
\Phi_4 = \frac{\sum_{j=1}^{n^{\nu-1}} (\theta T_m UC_r/V^2)}{(1 + R_{T_j})^\theta}.
\]  

(17)

The duration investment discount at the end of bond crowdfunding for par value is as follows:

\[
\Phi_5 = \alpha T_m U \left( \frac{C_r/V + 1}{(1 + R_{T_j})^{aV}} \right).
\]  

(18)

The investment period discount of bond crowdfunding is as follows:

\[
\Phi_6 = \sum_{\theta=1}^{aV} (UC_r/V) \left( \frac{1 + R_{T_j}}{1 + R_{T_{1}}^{aV}} \right)^\theta.
\]  

(19)

The investment discount at the end of bond crowdfunding is as follows:

\[
\Phi_7 = U \left( \frac{C_r/V + 1}{(1 + R_{T_j})^{aV}} \right).
\]  

(20)

The Macaulay duration for bond crowdfunding of utilities tunnel project is as follows:

\[
M = \frac{(\Phi_4 + \Phi_5)}{(\Phi_6 + \Phi_7)}
\]  

(21)

The convexity investment period discount of bond crowdfunding is as follows:

\[
\Phi_8 = \sum_{\theta=1}^{aV} (\theta(\theta + 1)UC_r/V) \left( \frac{1 + R_{T_j}}{1 + R_{T_{1}}^{aV+2}} \right)^\theta.
\]  

(22)

The convexity investment discount at the end of bond crowdfunding is as follows:

\[
\Phi_9 = \frac{aV(aV + 1)U}{(1 + R_{T_j})^{aV+2}}.
\]  

(23)

The convexity of bond crowdfunding for utilities tunnel project is as follows:

\[
C_b = \Phi_8 + \Phi_9.
\]  

(24)

Bond crowdfunding should optimize the Macaulay duration and convexity for the utilities tunnel project. The backers of bond crowdfunding for the project want to recycle the pledged capital \( \sum_{j=1}^{n} \varphi Q_S \) in a relatively short time, and they need a small Macaulay duration. The founder of bond crowdfunding will fulfill the operation, maintenance, and management of utilities tunnel after the delivery of project, and he/she need to choose suitable Macaulay duration to coordinate operation revenue and cost for long running of the utilities tunnel project. Suitable convexity of bond crowdfunding is also needed to improve bond price and management for the utilities tunnel project.

2.3. Simulation Analysis of Crowd Funding Based on Debt for Utilities Tunnel Project. Assume the financial capital is from \( n = 100 \) backers, and one backer supplies \( Q_S = 2000 \) numbers of basic unit \( \varphi = 5 \) dollars. Then, the total pledged capital \( I_S \) is one million dollars for the utilities tunnel project, which surpasses the pledged goal \( K = 0.8 \) million dollars. For crowdfunding platform of the utilities tunnel project with “All-or-Nothing” type, the usage fee rate is \( \eta = 5\% \). Then, the platform can get usage fee \( F_K = 50000 \), and the founder of the utilities tunnel project can get pledged capital 0.95 million dollars. For different conditions of pledged capital, the investment revenue rate \( H_S \) of the backers changes, and 13 simple cases are chosen to compute the investment revenue rate. Table 1 lists statistical description of main variables of crowdfunding based on debt.

Figure 3 lists the average annual investment revenue rate \( H_S \) of the backers for 13 simple cases. For same delivery period \( T_{\gamma_0} \) and same term to maturity \( \alpha \), the investment revenue rate is mainly decided by maturity revenue rate \( R_{T_j} \) and annual interest rate \( C_r \). Case 13 has maximum investment revenue rate 3.78%, and case 6 has minimum investment revenue rate 1.53%. Comparing with maturity revenue rate curve and annual interest rate curve, investment revenue rate curve is flatter, whose mean is 2.79% and standard deviation is the smallest.

3. Analysis of Crowdfunding Mode Based on Equity for the Utilities Tunnel Project

The second type is crowdfunding based on stock. Project backers for utilities tunnel as investors supply equity investment to crowdfunding project, and project founder does not have the duty to repay the pledged capital, while it may give certain amount dividend to backers, which comes from the profit after the delivery of project. The backers of debt crowdfunding mainly acquire fixed interest revenue from crowdfunding investment, while the backers of equity crowdfunding mainly acquire changeable dividend, capital revenue, and management vote right. The founder of equity crowdfunding for utilities tunnel is organizations, while the backers of utilities tunnel crowdfunding are usually individuals. This kind of crowdfunding company is usually not listed company.
Ahlers et al. [24] give a definition that equity crowdfunding is a method of financing whereby an entrepreneur sells equity or equity-like shares in a company to a group of small investors through an open call for funding on Internet-based platforms. Walker [25] points out that equity crowdfunding is the process whereby people invest in an early-stage, unlisted company in exchange for shares in that company. Butticè and Vismara [26] compare equity crowdfunding with traditional sources of entrepreneurial finance and find that the online dimension of equity crowdfunding offerings reduces the costs for entrepreneurial ventures to raise funds.

Because of the special character of equity crowdfunding, the cases for equity crowdfunding fulfillment are different in different countries. Some countries permit to operate equity crowdfunding projects on crowdfunding platform, while other countries do not permit to operate equity crowdfunding projects on crowdfunding platform now. There are still some countries that permit to give profit shares to the backers of equity crowdfunding project, but prohibit giving vote rights to the backers of equity crowdfunding project. Pekmezovic and Walker [27] point out that business angels refrain from buying common shares without voting rights, which tend to be common in crowdfunding. Crowdfunding investors do not participate on the boards of crowdfunded firms, and owing to small equity stakes, they may lack the necessary incentives to participate in the monitoring of the internal governance of the invested firms.

The tendency of equity crowdfunding is that it grows rapidly as legal barriers are being relaxed in many countries [24]. In 2015, Malaysia became the first Asia-Pacific country legislating equity crowdfunding, with six platforms approved [25].

### 3.1. Equity Crowdfunding with Dividend for the Utilities Tunnel Project

The backers of equity crowdfunding for the utilities tunnel project supply pledged stock capital without the tendency of equity crowdfunding is that it grows rapidly as legal barriers are being relaxed in many countries [24]. In 2015, Malaysia became the first Asia-Pacific country legislating equity crowdfunding, with six platforms approved [25].
the aim of refunding this investment capital. They can get dividend from project revenue according to dividend rate $g_D$ for stock par value $U$ and can take part in the management decisions for utilities tunnel crowdfunding. If founder of equity crowdfunding for utilities tunnel project believes this project will have good prospect and strong profit acquiring ability, the founder can regulate the issuing price $S_p > U$. If founder of equity crowdfunding for utilities tunnel project thinks it is better to give certain discount to the backers of equity crowdfunding to acquire pledged goal $K$ timely, the founder can regulate the issuing price $S_p < U$. Assume the founder regulates the issuing price $S_p = U$ for simplicity of analysis.

The dividend discount at delivery date for par value of equity crowdfunding is as follows:

$$D_S = \frac{U g_D}{R_T \left(1 + R_{T_D}\right)}$$

(25)

The dividend paid to $S_i$ backer of equity crowdfunding for utilities tunnel project with "All-or-Nothing" type is as follows:

$$D_S = \left\{ \sum_{j=1}^{n} \varphi Q_{S_j} (1 - \eta_1) + \sum_{j=1}^{n} \varphi Q_{S_j} (\eta_1 - \eta_2) \left( \sum_{j=1}^{n} \varphi Q_{S_j} \geq K \right) \right\} g_D$$

(30)

The revenue rate of equity crowdfunding backers for utilities tunnel project becomes

$$H_S = \frac{\sum_{j=1}^{n} \varphi Q_{S_j} (1 - \eta_1) + \sum_{j=1}^{n} \varphi Q_{S_j} (\eta_1 - \eta_2) \left( \sum_{j=1}^{n} \varphi Q_{S_j} \geq K \right) \varphi Q_{S_j}}{\sum_{j=1}^{n} \varphi Q_{S_j} \Phi_{11}} g_D$$

(31)

If the utilities tunnel project has strong profit acquiring ability, the dividend is assumed to increase at $g_l$ rate. The dividend discount at delivery date for par value of equity crowdfunding becomes

$$D_S = \frac{U g_D}{R_T \left(1 + R_{T_D}\right)}$$

(32)

The dividend discount rate of equity crowdfunding is as follows:

$$\Phi_{12} = \left( R_T - g_l \right) \left(1 + R_{T_D}\right)$$

(33)

The discount rate at delivery date of equity crowdfunding is as follows:

$$\Phi_{11} = \frac{\sum_{j=1}^{n} \Phi_{10}}{\Phi_{11}}$$

(27)

The backers of equity crowdfunding for the utilities tunnel project can get dividend

$$D_S = \frac{\sum_{j=1}^{n} \Phi_{10}}{\Phi_{11}}$$

(28)

The revenue rate of equity crowdfunding backers for the utilities tunnel project with "Keep-it-All" type can get dividend

$$H_S = \frac{\sum_{j=1}^{n} \Phi_{10}}{\Phi_{11} \sum_{j=1}^{n} \varphi Q_{S_j}}$$

(29)

The backers of equity crowdfunding for the utilities tunnel project with "All-or-Nothing" type can get dividend

$$D_S = \left\{ \sum_{j=1}^{n} \varphi Q_{S_j} (1 - \eta_1) + \sum_{j=1}^{n} \varphi Q_{S_j} (\eta_1 - \eta_2) \left( \sum_{j=1}^{n} \varphi Q_{S_j} \geq K \right) \right\} g_D$$

(30)

The dividend acquired by the backers of equity crowdfunding for the utilities tunnel project with "All-or-Nothing" type becomes

$$D_S = \frac{\sum_{j=1}^{n} \Phi_{10}}{\Phi_{12}}$$

(34)

The investment revenue rate of the backers of equity crowdfunding for the utilities tunnel project becomes

$$H_S = \frac{\sum_{j=1}^{n} \Phi_{10}}{\Phi_{12} \sum_{j=1}^{n} \varphi Q_{S_j}}$$

(35)
The dividend acquired by the backers of equity crowdfunding for the utilities tunnel project with "Keep-it-All" type becomes

$$D_S = \frac{\left\{ \sum_{j=1}^{n} \Phi Q_S (1 - \eta_1) + \sum_{j=1}^{n} \Phi Q_S (\eta_1 - \eta_2) I(\sum_{j=1}^{n} \Phi Q_S \geq K) \right\} g_D}{\Phi_{12}} \tag{36}$$

The investment revenue rate of the backers of equity crowdfunding becomes

$$H_S = \frac{\left\{ \sum_{j=1}^{n} \Phi Q_S (1 - \eta_1) + \sum_{j=1}^{n} \Phi Q_S (\eta_1 - \eta_2) I(\sum_{j=1}^{n} \Phi Q_S \geq K) \right\} g_D}{\sum_{j=1}^{n} \Phi Q_S \Phi_{12}} \tag{37}$$

3.2. Equity Crowdfunding with Dividend and Capital Revenue for the Utilities Tunnel Project. If the backers of equity crowdfunding for the utilities tunnel project sell the stocks at price $S_j$ at $\pi$ period, they will get capital revenue for equity crowdfunding. The dividend at delivery date for par value of $j$ backer is ($\pi S_j$ is the period $j$ backer sells the stocks) as follows:

$$D_S = U g_D \left( 1 - \frac{1}{\left( 1 + R_T \right)^{\pi_S}} \right) \phi Q_S \Phi_{11} \tag{38}$$

The backers of equity crowdfunding for the utilities tunnel project with "All-or-Nothing" type can get dividend

$$D_S = \sum_{j=1}^{n} \phi Q_S (1 - \eta_1) + \sum_{j=1}^{n} \phi Q_S (\eta_1 - \eta_2) I(\sum_{j=1}^{n} \phi Q_S \geq K) \left\{ 1 - \frac{1}{\left( 1 + R_T \right)^{\pi_S}} \right\} g_D \phi Q_S \Phi_{11} \tag{39}$$

The discount rate of capital revenue of par value for equity crowdfunding is as follows:

$$\Phi_{13} = \left( 1 + R_T \right)^{\pi_S} \left( 1 + R_T \right)^{\pi_S} \tag{40}$$

The capital revenue of backers for equity crowdfunding is as follows:

$$C_S = \sum_{j=1}^{n} \Phi S_j \left( - U \right) \Phi_{13} \tag{41}$$

The investment revenue rate of the backers of equity crowdfunding is as follows:

$$H_S = \frac{\left( D_S + C_S \right)}{\sum_{j=1}^{n} \phi Q_S} \tag{42}$$

The backers of equity crowdfunding for the utilities tunnel project with "Keep-it-All" type can get dividend

$$C_S = \sum_{j=1}^{n} \phi Q_S (\eta_1 - \eta_2) I(\sum_{j=1}^{n} \phi Q_S \geq K) \left\{ \frac{S_j - U}{U \Phi_{13}} \right\} \tag{43}$$

The capital revenue of backers for equity crowdfunding becomes

$$C_S = \sum_{j=1}^{n} \phi Q_S (1 - \eta_1) + \sum_{j=1}^{n} \phi Q_S (\eta_1 - \eta_2) I(\sum_{j=1}^{n} \phi Q_S \geq K) \left\{ \frac{S_j - U}{U \Phi_{13}} \right\} \tag{44}$$
The investment revenue rate of backers for equity crowdfunding becomes

\[ H_S = \frac{(D_S + C_S)}{\sum_{j=1}^{\eta} \varphi Q_{S_j}} \]  

(45)

If the utilities tunnel project has strong profit acquiring ability, the dividend is assumed to increase at \( g_i \) rate. The \( j \) backer of equity crowdfunding can get dividend

\[ D_{S_j} = U g_D \frac{\left( 1 - \left( \frac{1}{1 + g_i} \right) \left( 1 + R_{T_j} \right)^{\eta_j} \right)}{\Phi_{12}} \]  

(46)

The total dividend of the backers for equity crowdfunding with “All-or-Nothing” type becomes

\[ D_{S1} = \sum_{j=1}^{n} \Phi_{10} \frac{\left( 1 - \left( \frac{1}{1 + g_i} \right) \left( 1 + R_{T_j} \right)^{\eta_j} \right)}{\Phi_{12}} \]  

(47)

The capital revenue of the backers for equity crowdfunding becomes

\[ C_S = \sum_{j=1}^{n} \Phi_{13} \frac{\left( S_j - U \right)}{U \phi_{13}} \]  

(48)

The investment revenue rate of the backers for equity crowdfunding becomes

\[ H_S = \frac{(D_{S1} + C_S)}{\sum_{j=1}^{n} \varphi Q_{S_j}} \]  

(49)

The total dividend of the backers for equity crowdfunding with “Keep-it-All” type becomes

\[ D_{S1} = \left\{ \sum_{j=1}^{n} \varphi Q_{S_j} (1 - \eta_1) + \sum_{j=1}^{n} \varphi Q_{S_j} (\eta_1 - \eta_2) \right\} \left( \sum_{j=1}^{n} \varphi Q_{S_j} \geq K \right) \frac{\left( 1 - \left( \frac{1}{1 + g_i} \right) \left( 1 + R_{T_j} \right)^{\eta_j} \right) g_D}{\Phi_{12}} \]  

(50)

The capital revenue of the backers for equity crowdfunding becomes

\[ C_S = \left\{ \sum_{j=1}^{n} \varphi Q_{S_j} (1 - \eta_1) + \sum_{j=1}^{n} \varphi Q_{S_j} (\eta_1 - \eta_2) \right\} \left( \sum_{j=1}^{n} \varphi Q_{S_j} \geq K \right) \frac{\left( S_j - U \right)}{U \phi_{13}} \]  

(51)

3.3. Simulation Analysis of Crowdfunding Based on Equity for the Utilities Tunnel Project. Assume the financial capital is from \( n = 100 \) backers, and one backer supplies \( Q_{S_j} = 2000 \) numbers of basic unit \( \varphi = 5 \) dollars. Then, the total pledged capital \( I_S \) is one million dollars for the utilities tunnel project, which surpasses the pledged goal \( K \geq 0.8 \) million dollars. For crowdfunding platform of the utilities tunnel project with “All-or-Nothing” type, the usage fee rate is \( \eta = 5\% \). Then, the platform can get usage fee \( F_K = 50000 \), and the founder of utilities tunnel project can get pledged capital 0.95 million dollars. Assume the backers hold the stock of the utilities tunnel project for unlimited period and no consideration of capital revenue, and the project gives dividend to the backers according to fixed dividend rate \( g_D \). 12 simple cases are chosen to compute the investment revenue rate \( H_S \). Table 2 lists statistical description of main variables of crowdfunding based on equity. Figure 4 lists the total investment revenue rate \( H_S \) of the backers in holding period for 12 simple cases. For same delivery period \( R_{T_j} \), the investment revenue rate is mainly decided by maturity revenue rate \( R_{T_j} \) and dividend rate \( g_D \). Case 10 has maximum investment revenue rate 2.767 times, and Case 8 has minimum investment revenue rate 1.064 times. Comparing with maturity revenue rate curve and dividend rate curve, investment revenue rate curve is steeper, whose mean is 1.854 times and standard deviation is the biggest.
4. Analysis of Crowdfunding Mode Based on Reward and Crowdfunding Mode Based on Donation for the Utilities Tunnel Project

Debt crowdfunding and equity crowdfunding are two typical crowdfunding modes for the utilities tunnel project. In addition to these two types, there are other two types of crowdfunding for the utilities tunnel project.

4.1. Crowdfunding Mode Based on Reward for the Utilities Tunnel Project.

The third type is crowdfunding based on reward for the utilities tunnel project. The project backers supply pledged capital \( \sum_{j=1}^{n} Q_{S_j} \) to the project with the requirement of some noncash rewards after the delivery of project. In some cases, this reward may be a project product, which is supplied to backers after the delivery of project. In other cases, this reward may be reputation compensated to backer; for example, the backer’s name is listed in the crowdfunding film. When the utilities tunnel project uses crowdfunding mode to pledge the capital, the founder of crowdfunding for utilities tunnel project can give some products to the backers of crowdfunding. Read [31] explains nonprofits (no cash return) is more successful than other crowdfunding styles and nonprofits could do better by using physical rewards to express how the funds were allocated.

Utilities tunnel project is a complicated large-scale engineering, and many pipelines are laid inside the corridors. These infrastructure pipelines are necessary for people to live and work in cities, and the important role of utilities tunnel is to transport energy to the people in cities. The main users of utilities tunnel are pipeline using units. To arrive at pledged goal \( K \) through crowdfunding mode, pipeline using units can give free energy products or low price energy products to backers of crowdfunding after the delivery of utilities tunnel project. The backers of reward crowdfunding for the utilities tunnel project supply pledged capital \( \sum_{j=1}^{n} Q_{S_j} \) to the crowdfunding project, and the founder has

Table 2: Statistical description of main variables of crowdfunding based on equity.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dividend rate ( g_d )</td>
<td>7.00%</td>
<td>0.0165145</td>
<td>5.00%</td>
<td>9.00%</td>
</tr>
<tr>
<td>Maturity revenue rate ( R_T )</td>
<td>3.75%</td>
<td>0.0154479</td>
<td>2.00%</td>
<td>6.00%</td>
</tr>
<tr>
<td>Investment revenue rate ( H_S )</td>
<td>1.854</td>
<td>0.6812145</td>
<td>1.064</td>
<td>2.767</td>
</tr>
</tbody>
</table>

Figure 4: The investment revenue rate \( H_S \) of the backers of crowdfunding based on equity. 12 simple cases are chosen to compute the investment revenue rate. Cases 1–4 are that the utilities tunnel project will be delivered at \( R_T = 2 \) period. To compute investment revenue rate, the different conditions of pledged capital are as follows: Case 1: \( U = 10, g_D = 5\% \), and \( R_T = 2\% \); Case 2: \( U = 10, g_D = 8\% \), and \( R_T = 6\% \); Case 3: \( U = 10, g_D = 6\% \), and \( R_T = 4\% \); Case 4: \( U = 10, g_D = 9\% \), and \( R_T = 3\% \). Cases 5–8 are that the utilities tunnel project will be delivered at \( R_T = 3 \) period. The different conditions of pledged capital are as follows: Case 5: \( U = 10, g_D = 6\% \), and \( R_T = 4\% \); Case 6: \( U = 10, g_D = 5\% \), and \( R_T = 2\% \); Case 7: \( U = 10, g_D = 9\% \), and \( R_T = 3\% \); Case 8: \( U = 10, g_D = 8\% \), and \( R_T = 6\% \). Cases 9–12 are that the utilities tunnel project will be delivered at \( R_T = 1 \) period. The different conditions of pledged capital are as follows: Case 9: \( U = 10, g_D = 6\% \), and \( R_T = 4\% \); Case 10: \( U = 10, g_D = 9\% \), and \( R_T = 3\% \); Case 11: \( U = 10, g_D = 8\% \), and \( R_T = 6\% \); Case 12: \( U = 10, g_D = 5\% \), and \( R_T = 2\% \).
not the duty to refund the pledged capital to backers. The crowdfunding founder of the utilities tunnel project can give future products to backers as reward.

Assume pipeline using units give \( c(c = 1, 2 \ldots m) \) free energy products or low price energy products to backers for reward crowdfunding. The energy product price \( P_c \) is continuous function of utilities tunnel demand \( Q_T \):

\[
P_c = f_c(Q_T).
\] (53)

The discount rate of energy product is \( d_c(\varphi; P_c) \) for \( c \) energy product price \( P_c \) \((d_c(\varphi; P_c) \in (0, 1))\). \( d_c(\varphi; P_c) = 1 \) means pipeline using units give free \( c \) energy product to backers of reward crowdfunding.

The energy product price \( P_c \) is satisfied with

\[
dP_c(Q_T) \equiv \mu_c(t)P_c(Q_T)dt + \delta_c(t)P_c(Q_T)dW_S.
\] (54)

\( \mu_c(t) \) and \( \delta_c(t) \) are mean and standard deviation of energy product price \( P_c(Q_T) \) at time \( t \). \( dW_S \) is satisfied with stochastic process of standard Brown motion.

The variation of energy product price \( P_c \) is usually not independent, and energy product prices of stochastic time series among different periods are autocorrelated. The autoregressive time series for energy product price \( AR(p) \) is satisfied with

\[
P_c(Q_T) = \beta_0 + \beta_1 P_c(Q_T)_{t-1} + \beta_2 P_c(Q_T)_{t-2} + \cdots + \beta_p P_c(Q_T)_{t-p} + \epsilon_c(t).
\] (55)

Energy product price \( P_c \) is usually a process of martingale, and stochastic error term \( \epsilon_c(t) \) is not white noise.

\[
E(P_c(Q_T)|P_c(Q_T)_{t-1}, P_c(Q_T)_{t-2}, \ldots P_c(Q_T)_{t-p}) = P_c(Q_T)_{t-1}.
\] (56)

The first-order lag term of energy product price \( P_c \) is as follows:

\[
P_c(Q_T)_{t-1} = \beta_0 + \beta_1 P_c(Q_T)_{t-2} + \beta_2 P_c(Q_T)_{t-3} + \cdots + \beta_p P_c(Q_T)_{t-p-1} + \epsilon_c(t-1).
\] (57)

The first differentiation term of energy product price \( P_c \) is as follows:

\[
\Delta P_c(Q_T) = \begin{bmatrix} \beta_1 & \beta_2 & \ldots & \beta_p \end{bmatrix} \begin{bmatrix} P_c(Q_T)_{t-1} & P_c(Q_T)_{t-2} & \ldots & P_c(Q_T)_{t-p} \end{bmatrix} + \epsilon_c(t).
\] (58)

The first differentiation term of energy product price \( P_c \) is usually without unit root and becomes stationary time series, and this differentiation makes \( P_c \) be a stationary martingale process.

Assume pipeline using units give free or low price energy products to backers of reward crowdfunding for \( \lambda = 1, 2, \ldots q \) years. The reward for backers of crowdfunding at \( \lambda \) year with “All-or-Nothing” type is as follows:

\[
D_{E_\lambda} = \sum_{j=1}^{m} \left\{ \sum_{j=1}^{m} E(P_c(Q_T)_{t})d_c(\varphi; P_c)Q_{S_j}(1-\eta) + \sum_{j=1}^{m} Q_{S_j}(\eta_1-\eta_2)I \left( \sum_{j=1}^{m} \varphi Q_{S_j} \geq K \right) \right\}_{l_1}.
\] (64)

The reward for backers of crowdfunding at \( \lambda \) year with “Keep-it-All” type is as follows:

\[
\Phi_{15} = \sum_{i=1}^{q} \frac{D_{E_\lambda}^{I_1}}{(1+R_{\lambda})^{l_1}(1+R_{\lambda}))}.
\] (65)
The reward divided by investment for crowdfunding backers becomes 

\[ R_E = \frac{\Phi_{15}}{\sum_{j=1}^{n} \phi Q_S_j} \]  

(66)

4.2. Crowdfunding Mode Based on Donation for the Utilities Tunnel Project. The fourth type is crowdfunding based on donation for the utilities tunnel project. The backers of this kind of crowdfunding are completely philanthropic to supply the pledged capital to the utilities tunnel project. They need not any reward for the supply of pledged capital. Because the utilities tunnel project transports important energy to the people in the cities, the fulfillment of utilities tunnel project will be beneficial for people to live and work in cities. Many backers supply free pledged capital to crowdfunding for the utilities tunnel project. The ratio of bond revenue with interest divided by pledged capital for utilities tunnel project is as follows:

\[ R_B = \sum_{j=1}^{n} \phi Q_{S_2} \frac{(1 - \eta_2)(\Phi_1 + \Phi_2)}{(1 + R_{T16})\Phi_1} \]  

(69)

The ratio of bond revenue without interest divided by pledged capital is as follows:

\[ R_B = \sum_{j=1}^{n} \phi Q_{S_2} \frac{(1 - \eta_2)\Phi_2}{(1 + R_{T16})\Phi_1} \]  

(70)

For crowdfunding with “All-or-Nothing” type, the founder of crowdfunding can get pledged capital

\[ I_D = \Phi_{16} (1 - \eta). \]  

(68)

4.3. Crowdfunding Mode Based on Donation for the Utilities Tunnel Project. The fourth type is crowdfunding based on donation for the utilities tunnel project. The ratio of bond revenue divided by invested capital for utilities tunnel project is as follows:

\[ I_D = \Phi_{16} (1 - \eta_1) + \Phi_{16} (\eta_1 - \eta_2) I (\Phi_{16} \geq K). \]  

(71)

The ratio of bond revenue with interest divided by pledged capital becomes

\[ R_B = \sum_{j=1}^{n} \phi Q_{S_2} \frac{(1 - \eta_1) + \sum_{j=1}^{n} \phi Q_{S_2} (\eta_1 - \eta_2) I (\Phi_{16} \geq K))}{(1 + R_{T16})\Phi_1} \]  

(72)

The ratio of bond revenue without interest divided by pledged capital becomes

\[ R_B = \sum_{j=1}^{n} \phi Q_{S_2} \frac{(1 - \eta_1) + \sum_{j=1}^{n} \phi Q_{S_2} (\eta_1 - \eta_2) I (\Phi_{16} \geq K))}{1 + R_{T16} \Phi_1} \]  

(73)

5. Conclusions

This paper uses an exploratory pledging framework of crowdfunding to analyze the mode, procedure, and management for the utilities tunnel project. For Kickstarter as the largest crowdfunding platform in the world, this paper analyzes the status of 15 categories for crowdfunding projects. To the number of launched projects on the platform, the maximum is Film & Video projects, while the minimum is Dance projects. For the two types of “All-or-Nothing” and “Keep-it-All” crowdfunding platforms, the process and management among debt crowdfunding, equity crowdfunding, reward crowdfunding, and donation crowdfunding should be differentiated. Simulation analysis of crowdfunding based on debt shows that comparing with maturity revenue rate curve and annual interest rate curve, average annual investment revenue rate curve is flatter. Simulation analysis of crowdfunding based on equity shows that comparing with maturity revenue rate curve and dividend rate curve, the total investment revenue rate curve is steeper.

Flexible choice and usage of these four types of crowdfunding modes will decrease pledged time and increase pledged efficiency for the utilities tunnel project. Because there are not empirical crowdfunding data for utilities tunnel, quantitative empirical analysis on crowdfunding for utilities tunnel is impossible now. The future research can consider quantitative analysis after acquiring
crowdfunding data for utilities tunnel, such as the analysis on the influence factors for the success rate of utilities tunnel crowdfunding.

**Data Availability**

The data computed and processed in this paper come from Kickstarter platform website. The Stata software and the SPSS software are used to compute and analyze the data of crowdfunding development status and simulation analyses of crowdfunding based on debt and crowdfunding based on equity.

**Conflicts of Interest**

The authors declare that they have no conflicts of interest.

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**References**


