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Configuration Analysis of Integrated Project Delivery Principles' Obstacle to Construction Project Level of Collaboration

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Abstract: Integrated Project Delivery (IPD) with collaborative work as its core is supported by increasing numbers of scholars and practitioners, due to the performance improvement of project construction and projects' success promotion. However, some factors such as the contract, the technology, and the personnel behaviors hinder the application of IPD, which has negative impacts on the collaboration level of construction projects. On the basis of the configuration analysis, the purpose of this paper is to increase the effectiveness of collaborative management of construction projects by encouraging the application of IPD principles. This is achieved by introducing the proof of contradiction and thoroughly examining the impact of the application of IPD principles' barrier with the level of collaboration. Added to that, the research necessity of configuration analysis on IPD principles' obstacle to construction project collaboration is demonstrated through bibliometric analysis; thus, a questionnaire survey is applied to collect opinions related to IPD principles from 235 industry practitioners. Fuzzy set qualitative comparative analysis (fsQCA) is deployed to gather IPD principles' obstacles for construction project collaboration. The results show that (1) the absence of contractual and behavioral principles obstructs significantly the level of collaboration of construction projects in several cases, (2) catalysts for IPD have no significant impact in most cases, and (3) the unfamiliarity with IPD has negative impacts on the application of its principles. The theoretical contribution consists of filling the gap in IPD's collaborative management research and improving the research method in related fields. As for the practical contribution, it aims to prioritize the importance of IPD principles and provide valuable suggestions.

Keywords: Integrated Project Delivery (IPD); construction project; level of collaboration; path of obstruction; fuzzy set qualitative comparative analysis

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1. Introduction

The construction of a project is carried out by several participants at various stages [1], its performance depends largely on the participants' collaboration, which is critical to improving efficiency and delivering successfully the construction project [2]. With the increase in technical complexity and the diversification of specifications of these construction projects, the delivery is becoming increasingly fragmented [3,4]. To overcome this problem, a new delivery method, called Integrated Project Delivery (IPD), has emerged.

Moreover, the delivery of an integrated project is based on collaboration [5], consisting of integrating the personnel, the system, the business structure, and the practice in one whole process [6]. In this process, all participants will harness sufficiently their talents and insights to optimize project performance, increase value to the owner, reduce waste, and maximize efficiency through all the project phases of design, manufacturing, and construction [7]. Building Information Modeling (BIM) is growing up as the basis for the rapid development of IPD, which is advocated as a technological tool to promote work

with IPD, to provide opportunities for broader collaboration, promote the integration of architectural professionals to the greatest extent, and realize information sharing and efficient team collaboration [8,9].

However, due to several factors such as contracts, technology, and personnel behavior, the application of the IPD in traditional construction projects has slowed down [10,11]. In other words, the pure IPD cannot be applied directly in some countries, such as China [1]. However, some scholars and practitioners try to introduce the concept of IPD in traditional construction projects to improve the level of collaboration and management efficiency [12–14]. Added to that, the degree of application of the IPD principle will generate different effects on the level of collaboration in the project [15]. In view of the rapid development of the Chinese construction industry, the requirements for integrating project collaboration among the different groups are increasing. Considering the application of BIM technology in China and the barriers denying the direct introduction of pure IPD [16–18], this paper considers China as an example to study, analyze, and discuss the impact of IPD principles on construction project collaboration.

This paper studies systematically the effects of applying IPD principles at the level of construction project collaboration in detail on the basis of a questionnaire survey. Firstly, this paper uses bibliometric evaluation to analyze the literature related to IPD and construction collaboration. According to the research hotspots and deficiencies, it is found that the research needs to create a path for IPD principles for construction project collaboration depending on certain configuration analyses. Secondly, the technical route of detailed analysis is introduced. Based on the 15 IPD principles and 3 levels of collaboration adapted from NASFA et al. [8], the variables are selected and the questionnaire is designed and sent to practitioners experienced in BIM technology, and fuzzy set qualitative comparative analysis (fsQCA) is introduced as the research method. Thirdly, referring to the collaboration level of construction projects as the result variable and the three kinds of IPD principles (including contractual principles, behavioral principles, and catalysts) as the condition variable, the configuration analysis was carried out through fsQCA. Fourthly, based on the obtained results of configuration analysis and the previous research results, the reasons for the configuration formation were discussed and suggestions were put forward to reduce the obstruction along the configuration path. Finally, some contributions and future ideas are summarized. This study not only fills the gap in the field of IPD collaborative management obstacles, but also improves the research methodology based on fuzzy set qualitative comparative analysis and model asymmetry analysis. At the same time, the importance of IPD principles in the process of collaborative management is prioritized to provide a reference for improving the efficiency of collaborative management in practical engineering.

2. Literature Review

Bibliometric analysis refers to the cross science of quantitative analysis of all knowledge carriers by means of mathematics and statistics. The bibliometric analysis of literature keywords reflects the research hotspot and trend of the research field.

2.1. Research Hotspot Analysis Based on Bibliometric Analysis

Using China National Knowledge Infrastructure (CNKI) as the data source, the relevant literature search (including academic conference papers, journals, books, and dissertations) was carried out using the keywords "IPD" and "collaboration" as the search subject. A total of 150 non-repetitive literatures were retrieved, and 117 complete information literatures including 56 academic journals and 61 dissertations were retained to analyze the research status. VOS viewer was deployed to draw the keyword clustering diagram. As shown in Figure 1, the emerging clusters are mainly *IPD*, *BIM*, *collaborative management*, and *collaborative work*, indicating that these research directions in China's IPD collaboration field have attracted the attention of researchers and practitioners in the last 5 years.

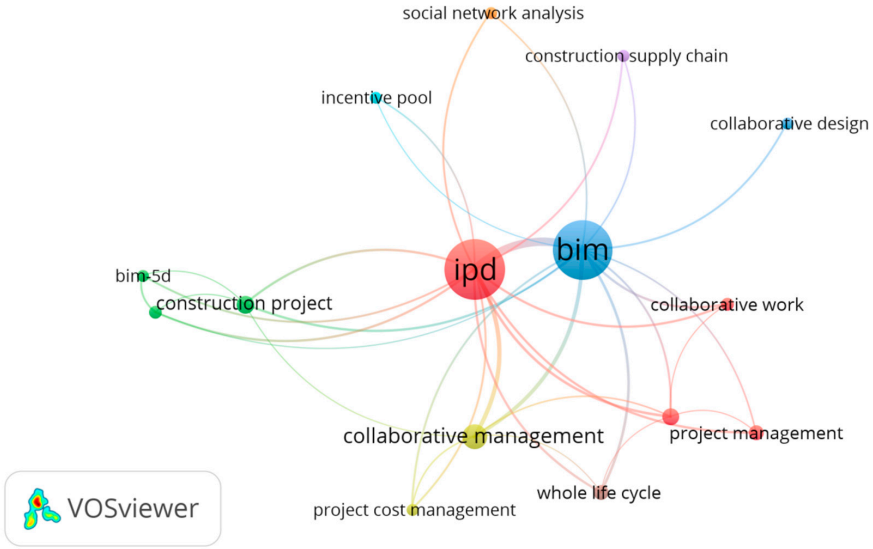

Figure 1. Cluster diagram of IPD collaborative keywords in China (keyword threshold is set to 3).

In opposite, using the Web of Science core collection as the data source, the relevant literature search was carried out with the two already listed keywords (e.g., IPD and collaboration). A total of 107 non-repetitive and complete information articles were retrieved, but 67 articles unrelated to the topic were excluded and 40 articles related to the topic were retained to analyze the research status. The keyword clustering diagram was drawn using VOS viewer. As shown in Figure 2, the emerging clusters are mainly *IPD*, *collaboration*, *BIM*, *performance*, and *management*, indicating that these research directions in IPD collaboration fields have attracted extensive attention in the world.

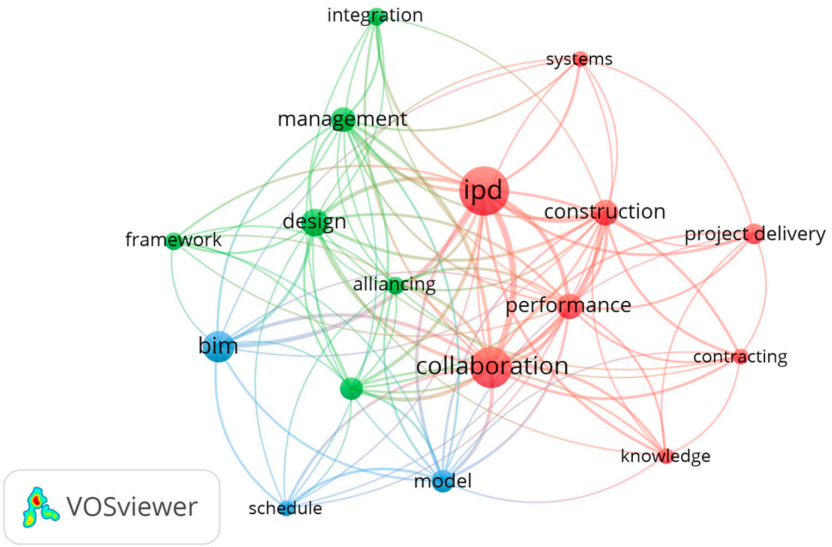

Figure 2. Cluster diagram of IPD collaboration keywords in the world (keyword threshold is set to 3).

Thus, to sum up, almost the same results have been obtained through the bibliometric analysis of literatures on related topics from two well-known databases, concerning the number of articles and the associated keywords found in the clustering of the retained papers.

2.2. Summary of Missing Parts in the Current Field of Research

What was mentioned above shows that BIM has become one of the research hotpots in the world as it serves as a technical basis for the rapid development of IPD [8,9]. Furthermore, IPD is used in construction projects to increase the project performance

through a highly collaborative process [19,20], so collaborative management is one of the main research hotspots. As the keywords threshold was set at three, rare literature references about IPD collaboration's obstacles were not shown in the cluster diagrams of Figures 1 and 2. Based on the Analytic Hierarchy Process (AHP) model, the BIM software function, the mode reorganization cost, and the number of BIM practitioners were found as the main factors that obstruct the development of the IPD collaborative model [21]. In addition, referring to Structural Equation Modeling (SEM), the factors that obstruct the application of IPD were studied [11]. Based on the related investigation, good team relationships and willingness to cooperate between teams were found to reduce significantly the risk of IPD [22].

As IPD principles involve many conditions and multi-party teams, the risk-sharing principle, the partnership of the participants, and the legal contract framework create some obstacles to the IPD's application [7]. This application is not limited to partial behavioral principles and catalysts, so the study of the interaction between various IPD principles and the degree of project cooperation in IPD mode has certain significance. However, the application of the IPD in construction projects and related cases is limited in China [16–18]. Thus, the main objective of this paper is to get research data based mainly on a questionnaire survey.

3. Research Design and Method

3.1. Technical Route

FsQCA is the main method that will be used throughout this study, and the technical route of this paper includes mainly four parts, as shown in Figure 3. These parts will be detailed here below: Part 1: Questionnaire design, involving mainly the selection of questionnaire variables, questionnaire design, distribution, and recovery. The selection of questionnaire variables and the questionnaire design are based on previous research and industrial standards, whereas its distribution and recovery are realized through the questionnaire star platform. Part 2: Research results, involving mainly the test of data and the configuration of the analysis results. The first one consists of testing raw data through SPSS, validating data rational distribution through descriptive statistics, and dividing the sample groups according to the "degree of familiarity with IPD". As for the configuration analysis, it includes the variable calibration, the necessity analysis for single antecedent variables, the conditional configuration analysis, and the robustness test. Part 3: Discussion, comparing the main results of this study with those of previous studies, the similarities and the differences were summarized. Part 4: Research conclusion, summarizing the main theoretical and practical contributions, as well as the research limitations.

3.2. Questionnaire Survey

A questionnaire survey is a method to collect data by designing detailed questionnaires and asking respondents to answer accordingly. This paper designs and recovers questionnaires to collect the data for analysis.

3.2.1. Selection of Variables

From the owner's point of view, IPD collaboration is divided into three levels, including typical collaboration, enhanced collaboration, and required collaboration [8]. The first two levels refer to projects that adopt IPD as a concept, whereas the third level refers to projects that adopt IPD as a delivery method [8]. IPD principles include a total of 15 principles, including contractual principles, behavioral principles, and catalysts for IPD. Among them, the contractual principles can be included in the agreement. As for behavioral principles, they are necessary for project optimization, but they are based ultimately on choice. Finally, catalysts for IPD are very useful for optimizing project results. To sum up, this paper chooses contractual principles, behavioral principles, and catalysts for IPD as antecedent variables [8] and the level of collaboration will be considered as the outcome variable [6–8]. Based on configuration analysis and the proof of contradiction, the

paper reveals the multiple concurrent paths that IPD principles obstruct the level of collaboration. Added to that, the paper summarizes the management enlightenment of the level of collaboration of construction projects in order to provide references for enhancing the construction project collaborative management efficiency under the application of IPD principles.

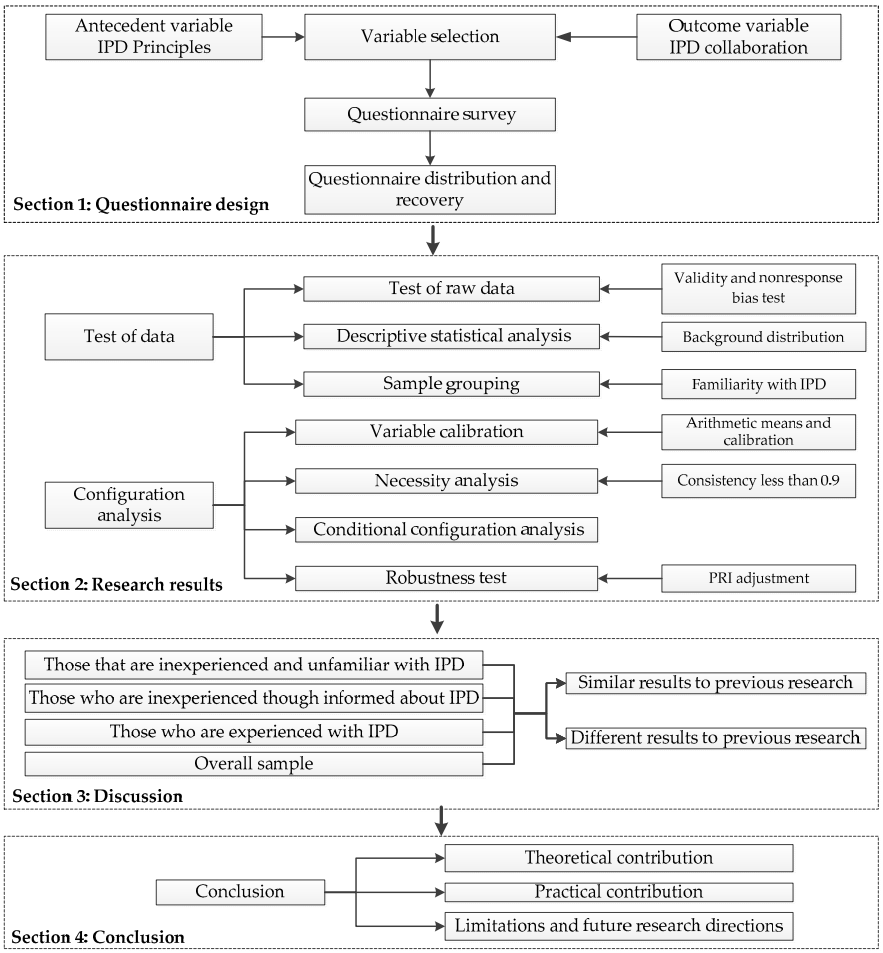

Figure 3. Technical route.

3.2.2. Questionnaire Survey

Through the questionnaire survey, this paper used the questionnaire star platform (https://www.wjx.cn/vm/waUUwNB.aspx (accessed on 31 October 2022) (Appendix A) to obtain the raw data. As the core of BIM technology and IPD mode consists of collaborative work, and the application of BIM technology belongs to the category of IPD principles, the research objective needs to have certain BIM experience. Thus, the contents of the questionnaire include mainly the following sections.(1) Background survey of the respondents: it includes mainly the type of institution the respondents work in, the number of years they have worked in the construction industry, the number of BIM projects they have participated in, their willingness to use BIM technology, and their familiarity with IPD mode. (2) Investigation on the influence of IPD principles on the level of collaboration of construction projects: it includes mainly a matrix scale designed based on Likert five points scale, with 15 secondary indexes of IPD principles presented in Table 1 as the vertical axis and five options as the horizontal axis (the options at the horizontal axis include the following: large negative influence, small negative influence, no influence, small positive influence, and large positive influence). The respondents were asked to select the most consistent parameters with the IPD principles' influence on the collaboration of construction projects based on their feelings and the implementation of the projects. (3) Investigation on the

level of collaboration of IPD in China: taking three kinds of IPD collaboration levels in Table 2 as options, a single choice question was set up to require respondents to choose the most consistent construction project collaboration level with the current situation of China's construction industry according to their true feelings.

Table 1. Selection of antecedent variables.

Antecedent Variables	Secondary Indexes	Observed Variables	Assignment
Contractual Principles (*X1~X8*)	Key Participants Bound Together as Equals	*X1*	1–5
	Liability Waivers between Key Participants	*X2*	
	Early Involvement of Key Participants	*X3*	
	Fiscal Transparency between Key Participants	*X4*	
	Jointly Developed Project Target Criteria	*X5*	
	Shared Financial Risk and Reward Based on Project Outcome	*X6*	
	Intensified Design	*X7*	
	Collaborative Decision-Making	*X8*	
Behavioral Principles (*X9~X11*)	Mutual Respect and Trust	*X9*	1–5
	Willingness to Collaborate	*X10*	
	Open Communication	*X11*	
Catalysts for IPD (*X12~X15*)	Multi-Party Agreement	*X12*	1–5
	Building Information Modeling (BIM)	*X13*	
	Lean Design and Construction	*X14*	
	Co-location of Team	*X15*	

Table 2. Selection of outcome variable.

Outcome Variable		Variable Description	Assignment	Reference
Collaboration Levels of IPD	Typical	Collaboration not contractually required	1	[6–8]
	Enhanced	Some contractual collaboration requirements	2	
	Required	Collaboration required by a multi-party Contract	3	

3.2.3. Questionnaire Distribution and Recovery

According to the literature induction, this paper adopts initially 15 IPD principles that reflect the level of collaboration of construction projects. The preliminary designed questionnaire was distributed to two construction units for trial filling, and the questionnaire was revised according to the feedback opinions of the filling personnel. Finally, a formal questionnaire was developed and distributed. Three main ways to distribute the questionnaire were adopted in Table 3:

Table 3. Three main ways to distribute the questionnaire.

Questionnaire Survey Objects	Ways of Questionnaire Invitation
Corresponding authors in the literature related to the subject from CNKI, WANFANG, CQVIP, and other core journals	Email
Practitioners and researchers participating in relevant conferences and forums in the construction industry	Combination of online and offline distribution
The staff of the professional practice base or the previous graduates engaged in the industry	Questionnaire link sharing

The main objective was to collect 400 questionnaires, and data collection started on 1 December 2021 and lasted till 31 October 2022, where a total of 372 questionnaires were collected. The questionnaire data was screened by the missing value test and abnormal value test, and finally 352 complete and valid responses were retained. Therefore, the effective recovery rate of the questionnaire was 88%. As the core of BIM technology and IPD is collaborative work, and in order to be more consistent with the actual situation of IPD application, only 235 valid questionnaires from respondents with BIM experience were analyzed in this paper. Moreover, the reliability of 235 questionnaires represents a value of 0.946; thus, the high sample size and reliability make it possible for further analysis.

3.3. Fuzzy Set Qualitative Comparative Analysis

FsQCA takes a holistic view and conducts a case-oriented comparative analysis, where each case is viewed as a configuration of conditional variables [23]. The purpose of fsQCA is to find a causal relationship between the conditional configuration and the outcome by comparing different cases and the corresponding configuration that causes the outcome to appear or not. The concept that the social phenomenon is linked to the circumstances is considered when taking into account the condition configuration as a whole. For the cases whose antecedent conditions is n, any antecedent condition includes two states (present and absent), and the possible configuration number of the logical combination of antecedent conditions is 2^n. Through fsQCA, the qualified configuration can be found from 2^n configurations. Consistency and coverage are the two main indictors to reflect the reliability of the results. Consistency refers to the degree of consistency between the conditional variable or path and the result. Coverage refers to the extent to which a condition or path subset physically covers the conditions or paths sets.

FsQCA is considered the most appropriate approach for this study [24], as it: (1) Allows for the exploration of conditional (pathways) combinations that combine the obtained result of specific outcomes. (2) Allows for equivalence, yielding in different paths that lead to the same result [23]. (3) Distinguishes between sufficient conditions (a single condition sufficient to predict the outcome), the necessary conditions (which must be included in each potential pathway to the given outcome), and the INUS (an insufficient but necessary part of a condition which is itself unnecessary but sufficient for the result) conditions (which are part of one of the possible pathways to the outcome). (4) Allows for asymmetry, which means that conditions can lead to results and the reverse of condition needs do not lead to the opposite results [24].

4. Research Findings

After screening the collected questionnaires, this paper carries out the following tests and configuration analysis on the questionnaire data.

4.1. Test of Data

The test of data aims to verify the reliability of the questionnaire data, demonstrating that the data can satisfy the requirements for further configuration analysis.

4.1.1. Test of Raw Data

As participants can't submit the questionnaire unless it is fully filled out, the questionnaire data has no missing values and outliers. At the same time, the validity of the 15 principles was tested, the overall Kaiser–Meyer–Olkin (KMO) value was 0.944, and the KMO value of the secondary indicators of three principles was greater than 0.7 [25]. Thus, the questionnaire is valid, as the data is suited for factor analysis. The survey was also separated into two stages based on various response years. The years of working in the construction industry and the number of BIM projects conducted by the participant involved in the two indicators of the chi-square test significant values are larger than 0.05, removing the potential of non-response bias [26–28]. As a result, the data from the questionnaire have a high level of validity and may be used for subsequent analysis.

4.1.2. Descriptive Statistical Analysis

The background distribution of respondents was analyzed, as shown in Table 4. Respondents were mainly chosen from construction units, design units, and research institutions, and the proportion of every unit is relatively balanced and covers a wide range. Moreover, more than two-thirds of the respondents were engaged in the construction industry for more than three years and nearly half of them have participated in more than three BIM projects; respondents with long-term industry experience and sufficient BIM project experience make their responses have reference significance for related research. In addition, nearly 90% of the respondents have a strong desire to use BIM technology. As

BIM is the basis for the rapid development of the IPD, the participants working on BIM projects and their strong willingness to use BIM have a strong reference for the analysis of the IPD project collaboration.

Table 4. Descriptive statistics.

Variables		Frequency	Percentage
Employment units	Real estate units	21	8.94%
	Construction units	73	31.06%
	Design units	52	22.13%
	Consulting units	28	11.91%
	Supervision units	0	0.00%
	Suppliers	1	0.43%
	Research Institutions	52	22.13%
	Others	8	3.40%
Years of working in the construction industry	≤3	71	30.21%
	3~5	34	14.47%
	5~8	47	20.00%
	>8	83	35.32%
Number of experienced BIM projects	1~2	126	53.62%
	3~5	42	17.87%
	6~10	20	8.51%
	>10	47	20.00%
Willingness to use BIM technology	0	1	0.43%
	1	7	2.98%
	2	18	7.66%
	3	45	19.15%
	4	45	19.15%
	5	119	50.64%

4.1.3. Sample Grouping

As can be seen from Table 5, respondents that are inexperienced and unfamiliar with IPD accounts for 38.3% of the total, respondents who are inexperienced though informed about IPD accounts for 44.7% of the total, and respondents who are experienced with IPD accounts for 17% of total. The ratio of respondents' "familiarity with IPD from low to high" is about 4:4:2, and most of them either have no direct experience with IPD or are not familiar with its concept, which is consistent with previous research conclusions [7]. To study the configuration path of construction project collaboration more systematically and comprehensively, in addition to the overall sample analysis of 235 valid questionnaires, this paper will evaluate the three groups of samples. Through the comparative investigation of multiple concurrent paths under multiple samples and tracing the antecedent conditions from the reductionism perspective, this paper will explain the reasons why IPD mode affects the level of collaboration of the construction projects in a more scientific and reasonable way.

Table 5. Sample distribution.

Variable		Frequency	Percentage	Sample Grouping
Respondents ' familiarity with IPD	Those that are inexperienced and unfamiliar with IPD	90	38.3%	1
	Those who are inexperienced though informed about IPD	105	44.7%	2
	Those who are experienced with IPD	40	17.0%	3

4.2. Configuration Analysis

Based on configuration analysis, the necessary conditions and configuration paths of low degree of cooperation can be found. The robustness of configuration analysis can also be tested through the robustness test.

4.2.1. Variable Calibration

In this study, fsQCA was used for analysis purposes. The arithmetic means of the secondary indexes in Table 1 are taken as three principles' scores [29], and the higher the score is, the higher the degree of influence will be. The objective of fsQCA is to calibrate and normalize the variables involved in the calculation so that scores can be converted into fuzzy scores between 0 and 1 to improve the interpretability of the results [30]. In this paper, complete subordination crossing points and complete non-subordination are located at 5, 3, and 1 for the three principles, and 3, 2, and 1 for level of collaboration, respectively.

4.2.2. Necessity Analysis of Single Antecedent Variable

The necessary conditions of a single factor are obtained, as shown in Table 6. Consistency is similar to the coefficient significance degree (*p*-value) in regression analysis, which refers to what extent a certain result requires the existence of a certain variable. Coverage refers to the extent to which a subset physically covers the target set, which is a direct indicator of the empirical importance of antecedent conditions. In fact, when the consistency is below 0.9, neither sample has a bottleneck, yet there is little collaboration [31,32]. As can be seen from Table 6, the necessary conditions were absent in both the overall sample and sample 1. Although in samples 2 and 3, the necessary conditions (contractual principles, behavioral principles, and catalysts for IPD in sample 2; catalysts for IPD in sample 3) of low collaboration levels exist, the low coverage of necessary conditions, less than 0.8, means that these subsets don't account for a large proportion of the total. Therefore, the multiple antecedent conditions need to be combined for configuration analysis in this study.

Table 6. Analysis of antecedents' necessary condition under multiple samples.

Outcome Variable	Condition Variable	Overall Sample		Sample 1		Sample 2		Sample 3	
		CY	CE	CY	CE	CY	CE	CY	CE
Low level of collaboration	Contractual Principles	0.88	0.75	0.83	0.79	0.93	0.76	0.89	0.63
	~Contractual Principles	0.25	0.89	0.28	0.85	0.22	0.93	0.26	0.92
	Behavioral Principles	0.89	0.75	0.85	0.8	0.93	0.75	0.89	0.63
	~Behavioral Principles	0.24	0.89	0.27	0.84	0.21	0.95	0.24	0.88
	Catalysts for IPD	0.88	0.75	0.83	0.79	0.91	0.75	0.9	0.63
	~ Catalysts for IPD	0.26	0.91	0.29	0.86	0.24	0.95	0.24	0.93

Note: A sideways tilde ~ indicates the absence or negation of the causal condition. CY indicates the consistency between the condition variable and low level of collaboration, and CE indicates the coverage between the condition variable and low level of collaboration.

4.2.3. Conditional Configuration Analysis

In this study, due to the values of samples 2 and 3, multiple antecedent variables need to be combined for analysis to explore the influence of the combination path on the outcome variables. The cutoff value for analysis at each sample size was set as follows: the acceptable number of cases was set at 1, the consistency threshold was set at 0.8 [33], and the Proportional Reduction in Inconsistency (PRI) was set at 0.7 [34]; thus, the complex solution, parsimonious solution, and intermediate solution can be obtained. This paper chooses the intermediate solution and the parsimonious solution to explain the configuration path model: low levels of collaboration (equal to f) (contractual principles, behavioral principles, and catalysts for IPD). The overall coverage of the overall sample, sample 1, sample 2, and sample 3 are 0.278718, 0.245517, 0.247738, and 0.279661 respectively, and the overall consistency values are 0.883432, 0.849868, 0.944798, and 0.884718 respectively. The combined path interpretability of the four groups of samples is relatively high.

According to the results of fsQCA, among all the antecedent variable combinations, the results of four sampling size studies show that there are seven obstacles relative to the low collaboration level in construction projects. In this study, the antecedent variable configurations are shown in Table 7.

In the overall sample, which includes all respondents, there exist two configuration paths. Path S1A shows that contractual principles are absent as the core condition, whereas

behavioral principles and catalysts for IPD have no impact on low collaboration levels. Concerning the path S1B, it indicates that behavioral principles are absent as the core condition, catalysts for IPD exist as the edge condition, and contractual principles have no impact on low collaboration levels.

Table 7. Antecedent variables with low collaboration levels under multiple samples.

Configurations	Overall Sample		Sample 1	Sample 2		Sample 3	
	S1A	S1B	S2	S3A	S3B	S4A	S4B
Contractual Principles	☆		☆		☆	☆	
Behavioral Principles		☆	☆	☆	■	■	☆
Catalysts for IPD		■	☆	■	☆		■
Raw Coverage	0.253329	0.227442	0.245517	0.214753	0.192206	0.238136	0.237288
Unique Coverage	0.051276	0.025389	0.245517	0.0555323	0.0329853	0.0423729	0.0415255
Consistency	0.890225	0.885845	0.849868	0.953646	0.954388	0.913821	0.893142
Solution Coverage	0.278718		0.245517	0.247738		0.279661	
Solution Consistency	0.883432		0.849868	0.9447982		0.884718	

Note: Among them, ☆ indicates the absence of the core condition, which indicates the existence of a strong causal relationship between the condition and the concerned result, and ■ indicates the presence of the edge condition, which indicates the weak causal relationship between the condition and the result. A blank indicates that the presence or absence of this condition has no effect on the level of collaboration [35].

In sample 1, which includes the respondents that are inexperienced and unfamiliar with IPD, there exists 1 configuration path. Path 2 shows that contractual principles, behavioral principles, and catalysts for IPD are all absent as the core conditions for low collaboration levels.

In sample 2, which includes the respondents who are inexperienced though informed about IPD, there exist two configuration paths. Path S3A indicates that behavioral principles are absent as the core condition, catalysts for IPD exist as the edge condition, and contractual principles have no impact on low collaboration levels. Path S3B shows that contractual principles and catalysts for IPD are absent as the core condition and behavioral principles exist as the edge condition.

In sample 3, which includes the respondents who are experienced with IPD, there exist two configuration paths. Path S4A shows that contractual principles are absent as the core condition, behavioral principles exist as the edge condition, and catalysts for IPD have no impact on low collaboration level. Path S4B indicates that behavioral principles are absent as the core condition, catalysts for IPD exist as the edge condition, and contractual principles have no impact on low collaboration levels.

4.2.4. Robustness Test

In this paper, the PRI threshold was set to 0.75 [36] in the analysis of the truth table of the four groups of samples. In addition, the robustness test results showed that the configuration path of the new model for the three samples (overall sample, sample 1, and sample 2) is completely consistent with the configuration path of the original model. However, through one of the two configurations of the new model of sample 3, it is completely consistent with the original model's S4A, where the other path only replaces the core missing condition with the misleading contractual principles under the comparison with S4B, and the overall change of the path is not much, indicating that the research conclusion is relatively robust [29,31].

5. Discussion

Most of the previous studies were to explore the IPD in well-determined construction application projects and the impact of the construction factors, as well as to demonstrate the significance of a single factor. However, there are few studies considering the obstruction of IPD principles to the collaborative management of construction projects, and the influencing factors involved are relatively limited. There are also some deficiencies in the applied method, and the combined influence of multiple influencing factors has not been considered so far from a configuration perspective. The necessity analysis results do

not have the necessary conditions with relatively high coverage, and corresponding to the configuration paths in one sample does not have the same conditional level of necessary conditions, so necessity analysis has no practical significance for the interpretation of the final configuration path. In four groups of samples in this paper, under seven concurrent obstruction paths were obtained by fsQCA. In fact, there are only five different paths obstructing the level of collaboration. The first path only consists of the absence of contractual principles, which are the core condition. The second path consists of the absence of behavioral principles, which are the core condition, and the presence of catalysts for IPD, which are the edge condition. The third path consists of the absence of three kinds of principles, which are all core conditions. The fourth path consists of the absence of contractual principles and catalysts for IPD, which are both core conditions, and the presence of behavioral principles, which are the edge condition. The fifth path only consists of the absence of contractual principles, which are the core condition, and the presence of behavioral principles, which are the edge condition. Compared to previous research findings, this paper presents its outcomes under two main aspects that will be detailed in the next two paragraphs.

5.1. Similar Results to Previous Research

The absence of behavioral principles can hinder significantly construction projects collaboration with the presence of catalysts for IPD. The paths S1B, S3A, and S4B in Table 7 are identical. In these paths, the absence of behavioral principles and the presence of catalysts for IPD represent the core and the edge conditions that obstruct the construction project collaboration, respectively. However, the presence or absence of contractual principles will not obstruct the level of collaboration of construction projects. The paths in samples 2 and 3 indicate that practitioners with IPD experience (and knowledge of IPD) believe that the catalysts for IPD, without matching behavioral principles, will obstruct construction projects collaboration regardless of the existence of contractual principles. In addition, the responses in sample 1 (from participants that do not know IPD) had a certain negative impact on the path in the overall sample; therefore, the S1B path consistency in the entire sample was lower than S3A and S4B of the same path.

In addition, the behavioral principles provide rules for the integration, the communication between parties, and the ability of team members to trust and support each other through cooperation, which is critical to eliminate the segregated roles of traditional contracting processes to reduce risks [23], increase value to the client, and reduce the amount of construction waste [37,38]. Moreover, appropriate catalysts, such as BIM and lean construction, which mainly provides a virtual design before the actual construction begins and enables the project stakeholders to see the building clearly [37,38], are the least important factors affecting the level of collaboration of IPD application [7] compared to contractual principles and behavioral principles. Behavioral principles can remove separations, consequently improving the collaboration environment that BIM implementation necessitates [39]. Therefore, even if there are catalysts for IPD, such as BIM technology, and if the behavioral principles cannot be guaranteed, it is difficult for construction projects under IPD mode to achieve good collaboration performance.

5.2. Different Results from Previous Research

(1) The absence of contractual principles will obstruct significantly the collaboration of construction projects. Thus, this absence in path S1A is the core condition to obstruct the level of collaboration of construction projects. However, the existence of behavioral principles and catalysts for IPD will not eventually obstruct the construction projects collaboration. One of the paths of the overall sample, S1A, reflects that the absence of the contractual principles at the overall sample level will seriously obstruct the level of collaboration of the construction projects. Hence, IPD acting as a collaborative contract approach changed the basic business and organizational and legal structure of the project to reduce dysfunction and improve performance [40]. Added to that, contractual principles are often associated with legal provisions and cannot be undermined to improve integration

and create a trust-based work environment by decentralizing project risks and outputs to all construction participants [41]. In addition, referring to the contractual relationships, early determination of project objectives and early formation of teams are essential keys to the IPD's success [6,42] where the principle of shared risk in the contract makes the construction industry more suspicious of the application of IPD [7]. Therefore, the absence of contractual principles can seriously obstruct the construction projects collaboration by hindering the mediating effect of IPD application;

(2) The absence of contractual principles can obstruct significantly the collaboration of construction projects under the assumption of the presence of behavioral principles. Thus, in path S3b, the absence of contractual principles and catalysts for IPD is the core condition that deteriorated the level of collaboration of the construction project; however, the existence of the behavioral principle is the edge condition. As an example, in path S4A, the absence of the contractual principle and the presence of the behavior principle are respectively the core and edge conditions of obstructing construction project collaboration, as the presence or absence of catalysts for IPD will not hinder the level of construction project collaboration. The contractual principles consist the premise that the relationship between team members becomes reliable, so that they respect each other and cooperate [19,20], whereas the absence of contractual principles will make the realization of the behavioral principles' lack of protection. At the same time, some principles are responsible for some characteristic improvement [43]. For example, in terms of the team aspect, the shared risk and reward principle can generate mutual goal achievement [44]. In fact, people who do not have IPD project experience in China believe that technological tools, such as BIM, have been applied in actual projects. Thus, the absence of catalysts for IPD will hinder seriously project collaboration, even though practitioners with IPD experience believe that the presence or absence of catalysts for IPD will not obstruct the level of collaboration of construction projects. In previous research, the practitioners with IPD experience had a higher ability to use BIM, so they believed that BIM should be applied to IPD projects to promote better application of the IPD principles [7], fitting with path S3 but contradicting S4A. As data from the previous research were derived mainly from various US research associations, and BIM is still not used widely in China [45,46], the background of BIM application varies so that the appearance of contradictions between this study and previous studies in the catalysts for IPD is logical. Combined with the current situation of BIM application in China, the S4A path is more in line with reality;

(3) The absence of contractual principles, behavioral principles, and catalysts for IPD can complicate significantly the collaboration of construction projects under the premise of behavioral principles. Thus, path S2 shows that the three principles of IPD are of equal importance (as considered by the participants who do not understand IPD), and the absence of these three kinds of principles are all core conditions that may obstruct the collaboration of construction projects. By comparison, it is more necessary to popularize the application of the IPD concept and its principles in construction projects [7].

6. Conclusions

This paper aims to promote the application of IPD principles to improve the level of collaboration and efficiency of collaborative management in construction projects. Based on the bibliometric analysis, this paper summarized the current hot spots of the IPD collaboration research field, such as IPD and BIM technology integration application, and the integration of IPD and collaborative management ideas. Through the proof by contradiction, the fsQCA method was used to analyze the obstacle configuration path of IPD principles at the projects' construction collaboration levels under multiple samples. Therefore, this paper globes both theoretical and practical contributions.

6.1. Theoretical Contribution

This paper expanded the scope of the IPD collaborative management research field. Based on the proof of contradiction, this paper studied the constraints of applying the IPD

principles to the level of collaboration of construction projects and expanded the research to show the problems of IPD in the field of collaborative management. In addition, this paper considered the influence of the combination of contractual principles, the behavioral principles, and the catalysts for IPD on the level of collaboration in project construction.

Additionally, the research methods in the field of IPD collaborative management were enriched. This paper is result-oriented, as it analyzes the influencing factors that obstruct the level of collaboration of construction projects from the perspective of "induction-tracing". In addition, configuration analysis is an asymmetric analysis, and it shows that the combination of one or more conditions constitutes the antecedent of a specific result. Added to that, the nonlinear superposition of causality and the multiple concurrent mechanisms are considered. Referring to complex system theory perspectives, this paper analyzed the complex system of construction project with multi-stages, multi-participants, and multi-management elements, which makes up for the deficiency of traditional deductive methods in studying causality and improving the research methods.

6.2. Practical Contribution

Based on the results of the configuration analysis, considering the actual situation of the project, to better implement IPD principles in construction projects and improve the level of collaboration in construction projects, this paper puts forward the following suggestions.

Some construction industry practitioners lack understanding of IPD mode, so the concept and related principles of IPD should be popularized in the industry. Appropriately increasing the familiarity of practitioners with IPD will promote for better application of IPD in construction projects, and their experience and suggestions can also promote the pertinence and accuracy of related research.

The contractual principles take priority over the behavioral principles. The absence of the first principle will obstruct seriously the collaboration performance of IPD mode projects; thus, ensuring that the contractual principles can be met first when the IPD mode is applied to construction projects is of major importance. The contractual principles guarantee that the participants in a construction project are connected on an equal footing, establish common standards for the project objectives, and share risks when they arise. The satisfaction of the contractual principles is the basis of the realization of the behavioral principle. The willingness to cooperate and mutual respect and trust are based on the contractual principles.

The behavioral principles take precedence over the principle of catalysts for IPD. The absence of the behavioral principles will restrict the collaboration performance of IPD mode projects. Thus, ensuring that the behavioral principles can be satisfied when the IPD mode is applied to construction projects is very important. The realization of the behavioral principles means that the project participants can reach the goal of cooperation based on respect and trust and create the premise for the implementation of the catalysts for IPD, such as the co-location of team and the multi-party agreement.

6.3. Limitations and Future Research Directions

This study still has the following limitations: (1) The original data came from the questionnaire, which may have subjective bias; thus, future works can try to use practical engineering cases to study the obstructing influence of IPD principles on the level of collaboration in construction projects. (2) The sample data of multi-contrast is limited; thus, future works can enlarge the investigation scope and the sample size so that the research results can adapt to a wider range of research objects and improve the pertinence of the research results. (3) In this study, the proof by contradiction is used to study the obstructed path of contractual principles, behavioral principles, and catalysts for IPD to define the level of collaboration in construction projects under IPD mode. However, future works can explore the configuration path at high levels of collaboration in construction projects under IPD mode.

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Appendix A. Questionnaire on the Influences of IPD Principles on Collaboration Level (I) [English Version]

Dear experts/professionals,

Thank you very much for taking the time to participate in this questionnaire. Thank you for your support and help. This questionnaire is only for academic research, and does not have any commercial use, nor will it disclose any of your privacy. We will obey the requirements of information confidence, and the questionnaires are anonymous. Please feel free to fill in the anonymous questionnaire! Your selection has a decisive impact on this study. Therefore, please spare your precious time in your busy schedule to answer the relevant questions of this questionnaire and correct the shortcomings. Thank you for your support and wish you a happy work!

Part 1 Basic Information

1. What is your age? ( )

○ 20~25 years old ○ 26~30 years old ○ 31~40 years old ○ 41 years old and more

2. What is your educational background? ( )

○ junior college and below ○ undergraduate ○ master's degree ○ doctor's degree or above

3. What's your professional title? ( )

○ junior ○ intermediate ○ senior ○ others

4. What is your employment unit? ( )

○ real estate units ○ construction units ○ design units ○ consulting units
○ supervision units ○ suppliers ○ research institutions ○ others

5. How many years have you worked in the construction industry? ( )

○ less than 3 years ○ 3~5 years ○ 5~8 years ○ 8 years and above

6. How many BIM projects have your experienced? ( )

○ never ○ 1~2 ○ 3~5 ○ 6~10 ○ more than 10

7. What is your willingness to use BIM technology? ( )

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

Part 2 IPD Information Survey

Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures, and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication and construction.

1. How familiar are you with IPD? ( )

○ those who are experienced with IPD ○ those who are inexperienced, though informed about IPD ○ those that are inexperienced and unfamiliar with IPD

2. Based on your experience in the BIM project and the implementation of the actual project, what do you think is the impact of the following IPD principles on information collaboration? ( )

	Very negative	More negative	No effect	More positive	Very positive
Key participants bound together as equals					
Liability waivers between key participants waivers					
Early involvement of key participants					
Fiscal transparency between key participants					
Jointly developed project target criteria					
Shared financial risk and reward based on project outcome					
Intensified design					
Collaborative decision-making					
Mutual respect and trust					
Willingness to collaborate					
Open communication					
Multiparty agreement					
BIM					
Lean design and construction					
Co-location of team					

3. What stage of collaboration do you think our industry is in now ( )

○ Typical (Collaboration not contractually required) ○ Enhanced (Some contractual collaboration requirements) ○ Required (Collaboration required by a multi-party Contract)

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