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A methodology for strategy-oriented project portfolio selection taking dynamic synergy into considerations

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Abstract The selection of an optimal project portfolio from multiple project proposals to implement management strategy is always a challenge task for project managers, especially, in the selection of large-scale and complicated projects. This is particular true because project portfolio selection decisions have to be made based on complicated evolution, comprehensive strategic criteria and dynamic synergies. This paper presents a proposed methodology of system dynamic model with consideration of dynamic synergies to predict the value of strategic realization through project portfolio implementation. This method can be applied in the project portfolio selection process, which consists of three procedures: project elimination by resource constraints, project functional value determination and system dynamics approach modelling simulation. In this case, dynamic synergy considerations can help to produce more rational selection results while strategy-oriented selection can ensure that the selected project portfolio aligns with a company's strategy. A case study is used to demonstrate the application of the proposed methodology. The results show that the proposed method can help project managers to select an optimal project portfolio with maximal strategic criteria. The proposed method can be incorporated into expert systems in the organizations to enhance the organizational objective priorities in the decision-making process.

1. Introduction

Project portfolio selection (PPS) is a decision-making process to select a set of projects from candidate projects, which can strengthen enterprise competitive advantages and fulfill the stated strategy to meet sustainable development in the organization [10,8]. Effective use of PPS can help project managers and experts in the decision-making process to choose an optimal project portfolio according to significant objectives of the

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projects [1] and to ensure a successful execution within the resources available in the organization [55]. An enterprise usually depends on the definition and implementation of the project portfolio selection criteria established in the organisation to accomplish its strategy [2], which helps the company to select a suitable project portfolio to implement the strategy [58] by sustainably generating project value for its shareholders, employees and customers [33]. Therefore, strategy-oriented PPS is important that makes a significant precondition to guarantee for strategy implementation in the organization.

Many PPS frameworks have been developed in the literature that focus on selecting an optimal project portfolio, which can best align with the organization's strategic priorities [21,39]. To select an optimal project portfolio and avoid strategic loss, Bai et al. [5] proposed a robust project portfolio selection method that focuses on the impacts of historical performances of projects in the project portfolio selection process. Zhang et al. [61] developed a hybrid project portfolio selection procedure, which helps the organizations to select robust project portfolios for their long-term strategies. Two types of models were proposed respectively by Dou et al. [16] based on single and multi-objectives to select the optimal portfolio to maximize objective values. However, these approaches are not always suitable for two main reasons [40]: (i) evolutional and comprehensive strategy regulates the criteria to select project portfolios, but poorly selected criteria could hinder portfolio implementation to reach its strategy [25], (ii) There may exist complicated and dynamical synergies [44] among candidate projects, which can be easily omitted by mistake in PPS and this is quite common that will affect PPS decision making [4]. However, the best project when taking individually, may not necessarily form the best set of projects when taken as a group of projects in project portfolio.

The difficulties in PPS decision-making process are from the establishment of evolutional and comprehensive strategic criteria. The evolutional strategy could be affected by assessment criteria when transforming strategy into criteria for PPS, in turn, alter the PPS results. For example, financial target is an important issue to maximize the benefits from the projects in the strategic criteria to select optimal project portfolio [6]. However, over-reliance on the financial selection criteria may conflict with organizational long-term development objectives [4]. Therefore, an organizational strategy not only includes the combination of financial and non-financial targets, but also must include long- and short-term plans, and the internal and external stakeholder management that all need to be considered in PPS process. As stated above, selection criteria of the project portfolio should include a wide range of targets such as sustainable development of the organization that aligns with the strategy of the organization. The major challenge is how to design comprehensive criteria for PPS in decision-making process which can reflect to organizational strategy.

Furthermore, dynamic synergies among the candidate projects to be selected also reinforce the difficulty of the choice of the optimal project portfolio in PPS process. Early studies usually considered the candidate projects separately in PPS process [12], which each project is considered separately and has no relationship linked with other projects. However, this is not true because the candidate projects may link to each other and perform better in PPS because of synergies. For example, as stated earlier in this paper, a best candidate project when considering individually, may not necessarily form the best set of projects in a group of a project portfolio [53]. Therefore, many studies have recognized that synergies have significant impacts on PPS after explored the complex interactions among the candidate projects [28,40,54]. Some scholars proposed the synergy degree models to estimate synergy degrees of group projects [6,21]. The results showed if a project had a higher synergy degree, this project would be a preferred project in PPS. To calculate the synergy degree, an expert scoring method was applied to evaluate the order parameters (primary parameters) as proposed by Zhang and An [62]. But, however, in some cases, the expert opinions may subjectively influence the results from PPS because these researches ignored the truth that synergies among the candidate projects evolved dynamically over the time and had significantly impacts on accuracy in PPS process. Therefore, it is necessary to explore synergy dynamical effects on the expected strategy to quantify the synergetic effects in PPS process. This study presented in this paper also addresses this issue as described above towards bridging the existing knowledge gap between the literature and practice. The aim is to develop a method for selection of an optimal project portfolio from the candidate projects that maximizes strategy criteria, simultaneously, considers the dynamic synergic effects. In this study, a methodology for strategy-oriented project portfolio taking dynamic synergy into consideration has been developed in which intricates dynamic relationships among the candidate projects can be embodied in the PPS process.

Additionally, the PPS must be conducted in a virtual environment before implementing the project portfolios in a real-world setting [21]. The system dynamics developed by Yu et al. [59] is used to solve problems of production and inventory management, which is an analytical simulation technique representing more explicitly nonlinear relationships, delay, and information feedback [57]. This approach has been widely applied in many areas, such as science and technology [59], control and engineering [17], and computer science [8]. With regards to strategic management, the system dynamics modelling approach has also been widely used to analyze and improve project performances [18,51]. In this study, the system dynamics modelling approach has been employed to study the equilibrium level of the proposed modelling methodology that can help project managers to achieve a greater comprehension of strategy realization through project portfolio execution. Simultaneously, the system dynamics modelling approach can also be used to measure how the synergies dynamically affect the strategy in the organization, to simulate different schemes (i.e., project portfolios), to predict values of strategic achievements, and to provide guidance for managers to evaluate projects and make judgments whether or not the portfolios should be rejected or invested.

It is obvious that the selection of an efficient project portfolio while satisfying the strategic objectives of a project and dealing with the dynamic synergies, is a momentous and challenging task. This paper presents a system dynamics approach (SDA) model to assess the realized value of strategy by project portfolio implementation in PPS process to support decision-making in which consists of (i) defining the concept of project function and establishing a project portfolio strategy index system; (ii) developing a causal loop diagram to analyze the synergetic relationships among projects, which is embodied in the process of strategic realization based on ‘function’ perspective; (iii) developing a method to quantify the complex relationships in which the stock-flow diagram is created in order to construct a SDA model for prediction of the value of strategic realization; and (iv) applying the proposed SDA model to PPS process that contains project elimination by resource constraints, functional value determination and modelling simulation. The significant contributions from this study can be summarized as follows:

- new portfolio selection criteria have been established in which consider sustainable strategic development in the organization,
- a SDA model has been developed to predict and measure the value of strategic realization,
- the positive promotion of dynamic synergy has been taken into strategy implementation analysis process qualitatively and the synergetic effects have been quantified by formulas and logic functions,
- The proposed method provides a great opportunity to incorporate it into expert systems in the organizations to enhance the organizational objective priorities with the criteria of maximal strategy in the decision-making process in which resource limits are taken into consideration.

The rest of this paper is structured as follows. Section 2 describes the proposed SDA model development. An illustrative example is used to demonstrate the effectiveness and feasibility of the proposed methodology is presented in Section 3 in which the PPS process and result analysis from simulations are also included in this section. Discussions of theoretical and managerial implications, and drawbacks are presented in Section 4. Finally, conclusions are presented in Section 5.

2. SDA model development

This section describes the process of SDA model development for the simulation of dynamical complicated strategy implementation in the organizations as the basis of portfolio selection, which focuses on generalizable model structures [26]. The proposed model can help to predict and measure the strategic realization situation via project portfolios execution by using strategic realization to measure project portfolios in order to select the appropriate project portfolio. Meanwhile, the pattern to process data (the value of project functions) of this model can be conducted in expert systems. The proposed model is formulated in three phases as shown in Fig. 1, i.e., Phase 1 is to establish the project portfolio strategy index system using the organizational ‘sustainability balanced scorecard’ (SBSC) approach and ‘systematic literature review’ (SLR) measures; Phase 2 is to develop the causal loop diagram based on analysis of the relationships among indices quantitatively; and Phase 3 is to develop the stock-flow diagram for execution of the computer-based simulation.

2.1. Phase 1: Strategy-oriented index system construction

Variable determination is the first step in the development of a SDA model. The indices in the project portfolio strategy index system have been developed in which consists of three layers, i.e., strategy layer, objective layer and the function layer. The three layers are interrelated and gradually progressed. The strategy layer is composed by the objective layer, which will be achieved by the function layer. The strategy layer includes indices to indicate organizational strategy covering the comprehensive programme and overall arrangement in the organization.

The objective layer contains indices that indicate goals of the strategy that the organization plans to achieve. “The Balanced Scorecard“ (BSC) [15,22,27] is applied to translate strategy into specific and measurable objectives in which includes a combination of financial and non-financial targets, and long- and short-term strategy to measure internal and external management, and to predict actions. The BSC has been widely applied in the modelling organizational strategy, but it omits the sustainable development in the organization such as environmental and moral issues. Noting the limitations, Sustainability balanced scorecard is introduced and employed in this study to transfer strategy to seven objectives from five perspectives as shown in Table 1, which are discussed below.

- **Finance perspective (F)** represents the quality of affording economic efficiencies. This perspective measures organizational success and focuses on maximizing profits in the organization.
- **Customer and market perspective (C)** indicates the relationship between an **organization** and its clients or customers to understand what customer needs, to offer their wants, and to keep them satisfied to expand market share in such a way so that financial objectives can be achieved.
- **Internal process perspective (I)** shows the development, maintenance and improvement of the organization in a well-established standard **operational** procedure for each activity including the management maturity objective. This perspective focuses on enhancement of management processes that may impact on the employee working efficiency.
- **Learning and innovation perspective (LI)** considers the development and innovation of technology and manufacture, and the learning process and growth of employees. The organization endeavor to improve **technology**, employee training and employee’s satisfaction to develop themselves steadily.
- **Sustainability perspective (S)** concentrates on foresight. This perspective is viewed as a critical development issue, namely, the operation should address environmental and societal prosperity such as compliance with environmental certifications, provision of economic assistance to persons in need.

The function layer contains indices to reflect the functions of candidate projects. As different projects in the portfolio contribute to the organizational strategy multifariously, the indices in function layer can be used to realize strategic objectives called as “functions” of projects to be achieved [63]. A systematic literature review is carried out to search the functions indices in this study. The paradigm indicators are shown in Table 1.

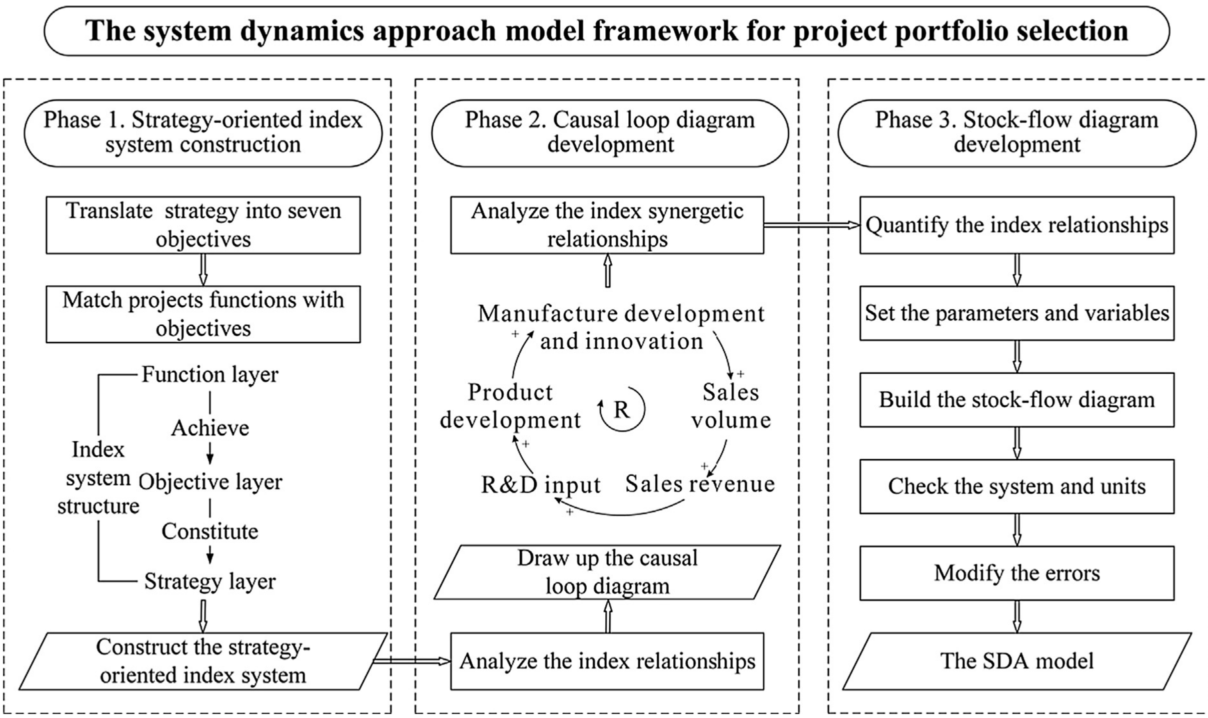

Fig. 1 The SDA model framework for project portfolio selection.

Table 1 The strategy index system.

Strategy layer	Perspectives	Objective Layer	Function Layer	References
Strategy	Finance	Profitability (**F**)	Increase profits	[41]
			Mitigate cost	[27]
	Customer and market	Customer satisfaction (**C**)	Predict customer preference	[15,60]
			Offer high quality of services	[14]
			Shortened order processing time	[49]
		Brand market value (**C**)	Expand market share	[47]
			Improve brand's value	[42,45]
	Internal process	Management maturity (**I**)	Establish standardization management system	[24,50]
			Creation of PM manuals	[20]
			Establish management information platform	[31]
	Learning and innovation	Manufacturer development and innovation (**LI**)	Improve efficiency of productivity	[9]
			Shorten lead time	[43]
			Improve quality of products	[29]
			Product development	[13]
		Employee development and innovation (**LI**)	Increase employees' satisfaction	[23,35]
			Enhance employees' ethics	[19]
			Improve knowledge and skills of employees	[3]
			Increase employees' acceptance of corporate culture	[38]
	Sustainability	Organization contribution (**S**)	Provision of social welfare	[11]
			Human resource management	[7,36]
			Environmental protection	[34]

2.2. Phase 2: Causal loop diagram development

The aim to develop the causal loop diagram (CLD) is to process the SDA model that can help to map the cause-and-effect relationships among variables and explore the causalities, loops, and feedback effects in the system [21]. In this study, the CLD has been developed and applied to analyze relationships of indices in three layers quantitatively, which are used as the basis for constructing the stock-flow diagram. The CLD considers how the strategy can be achieved via different project functions. The process of strategic realization is integrated in the proposed SDA model as shown in Fig. 2.

As can be seen in Fig. 2, the lines with symbolized polarity ‘ +’ indicate that the two related variables change in a same direction. The yellow lines with ‘-’ denote that the two linked variables vary in two different directions. The red lines show that the bidirectional connection of functions from different perspectives. For example, to increase customer satisfaction, sale volumes should be boosted. Arrows with five colures, i.e., black, blue, green, ultramarine and pink represent variables in five perspectives as described in Section 2.1.

There are ten feedback loops that represent the synergetic relationships of indices in Fig. 2. For example, with the addition of “*sale revenue*”, the benefit from project is substantially improved, and then the funds for *R&D input* are increased, and eventually, the consequence on the potential innovation capacity of products is that it contributes to “*Manufacture development and innovation*” objective. Once a positive loop is formed; the feedback effect of a positive loop is amplifying and self-reinforcing synergy.

2.3. Phase 3: Stock-flow diagram development

The CLD aids in visualizing a system structure and behavior, and analyzing the system qualitatively [56]. To perform a more detailed quantitative analysis and predict strategy realizations via project portfolios, a CLD needs to be transformed into a stock-flow diagram as shown in Fig. 3. This stock-flow diagram is constructed and tested by the Vensim DSS software [32] in order to validate the effectiveness of the developed CLD. The variable and parameter settings and the formulas used in this study are discussed below.

The variables are divided into state variables, auxiliary variables, rate variables and constants in combination with the SDA modelling simulation. Strategy of the organisation is set as the auxiliary variables. The four perspectives as stated in Section 2.1 are set as the state variables and accumulated with the time. The indices in the objective layer are set as the rate variables to reflect the state variable inputs and outputs speed, and the indices in the function layer are set as the auxiliary variables. For those variables having no change of values are classified as the constants. Usually, expert opinions and market research data are used to estimate the initial conditions and parameters [48,52]. As the aim of this study is to propose a SDA model for PPS which can be applied in real contexts, therefore, parameters discussed in this paper are set by using expert questionnaire based on the illustrative example as described in Section 3. However, parameters can be re-set by users based on their focuses and project conditions.

To quantify the realized function (RF) of projects with consideration of the synergetic effects it can be calculated by

$$RF = \sum_{i=1}^{n} VF + \sum_{i=1}^{n} SI \times VF \tag{1}$$

where RF represents the total realized value of project function implementation including the synergies generated from projects [28]. The VF denotes the project value created by a single project implementation. When projects are undertaken in parallel, they not only perform their own functions, but also create synergies. The positive effects caused by project resource sharing and scale merit behave as the increasing functions [30]. The second term of Eq. (1) represents the additional value of functions caused by synergies, which can be calculated by

$$SI = k/\left[1 + a \times e^{(b \times Times)}\right] \tag{2}$$

where the synergy index SI represents the synergy effect coefficients of project functions to quantify the synergetic effects, and a, b and k represent parameters of logistic s-shaped curve. For example, as described in Section 3, a, b and k are set as a = (1, 3, 2), b = (−0.1, −0.05, 0.075), and k = (0.015, 0.005,

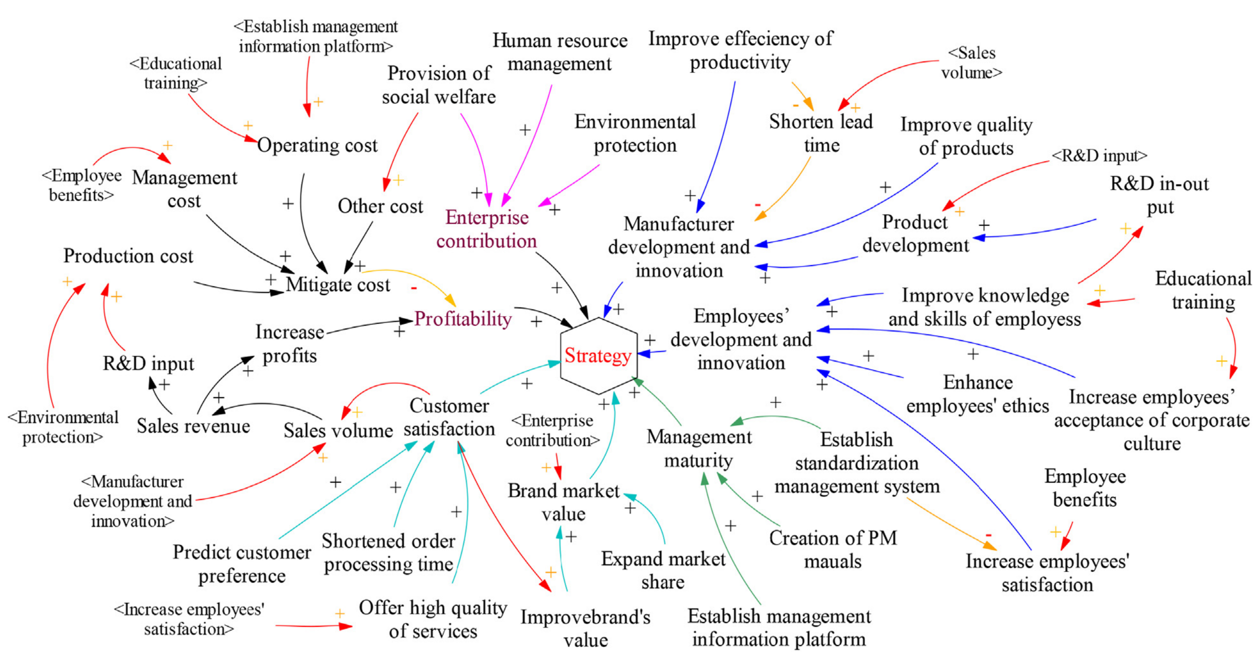

Fig. 2 Causal loop diagram of synergetic relationships.

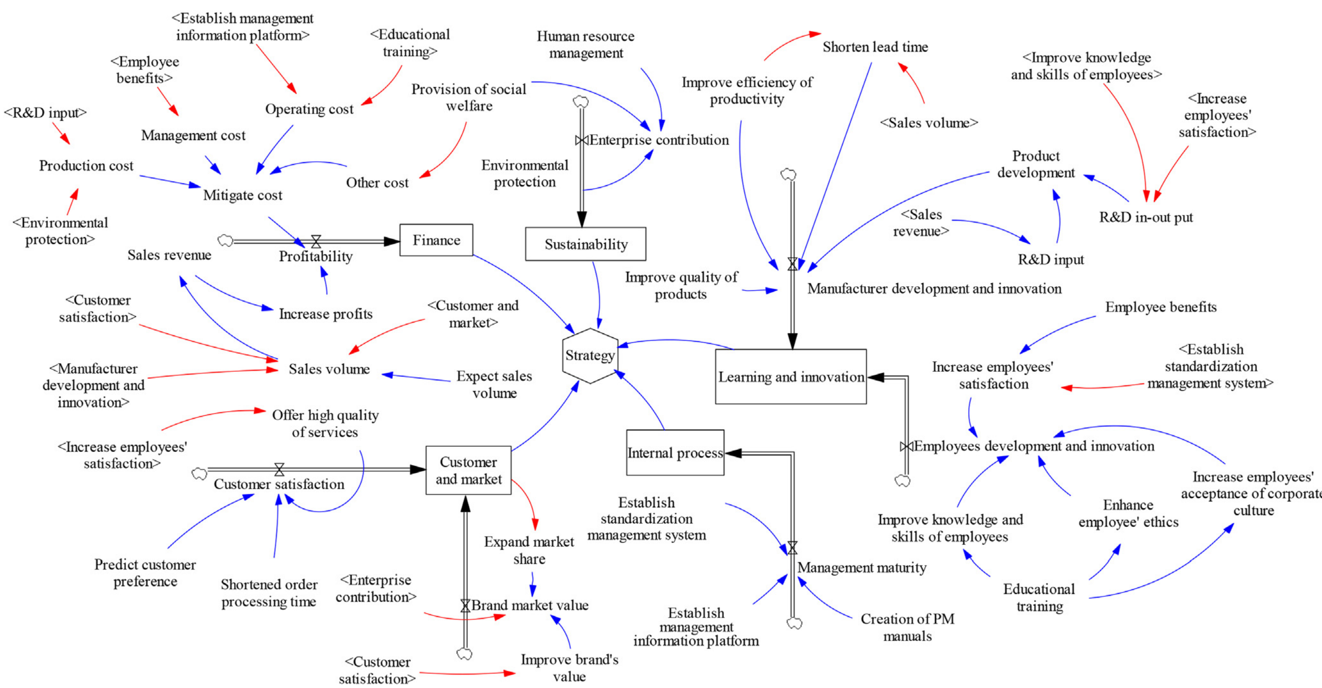

Fig. 3 Stock-flow diagram of strategy realization processes.

0.01) for the case study that are borrowed from literature [53] by using 'systematic literature review' measures. Then, the holistic synergic effects over time by multiplying the *VF* can be obtained.

Structural verification and behavioral validity of the SDA model have been undertaken to ensure the reliability of the proposed model. Structural verification has been conducted to imitate a real-life environment by using the unit check function of Vensim DSS [32] in which the influential factors have been counted and transformed into mathematic relations by functions. Behavioral validity aims to enhance model credibility with the participation of model stakeholders in which expert judgment method has been applied and consultations with five project practitioners having knowledge in their domains have been conducted.

3. Illustrative case example

This section describes a project portfolio selection process by using an illustrative case example to demonstrate the proposed PPS methodology in which consists of three parts, (i) the determination of desirable portfolios with the resource limits in the organization, (ii) evaluation of project functions, and (iii) analysis of results from SDA model simulation. The PPS process is shown in Fig. 4.

3.1. Background of case example

Company A is a manufacturing company and its business is mainly to provide manufacturing advisory service, and products for construction industry. The company employs 40 employees and has an approximate revenue of US$ 160 K and 24 production machines. In the project development phase, weaknesses of the company have been identified in overall strategic management such as funds deficiency and customer inadequacies. In this context, the objectives of *Company A* are refined to include gaining maximization of the financial value, escalating market share and customer satisfaction with resources that the company has. There are ten projects in hand, which *Company A* intends to select five out of ten projects and draw up schemes to decide the optimal project portfolio, which can maximize company's strategy. Table 2 shows the detailed information of such ten projects and Table 4 presents the resources consumptions of projects.

3.2. Process of project portfolio selection

3.2.1. Eliminate infeasible project portfolios due to resources constraint condition

The implementation of project portfolio requires various types of resources such as materials, workforces and funds. If a project exceeds the company's capability of resources, it needs to be eliminated. Due to flexible expenditures caused by resource sharing among candidate projects, the consumptions of project portfolio are not computed merely by calculating total cost of each project. Therefore, the elimination of projects is divided into two steps.

Step 1: Examination of each single project. If a single project requires more than available resources in the organization, it should be removed from the candidate project list. Table 2 presents the consumption data of each project. Clearly, Projects A (US$170 K) and C (US$180 K) exceed the total budget of US$160 K, respectively, and Project E requires the workforce that is more than workforce constrain of 40 employees the *Company A* has. Therefore, Projects A, C and E should be removed from the candidate project list, which only Projects B, D, F, G, H, I and J are suitable for *Company A* to choose five projects to formulate 21 project portfolios, i.e., $C_5^7/2 = 21$.

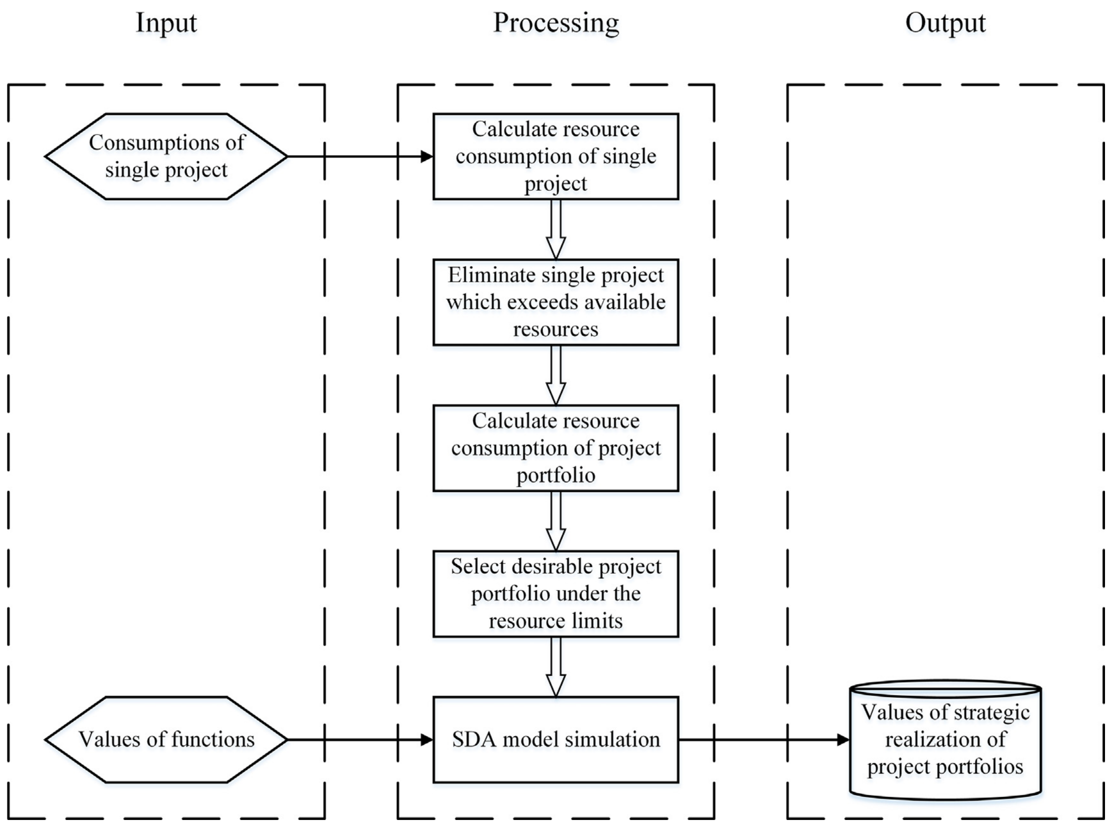

Fig. 4 Project portfolio selection process.

Table 2 Project details.

Project Type	A	B	C	D	E	F	G	H	I	J
Production machines (No.)	6	4	6	0	3	3	4	8	7	7
Workforces (No. of People)	11	12	8	8	45	6	9	3	10	5
FundsUS$(K)	170	40	180	28	50	25	30	24	45	15

Step 2: Once those projects that exceed available resources have been removed from the candidate project list, the multi-project assessment [46] needs to be applied by considering resources required for remaining projects. Screening project analysis can be applied to remove those remaining projects that exceed the total resource of *Company A*. Let$P = (P_1, P_2 ... P_i ... P_n)$denote the set of i candidate projects, where i is the number of projects. Suppose that the consumption of different resources required is $C = (C_1, C_2 ... C_j ... C_n)$, and j represent the number of resources. Then, the resource consumption (RC) of each remaining project can be calculated by Eq. (3) and Table 3 shows the interdependencies of seven projects.

$$RC = \sum_{j=1}^{n} C_j \pm \sum_{i,j=1}^{n} f(x) \cdot \Delta C_j \quad (3)$$

where $\sum_{j=1}^{n} C_j$ represents the total of individual resource consumptions of the same types of resources, for example, machines, workforce, and funds, $f(x)$ is a function.

$$f(x) = \begin{cases} 1 \\ 0 \end{cases} \quad (4)$$

Table 3 Interdependences.

No.	Projects	Interdependence Type	Explanation
1	F, G	Fund interdependence	Reduced by US$15 K in cost
2	B, H	Fund interdependence	Reduced by US$10 K in cost
3	B, D	Workforce interdependence	Reduced by 3 people in Workforce
4	C, I	Material interdependence	Reduced by 2 production machines in Materials
5	I, J	Material interdependence	Increased by 2 production machines in Materials

where $f(x) = 1$when the interdependent project is chosen, otherwise, the interdependent project in the portfolio do not correlate, i.e., $f(x) = 0$. $\sum_{i,j=1}^{n} f(x) \cdot \Delta C_j$ calculates the effects of interdependencies in resource consumptions. ΔC_j denotes the results of interdependence. Table 3 summarises the five identified interdependences. As can be seen that, for example,

Table 4 The resources consumptions.

Project portfolio	Funds US$(K)	Production materials (No. of Production Machines)	Workforces (No. of People)
BDFGH	122	19	33
BDFGI	153	18	40
BDFGJ	123	18	35
BDFHI	152	22	34
BDFHJ	122	22	29
BDFIJ	153	23	36
BDGHI	157	23	37
BDGHJ	127	23	32
BDGIJ	158	24	39
BDHIJ	142	28	33
BFGHI	154	33	43
BFGHJ	109	26	33
BFGIJ	140	27	40
BFHIJ	139	31	34
BGHIJ	144	32	37
DFGHI	137	22	36
DFGHJ	112	22	31
DFGIJ	128	23	38
DFHIJ	137	27	32
DGHIJ	142	28	35
FGHIJ	124	31	33

Interdependence 1 shows that if Projects F and G are both selected, the total cost of the two projects required will be reduced by US$15 K. Similarly, Projects B and H, Interdependence 3 shows that Projects D and B have some complementarity, which the total of *Workforce* required will be reduced to 3 employees. While interdependence 4 shows that Projects C and I have some resource sharing, for example, if both of Projects C and I are selected, the *Materials* required for production will be reduced by 2 production machines. Interdependence 5 shows that Projects I and J have some competitiveness, for example, if both of such two projects are selected, the resources required will be shared to use, in other words, the *Materials* required for production will be increased by 2 production machines.

The results by applying Eq. (3) are presented in Table 4. As can be seen that PP(BDFGI), PP(BDGIJ), PP(BDHIJ), PP(BFGHI), PP(BFGHJ), PP(BFGIJ), PP(BFHIJ), PP(BGHIJ), PP(DFHIJ), PP(DGHIJ), PP(FGHIJ) do not meet the three constraints, i.e., machines, workforces and funds, they should be removed from list of project portfolios.

3.2.2. SDA model inputs: The values of functions

As described in Section 3.2.1, once those unavailable single projects and project portfolios have been eliminated, Ten desirable portfolios (DP) are available to be implemented, i.e., DP(BDFGH), DP(DFGHJ), DP(DFGHI), DP(BDGHJ), DP(DFGIJ), DP(BDFHI), DP(BDFIJ), DP(BDGHI), DP(BDFHJ) and DP(BDFGJ). The data required by the SDA model are the functional values of projects that are shown in Table 5. It should be noted that users have the opportunity to modify and evaluate the functional values based on conditions and required resources of the candidate projects as the input data for SDA model. The description of values of project functions are based on the case in this study. The values of project functions present the ability of projects to achieve the objectives, for example, Project D has a function value 0.12 of *Increase benefits*. Table 5 presents values of functions of candidate Projects B, D, F, G, H, I and J.

3.3. Results

After Company's resources have been filtrated and function values of candidate projects have been identified and calculated, the function values of candidate projects in project portfolios then are entered to the proposed SDA model. Assuming that the strategy development in *Company A* has a five-year plan without any change. In other words, the selected project portfolio will be executed for sixty months period without any delay and interruption.

Function values presented in Tables 5 then have been input into the proposed SDA model for simulation, and the results are presented in Fig. 5. It should be noted that value of strategy has been used as the selection criterion in this case to select the optimal project portfolio from the ten desirable project portfolios.

Due to the investment and potential payback of project portfolios, the company requires to select the best project portfolio to support organizational strategy. Thus, strategy as a criterion is used to determine a proper portfolio. As can be seen from Fig. 5, the DP(BDFGH) has received the highest realized value of 1.48, which has been ranked at the first place. The DP(BDFGH) is the optimal portfolio because it achieves the maximum strategy and five Projects B, D, F, G, and H require a total cost of US$122 K and 19 number of people that are resources within the organisation. The ranking of ten desirable portfolios on the basis of realized values is DP(BDFGH) > DP(BDFGJ) > DP(BDFHJ) > DP(BDFIJ) > DP(BDGHJ) > DP(BDFHI) > DP(DFGIJ) > DP(DFGHJ) > DP(DFGHI) > DP(BDGHI).

An expert system is a computer system emulating the decision-making ability of a human expert (Jackson & Peter, 1998). This proposed PPS process can be incorporated into expert system to select the optimal portfolio by taking the objective priorities into account. Considering the actual situations of company's primary objectives, i.e., gaining maximization of the company benefits, escalating market share and customer(/client) satisfaction, Fig. 6 shows the realized values of the strategy and five perspectives at the end of month sixty. Clearly, the realization of company benefits by finance, market share, and customer(/client) satisfaction have great impacts on strategic realization. For example, as can be seen in Fig. 6, DP(BDFHJ) shows the first choice is to meet profit, customer attraction, and internal process optimization for *Company A*. The information produced from simulation by using the proposed SDA model can provide leaders and managers of the organizations very useful information to make decisions to maximize their benefits.

4. Discussions

Organizations always face the challenges of selection of correct project portfolio from a number of optional candidate projects that satisfy to organizational development strategy. As described earlier in this paper, there are many influential factors that affect the choice of project portfolios. However,

Table 5 Data set.

Project Function	B	D	F	G	H	I	J
Increase benefits		0.12				0.15	
Mitigate cost					0.18		
Predict customer preference							
Offer high quality of services		0.76					
Shortened order processing time							
Expand market share	0.29				0.13		
Improve market value	0.32						0.48
Establish standardization management system		0.01			0.26		
Creation of project management manuals				0.46			
Establish management information platform			0.41			0.01	
Improve efficiency of productivity			0.04				
Shorten lead time			0.51				
Improve quality of products	0.03						0.35
Product development				0.34			
Increase employees' satisfaction							
Enhance employees' ethics	0.36		0.04				
Improve knowledge and skills of employees		0.11				0.48	
Increase employees' acceptance of corporate culture							0.15
Provision of social welfare				0.01			
Human resource management				0.19		0.36	
Environmental protection					0.43		0.02
Total Value of Function Σ	1.00	1.00	1.00	1.00	1.00	1.00	1.00

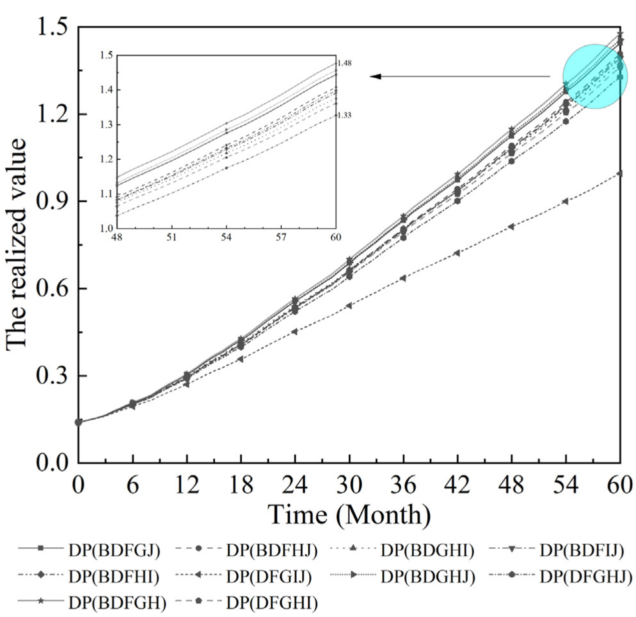

Fig. 5 The realized value of strategy.

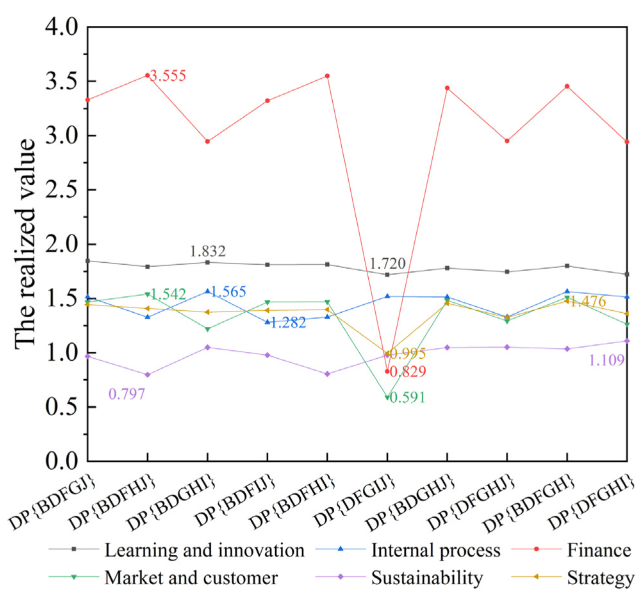

Fig. 6 The realized value of strategy and five perspectives.

synergetic and dynamic relationships between the candidate projects have major influences on the project portfolio choice. This study addresses this issue in which synergies and dynamic relationships between projects and complementation of individual project functions have been taken into consideration to develop a SDA model that can be applied in PPS process. Strategy as a criterion is also utilized in the proposed SDA model to select the appropriate and optimal project portfolio. The developed PPS can provide a methodology and tool that can help companies to build up their expert systems to find the optimal project portfolio at the right time and implement it in strategy of the organization in decision-making process.

4.1. Theoretical implications

Selection of appropriate projects that can meet company strategy from a list of to-do projects in the decision-making process is a very challenging issue that the organization faces in their project management practices. An effective PPS can help the company to select the optimal project portfolio that can maximize company's benefits, deliver products on time, and manage costs with defined budgets. As described earlier in Section 1, current researches and developments usually consider projects in the portfolio are individually, which ignore that single project selection criterion may conflict with strategy of the organization. Nowak & Trzaskalik [37] proposed a trade-offs approach and developed assessment criteria, which can be used to evaluate the project selection process over a specified period to solve a stochastic discrete project portfolio selection problem. However, such an approach ignores that the dynamically synergetic relationships among candidate projects have a major impact on the selection of projects that needs to be taken into consideration to satisfy the company's strategy. This study has addressed this issue and considered a synergetic perspective in the development of a SDA model, which contributes to the knowledge body: Firstly, a strategy-oriented PPS evaluation index system is proposed in which considers sustainable development in the organization. Secondly, synergies between projects are considered in PPS, i.e., (i) the synergies of candidate projects are considered to take company resource sharing into account in the SDA model, and (ii) the complementation of project functions is consequently considered in synergies, which identification of synergies can be conducted by qualitative analysis to produce synergetic relationships of project portfolios. Thirdly, quantitative analysis of synergies by using formulas and logic functions as described in Section 2.3 can help to narrow the research gap on synergies quantification. Finally, system dynamics approach is utilized to construct a SDA model by considering the relationships among candidate projects. Therefore, the developed PPS method and the proposed SDA model can provide insights into how the strategy in the organization is realized by the implementation of the selected optimal project portfolio.

4.2. Managerial implications

The proposed PPS methodology raises managerial implications. Simply combination of candidate projects is not suitable for every project, and it is vital to understand how to utilize alliancing [21]. This study has developed a universal process for the selection of optimal project portfolio to address such challenges. Also, the proposed PPS process can guide companies to build up their expert systems which emulate the decision-making of human experts. The process consists of three steps, i.e., project portfolio filtration, functional value determination and SDA model simulation. The results produced from SDA simulation can provide useful information for leaders and project managers in the organizations to choose the best project portfolio with a maximum strategic realization while to satisfy pursuits of the company that can also be determined.

The proposed SDA model is constructed based on general environment as described in Section 2.3. Due to the complexity of the relationships among projects (both positive aspects and negative influences), it is difficult to implement projects into the strategy of an organization. By using the proposed SDA model, the process to take project objectives into consideration can help the organization to approach real scenarios of projects. Meanwhile, expert questionnaires and systematic literature reviews are most effective ways that can be used to determine the parameters. The proposed SDA model allows project managers to modify variables required in the model according to different project conditions and objectives in which the weights of variables can be reset. This study offers formulas to calculate and eliminate the resource consumptions of project portfolios that do not satisfy the resource limits in the organization. It is easier to reduce the number of infeasible schemes in the developed SDA model. Subsequently, after SDA simulation is completed, the value of strategic realization can be obtained. Managers can estimate each desirable project portfolio based on results produced from the simulation to select more suitable project portfolio that can maximize strategy and preferential objectives in the company.

As project portfolio should be selected in consideration by assessment multi- criteria and synergetic relationships among candidate projects, the proposed SDA model can be also used to predict the strategic realization of different project portfolios based on calculation of the consumptions of each project portfolio. The results produced from SDA simulation provide useful information to leaders and project managers in the organization to determine the best project portfolio.

4.3. Limitations and future research

Limitations and future research are discussed in this section. Firstly, the proposed model described in this paper can be used more effectively and efficiently in the project portfolio selection process to determine the optimal project portfolio without considering project delay and interruption. However, project delay and interruption sometimes are occurred during project portfolio execution. This is a particular true because the organisations always face the risks and uncertainties because of the changes of project objectives, situations, and conditions during project portfolio operation. Therefore, risk analysis and assessment should be taken into consideration in the project portfolio selection process. Secondly, a software that considers intelligent information management should be developed to enable the organizations to use the proposed methodology more conveniently.

5. Conclusions

The implementation of organization's strategy and strengthen competitive advantage, a company must select an optimal project portfolio from candidate projects that aligns with its strategic criteria. Simultaneously, dynamic synergies need to be taken into the decision-making process consideration to improve accuracy of project selection. A SDA approach combining with PPS is presented in this paper to help leaders and managers in the organizations to select the appropriate portfolio with maximal strategy criterion, while considering the impacts of synergies on strategic increment. In the meanwhile, synergies of resources consumption of projects are also needed to be counted into the project portfolio elimination process. All of these may contribute to more rational selection results. The PPS methodology and SDA model described in this paper can be used to the PPS process in which strategic achievements of each potential project portfolio can be calculated and ranked, and the best project portfolio can be determined. The proposed PPS methodology and SDA model have also provided an opportunity for the organizations to incorporate them into expert systems. A case study is presented in this paper to demonstrate the application of the proposed methodology. The results show that the proposed method can provide very useful information for leaders and project managers in the organizations to choose the best project portfolio to meet objective priorities of the organizations.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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