

**ENGAGING A MULTI-DISCIPLINARY LITERATURE REVIEW IN THE
DEVELOPMENT OF A FRAMEWORK TO ASSESS CONSTRUCTION
COLLABORATION**

A Thesis

by

SHRUTHI RAVI IYER

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Chair of Committee,	Zofia K. Rybkowski
Committee Members,	José L. Fernández-Solís
	Rodney C. Hill
Head of Department,	Joseph P. Horlen

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ABSTRACT

Collaboration is essential in the construction industry for successful project delivery. There are various factors that impact collaboration and it is essential to understand and implement these key factors within the project team. Several individuals and firms assist in measuring collaboration among the team members in construction industry. However, the effectiveness of these collaboration measurement tools, developed and used in their management practices needs to be validated, to ensure comprehensiveness of the tool. This can aid in enhancing the quality of the measurement tools and authenticating it.

Extensive research has been done to discover factors that impact collaboration in a specific field. This research aims at discovering factors that impact construction collaboration through a multi-disciplinary study and developing a Pareto chart and consolidated graph that can aid individuals and firms to identify the key factors. Firms assisting the industry can incorporate the factors identified through this research in their collaboration measurement tools.

As a result of this research, the five key factors that impact collaboration are found to be information or knowledge sharing, trust, open communication among the members, joint decision making abilities and a good team composition with diversity among members.

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NOMENCLATURE

AEC	Architecture Engineering Construction
BIM	Building Information Modelling
DB	Design-Build
GDP	Gross Domestic Product
IPD	Integrated Project Delivery

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1. INTRODUCTION

1.1 Background of the Problem

The construction industry contributes an annual revenue of approximately \$960 billion in the United States, as per the United States Census Bureau (USCB 2014). This industry thus influences numerous lives and is an important element in several societies. Nonetheless, it is plagued by problems faced by the industry participants- owners, architects, engineers and contractors. The major issues identified in the industry are ineffective communication, lack of collaboration and trust leading to antagonistic relationships among the stakeholders of the project (Elmarsafi 2008).

Construction management is characterized by project based management and has different independent participants with separated responsibilities and hence collaboration is essential in the architecture, engineering and construction (AEC) industry as it plays a crucial role as several teams are required to work together on a project as a team (Wenfa Hu 2008; Andreas 2009). Today, construction industry is witnessing a transition to more collaborative delivery methods such as Construction Management at Risk, Design-Build, Integrated Project Delivery and IPD-like delivery methods so as to deliver safer and quality projects within time and budget (Kenig 2011). Research shows that within the construction industry, project performance and efficiency can be increased with collaboration (El Asmar et al. 2013). Competent and multidisciplinary project team is an important factor that impacts construction project.

To ensure that a project is working well from the standpoint of collaboration, it is essential to conduct a proactive and real-time assessment, to identify bottlenecks, and take the required action to improve collaboration (Abdirad and Pishdad-Bozorgi 2014). It has been confirmed that one of the major reasons for failure of project alliances is poor collaboration (Weiss et al. 2001).

A multitude of theoretical perspectives has eventually led to a large set of definitions and understanding of the term collaboration, leading to difficulty in measuring collaboration in its true sense (Thomson 2007). This research aims at identifying most of the factors that impact collaboration and thus is based on a multi-disciplinary study. The chosen disciplines of study apart from construction are health care, psychology, business and engineering management and supply chain management.

1.2 Problem Statement

Research shows that several tools have been developed to measure collaboration among the various inter and intra organizational teams. However, Abdirad and Pishdad-Bozorgi (2014) state that no research has been carried out, that deals with proactive collaboration assessment to monitor collaboration and further state that “there is a need to measure collaboration performance”. Stamatis (2011) affirms that it is essential to assess the collaborative team for ensuring continuous improvement. Erdogan (2008) states that there is a constant need for new and more efficient collaboration measurement tools in the construction industry.

To assess collaboration it is imperative to recognize the factors impacting collaboration. It is essential that the creation of the rubric to evaluate the measurement tool should be through a holistic approach to develop an efficient measurement tool.

Abdirad and Pishad-Bozorgi (2014) further state that non-construction related literature on collaboration measurement should be investigated to measure collaboration effectively and efficiently and develop metrics. Hence, the purpose of this study is to perform a thorough literature review to identify the factors impacting collaboration.

1.3 Research Objective

The aim of this research is to engage a thorough multi-disciplinary literature review in the development of a framework to assess construction collaboration.

1.4 Significance of the Study

The success or failure of construction projects is mainly dependent on collaboration between the team players. By identifying the factors that impact collaboration and developing a framework to assess it, a better understanding of collaboration can be achieved. This can assist in developing efficient collaboration measurement tools or assess existing ones effectively.

2. LITERATURE REVIEW

2.1 Definition of Collaboration

The origin for the word ‘collaborate’ is in Latin ‘collaborar’ which means ‘to labor together’ (Henneman et al. 1994). Comprehensive research has been done to define the term collaboration.

Kraus (1980) refers to collaboration as ‘a cooperative venture based on shared power and authority.’ Gray (1989) states that collaboration is a joint or combined decision making process between the significant stakeholders. Wood and Gray (1991) conclude that “collaboration occurs when a group of autonomous stakeholders of a problem domain engage in interactive process, using shared rules, norms, and structures to act or decide on issues related to that domain.” Collaboration is defined by Schrage (1995) as a shared creation where two or more individuals, having skills that are complementary and have never before possessed or had a chance to create a shared understanding, now come together to interact, creating a mutual understanding and an innovative outcome. Eriksson and Westerberg (2011) assert that collaboration helps in increasing the understanding between cooperative procurement procedures and project performance.

Schottle et al. (2014) define collaboration as “an inter-organizational relationship with a common vision to create a common project organization with a commonly defined structure and a new and jointly developed project culture, based on trust and transparency; with the goal to jointly maximize the value for the customer by solving problems mutually through interactive processes, which are planned together, and by sharing responsibilities, risks and rewards among the key participants.”

Weiseth et al. (2006) state that collaboration occurs when two or more individuals communicate and interact with each other to achieve common goals. Fawcett et al. (2008) define collaboration as an ability to work across different organizational boundaries to meet the needs of the customer by building and managing unique value added processes.

Appley and Winder (1977) define collaboration as a “value system” wherein individuals who belong to a group, share mutual aspirations and interactions among these collaborative individuals is justified and fair. Collaboration among these individuals is also characterized by mutual respect and care for each other and commitment to work.

Necessity of Collaboration

Collaboration fosters productivity and leads to the most efficient and effective use of the personnel as the collaborative group members utilize their skills and talents in a cooperative and non-competitive manner (Henneman et al. 1994). It is also indicated that employees have higher levels of satisfaction and feel their contribution is valued due to joint planning and joint decision making and this promotes inter-professional cohesiveness.

2.2 Collaboration in Construction

It has been stated in literature that it is important to identify factors impacting collaboration. This aids in understanding collaboration better and assist in development of a framework to assess collaboration. It is important to assess collaboration so as to identify measures for making changes and improvements (Abdirad and Pishad Bozorgi 2014). Further, collaboration has been stated as a critical requirement in IPD projects (O’Connor 2009). Hence, it is important to study collaboration.

Effective collaboration is essential for success of construction projects and projects are best delivered by collaborative working (Phelps and Reddy 2009; Akintan and Morledge 2013). Collaboration is essential in the AEC industry, especially between the design and construction teams (Shelbourn et al. 2007). El Asmar et al. (2013) state that collaboration aids in the enhancement of project performance and efficiency within the construction industry and poor collaboration leads to failure of project alliances. It should further be noted that collaboration is a critical and legal requirement in IPD (O'Connor 2009). It is noted that efficient collaboration between the team players in construction industry plays a crucial role in improving construction management performance (Wenfa Hu 2008).

Communication plays a crucial role in construction collaboration as it is necessary to share information among the project participants and aids in minimizing errors and leads to more effective procurement (Wenfa Hu 2008).

Tutesigensi and Oak (2007) state that “working together in an open, co-operative and collaborative relationship based on trust is the true spirit of partnering”. They also state that having a clear knowledge of the individual’s roles and responsibilities, interpersonal relationship between the partners, implementation of technology and incentivizing increases collaboration among collaborative partners. Schottle et al. (2014) in their latest research on collaboration in lean construction identify few factors impacting collaboration and these include having common goals, executing a legal collaborative agreement, open and collaborative communication between the team members, mutual respect for each other, interpersonal relationship between the members, trust, sharing

resources and information, sharing rewards and profits, implementing technology such as BIM, jointly planning and making decisions and most importantly cooperation between the collaborative team members.

El Asmar et al. (2013) identify the factors impacting collaboration in construction industry their research. The factors identified in their research are: legal collaborative agreement, open communication, trust, sharing resources and profits, implementing BIM, common goals, joint planning and interpersonal relationship. Abdirad and Pishad Bozorgi (2014) developed a metrics to assess collaboration and the key factors stated by them were implementing technology such as BIM, sharing information, team composition and diversity, organization structure, co-location, giving feedback, psychological factors, training to members and measuring team productivity.

Collaboration was found to have a crucial impact on various disciplines other than construction. This paper identifies four other disciplines to have a better understanding of collaboration factors and these are health care, supply chain management, psychology, business and engineering management.

2.3 Collaboration in other Disciplines

Collaboration in health care is defined as a joint communicating and joint decision making process that focuses on a shared goal of satisfying and fulfilling the patient's wellness and illness needs while respecting the distinctive qualities and capabilities of each professional involved (Coluccio and Maguire 1983).

It has been identified that team work among the health care professionals and coordination of their activities leads to optimal patient outcomes (Hojat and Gonnella

2011). Collaboration is found to be essential between nurses and physicians to create and improve positive patient outcomes in health care (Baggs et al. 1992). Petri (2010) defines physician-nurse collaboration as a process wherein both physicians and nurses have common shared objectives and goals. Baggs and Schmitt (1988) state that ICU nurses and physicians work together cooperatively and share the responsibilities for solving problems and further jointly make decisions to formulate plans for effective patient care.

Henneman et al. (1995) summarized the factors impacting collaboration in his study and these include cooperation, joint planning and joint decision making, sharing knowledge, having clear specification of responsibilities, open communication, mutual respect, trust and willing participation. It was further stated that it is necessary to understand one's roles and responsibilities and have confidence in their ability. Communication is termed as critical for collaboration as it leads to respect, trust, knowledge sharing, having shared goals and visions and commitment (Henneman et al. 1995). Tang et al. (2013) indicate that factors such as open communication, mutual respect, trust and having a clear understanding of roles and responsibilities is important for successful physician – nurse collaboration.

Collaboration is necessary among the supply chain partners for better performance and increased efficiency of supply chain. Simatupang and Sridharan (2002) define supply chain collaboration as two or more members working to create a competitive advantage, by working and performing not individually but together, by sharing information, making decisions mutually, and sharing profits and benefits which result from higher profitability of satisfying the needs of the customer. A few other factors impacting collaboration in

supply chain are found to be trust, joint planning, sharing rewards, and interpersonal relationship.

Collaboration was found to be necessary in business and engineering management discipline as it increased productivity, reduced cost and added value and profit to the work. The papers related to psychology defined collaboration based on human factor view and applied ergonomics; thus providing a general perception about collaboration and collaboration factors.

2.4 Existing Collaboration Measurement Tools

A few tools were identified that measure collaboration in different disciplines. The tools were developed using either literature review or survey as a methodology. Shelbourn et al. (2007) used interview and questionnaire to develop a framework to measure effectiveness of collaboration in construction. Abdirad and Pishad Bozorgi (2014) developed a framework to measure construction collaboration using literature review as a methodology. Hojat and Gonnella (2011) developed an instrument to assess nurse-physician collaboration in healthcare using statistical analysis. Gedney (1994) utilized literature review to develop a questionnaire as the tool to assess physician nurse collaboration. Kumar and Banerjee (2014) used statistical analysis to develop a tool to assess collaboration in supply chain management. Simatupang and Sridharan (2005) utilized survey to develop a collaboration index to measure collaboration in supply chain. Cao et al. (2009) utilized literature review to develop an instrument that employed survey to measure collaboration in supply chain management. Thomson et al. (2007) employed

multi-disciplinary study to develop a comprehensive tool to conceptualize and measure collaboration.

The tools identified in this study assessed collaboration in a particular discipline by identifying factors that impact collaboration with regard to that discipline. However, there were limited comprehensive tools developed using a multi-disciplinary to assess collaboration. Since multi-disciplinary study was observed to be more elaborative concept that identified maximum factors impacting collaboration and the maximum number of papers reviewed for this study utilized literature review as a methodology to develop metrics to measure collaboration, it may be regarded that multi-disciplinary literature review is realistic method to develop the framework to assess collaboration.

3. RESEARCH METHOD

3.1 Introduction

The objective of the study is to develop a framework to assess collaboration and this can be done in three parts: Data Collection, Data Organization and Development of Framework. Two of the construction collaboration measurement tools were also analyzed.

3.2 Data Collection

Literature review

- Data was collected from data bases available with the Texas A&M University system.
- An extensive literature review on the research that has been done regarding the various factors impacting collaboration was done.
- The key words used to find papers were “factors of collaboration”, “collaboration factors”, “assessing collaboration factors”, “measuring collaboration” and “metrics to measure collaboration”.
- The maximum citations with these keywords were from construction, health care, supply chain management, psychology, and business and engineering management. Hence, they were chosen as the five disciplines to carry out this multi-disciplinary study.
- Data was also collected on existing tools to assess collaboration.

3.3 Data Organization

The data was organized as shown below:

- Each discipline was studied distinctly.

- The various factors impacting collaboration in the each of the disciplines were identified and tabulated distinctly.
- The appearance of each factor from various papers researched was summed up.
- The collaboration factors were arranged in decreasing order of their total sum.
- This sum was compared with the total number of papers reviewed and converted into a percentage form.
- A Pareto chart was developed for each of the disciplines by plotting the percentage of times the factor was quoted versus collaboration factors.

3.4 Development of Framework

Development of Unified Pareto Chart:

- The individual tables from the five distinct disciplines were then integrated into one table and accordingly a unified Pareto chart was prepared from this table in a similar method as stated previously.

Development of a consolidated graph representing factors impacting collaboration in each discipline:

- The percentages of number of times each of the factors was quoted in each of the disciplines was noted.
- A scatter graph was then plotted and considered all the five disciplines.

- The abscissa of the graph represents all identified factors that impact collaboration in the five disciplines studied and the ordinate represents the percentage of the number of times the factor has been quoted in each discipline.

3.5 Analysis of the Data

The number of times each factor was quoted was summed up and the factors were arranged in a decreasing order of their total sum. The first five most frequently quoted factors have been considered as the key factors impacting collaboration in each discipline and with regard to all disciplines together.

3.5.1 Analysis of two collaboration measurement tools available

The two collaboration measurement tools available were analyzed in the following way:

- Two tools were analyzed with respect to the unified Pareto chart and consolidated graph. The tools were checked for the factors mentioned and the number of times the factor was quoted in general and with respect to construction.
- Comments were made and the tools were further analyzed to determine if there was any potential for improvement.

3.6 Assumptions

The research is based on the following assumptions:

- The research is based on an assumption that the four chosen disciplines other than construction are a good reference point for analyzing collaboration, and the nature of collaboration required in these disciplines is similar to that of construction.
- It has also been assumed that the most quoted four to five factors are, in fact, the key factors that impact each discipline.

3.7 Limitations

A few limitations that apply to this research are:

- Although there are numerous disciplines where collaboration may have a significant impact, only five disciplines have been chosen for this study.
- This paper assumes that the factors identified that impact collaboration in this multi-disciplinary study also affect construction collaboration; however it must be acknowledged that this may or may not be true.
- The number of relevant papers found in each of the five disciplines is not equal and this may cause a discrepancy in the results and affect the percentage of number of times each factor was quoted.
- This tool was developed primarily based on information currently available through published peer-reviewed articles. However, it must be acknowledged that this poses a limitation. For example, some factors of collaboration, such as mutual respect, appear less frequently as research topics. This may reflect a limitation in the current state of collaboration

research, as it is likely that additional factors will be more thoroughly studied in the future.

- Although this research aggregates various factors, the definitions of factors are in reality not mutually exclusive. This makes it difficult to accurately quantify the appearance of factors. It needs to be acknowledged that this was a limitation of the methodology and analysis used in the research.

3.8 Delimitations

The delimitations are:

- This research only includes data from five selected disciplines wherein collaboration has a significant impact.
- All data collected are from papers published in the English language and that are available within the Texas A&M University library database system.

4. RESULTS AND ANALYSIS

4.1 Introduction

This chapter summarizes the findings of the multi-disciplinary literature review. The various factors that impact collaboration in construction, psychology, business and engineering management, health care and supply chain management have been identified.

The factors that impact collaboration in each of the disciplines have been tabulated distinctly in different tables with respect to each discipline. Using the information from these tables, Pareto charts have been made with respect to each discipline. In addition to this, an integrated table with respect to all the disciplines put together, has also been presented. Based on this integrated table, unified Pareto chart was developed.

The factors impacting collaboration in all the five disciplines studied have been summarized in the consolidated graph and can be used as a basis for identifying most of the factors impacting collaboration with respect to each discipline.

4.2 Collaboration Factors in Construction

It was observed that much research has not been done on collaboration factors in the construction industry. However, some research has been done on collaboration in IPD projects. Twelve papers that were relevant are presented in this study.

The factors that impact collaboration as quoted in this discipline were having a legal collaborative agreement, open communication between team members, trust, incentivizing and sharing rewards, implementing technology like BIM, information sharing, having shared goals, business climate or organization culture, joint planning among team members, sharing resources, team composition and diversity, having a clear

specification of roles and responsibilities, cooperation, joint decision making, organization structure, co-location, giving feedback to the team members, interpersonal relationship, mutual respect, performance- individual and team, team productivity, coordination, management support, training and psychological factors and can be seen in Table 1. The Pareto chart has also been presented (Figure 1).

Table 1: Factors Impacting Collaboration in Construction

Factors Impacting Collaboration in Construction	Total	% of times factor has been quoted	Abdirad and Pishad-Bozorgi (2014)	Akintan and Morledge (2013)	Akintoye <i>et al.</i> (2000)	Ashcraft (2011)	El Asmar <i>et al.</i> (2013)	Franz and Leicht (2012)	Ingirige and Sexton (2006)	O'Connor (2009)	Raisbeck (2010)	Schottle <i>et al.</i> (2014)	Shelbourn <i>et al.</i> (2007)	Tutesigensi and Oak (2007)
Collaborative Agreement (legal)	8	67		x		x	x	x	x		x	x	x	
Open Communication	8	67	x		x		x	x		x		x	x	x
Trust	8	67		x	x		x	x		x		x	x	x
Incentives/Share d rewards	7	58		x			x	x	x		x	x		x
Information/ Knowledge Sharing	6	50	x	x		x	x		x			x		

Table 1 Continued

Factors Impacting Collaboration in Construction	Total	% of n factor has been quoted	Abdirad and Pishad-Bozorgi (2014)	Akintan and Morledge (2013)	Akintoye <i>et al.</i> (2000)	Ashcraft (2011)	El Asmar <i>et al.</i> (2013)	Franz and Leicht (2012)	Ingirige and Sexton (2006)	O'Connor (2009)	Raisbeck (2010)	Schottle <i>et al.</i> (2014)	Shelbourn <i>et al.</i> (2007)	Tutesigensi and Oak (2007)
Shared Goals	6	50				x	x	x		x	x	x		
Business Climate/ Organization Culture	5	42							x	x	x		x	x
Joint Planning	5	42			x	x	x	x				x		
Sharing Resources	5	42				x	x		x		x	x		
Team Composition and Diversity	5	42	x	x		x			x	x				
Clear Roles and Responsibilities	4	33				x		x				x		x
Cooperation	4	33			x				x			x		x
Joint Decision Making	4	33	x			x		x				x		
Organization Structure	4	33			x	x					x	x		
Co-location	3	25	x			x				x				
Feedback	3	25	x								x			x
Interpersonal Relationship	3	25					x					x		x
Mutual Respect	3	25						x		x		x		
Performance-Individual and Team	3	25				x		x						x

Table 1 Continued

Factors Impacting Collaboration in Construction	Total	% of times factor has been quoted	Abdirad and Pishad-Bozorgi (2014)	Akintan and Morledge (2013)	Akintoye <i>et al.</i> (2000)	Ashcraft (2011)	El Asmar <i>et al.</i> (2013)	Franz and Leicht (2012)	Ingirige and Sexton (2006)	O'Connor (2009)	Raisbeck (2010)	Schottle <i>et al.</i> (2014)	Shelbourn <i>et al.</i> (2007)	Tutesigensi and Oak (2007)
Team Productivity	3	25	x					x		x				
Coordination	2	17			x						x			
Management Support	2	17			x	x								
Training	2	17	x			x								
Psychological Factors	1	8	x											

4.2.1 Analysis

The most frequently mentioned collaboration factors in construction industry were having a legal collaborative agreement, open communication between team members and trust. These factors were quoted in 67% of the research papers and may be regarded as the most important ones in construction collaboration.

It was observed that there were two other factors which were quoted in 58% of the papers reviewed. These were incentivizing and sharing rewards, and implementing technology (Building Information Modeling) as a tool to improve collaboration. The above mentioned five factors, may be identified as the key factors impacting collaboration in the field of construction as they have been quoted most frequently in this discipline.

The other factors impacting collaboration in construction were information sharing, having common and shared goals, the business climate or organization culture, joint planning, sharing resources, team composition and diversity. These factors were quoted in 40%-50% of the papers. Due to the number of citations, it may be determined that in addition to the four key factors, these identified factors are also important for collaboration in this discipline.

Additional factors identified were joint decision making, having a clear specification of roles and responsibilities, cooperation, organization structure, co-location, giving feedback to the team members, interpersonal relationship, mutual respect, performance- individual and team, and team productivity. These factors were quoted a limited number of times (25%-35%) in the papers.

As per the findings, factors such as coordination, management support, training and psychological factors also impact collaboration in construction; but, these factors were quoted seldom in about 8%-18% of the papers. However, these factors were found to be important in other disciplines.

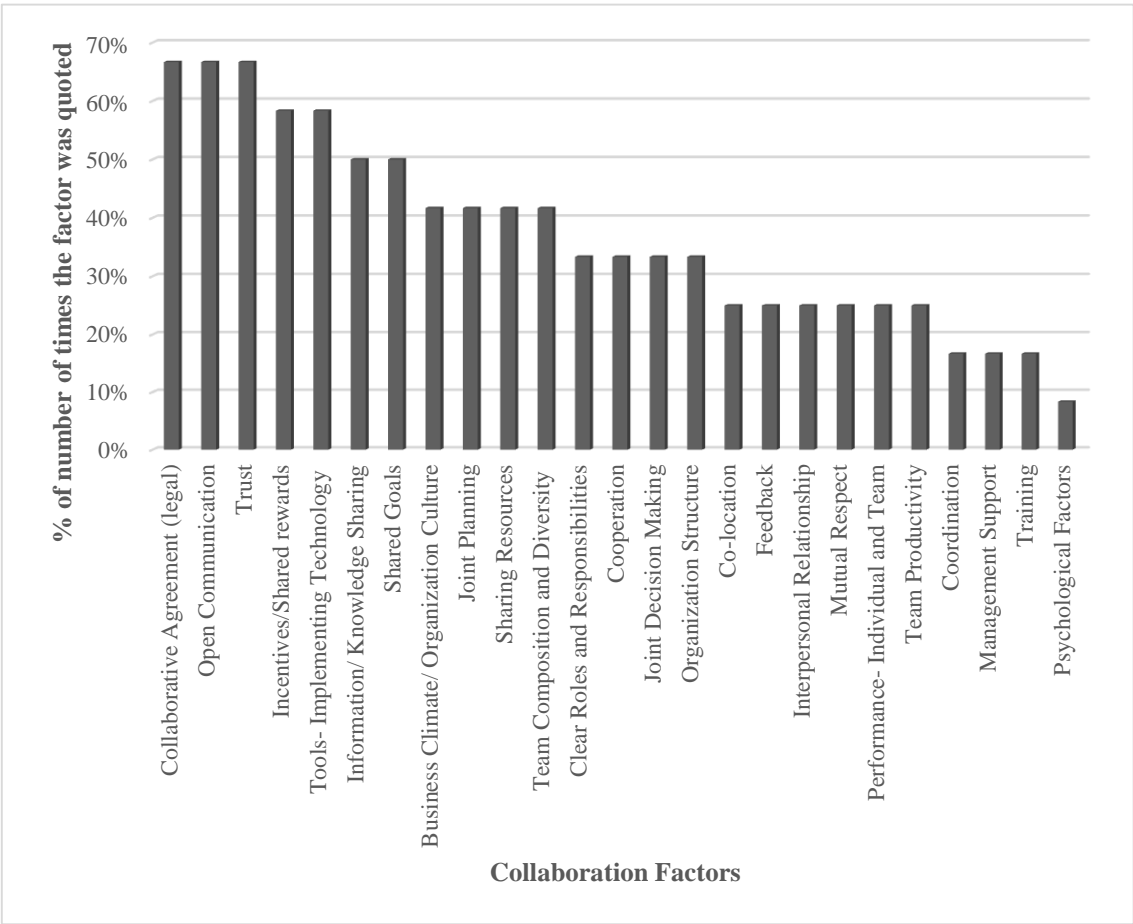


Figure 1: Pareto Chart Representing Factors Impacting Construction Collaboration

4.3 Collaboration Factors in Health Care

In healthcare studies, it was noted that collaboration was necessary between nurses and physicians and in some cases, between pharmacists and physicians.

The factors that impact collaboration in health care were identified as open communication, clear specification of roles and responsibilities, information or knowledge sharing, coordination, trust, cooperation, joint or collaborative decision making, organizational culture, mutual respect, joint or collaborative planning, commitment, psychological factors, having shared goals, willing participation, sharing available resources. These can be seen in Table 2.

Table 2: Factors Impacting Collaboration in Health Care

Factors Impacting Collaboration in Health Care	Total	% of times factor has been quoted	Alpay and Littleton (2001)	Baggs, J.D (1994)	Doherty <i>et al.</i> (1996)	Gregson, B.A et al. (1992)	Henneman et al. (1994)	Hojat, M. and Gonnella, J.S. (2011)	Jirotko et al. (2005)	McCaffrey et al. (2010)	Nathanson et al. (2011)	Risser <i>et al.</i> (1999)	Rosenstein and O'Daniel (2005)	Tang, C.J et al. (2013)	Weller et al. (2011)	Yeager (2005)	Zwarenstein <i>et al.</i> (2009)
Open Communication	13	87	x	x	x	x		x	x	x		x	x	x	x	x	x
Clear Roles and Responsibilities	8	53	x		x			x			x	x		x		x	x
Information / Knowledge Sharing	8	53	x				x		x	x		x	x			x	x
Coordination	6	40	x	x					x			x				x	x
Trust	6	40						x	x			x		x	x	x	
Cooperation	5	33		x		x	x	x				x					
Joint Decision Making	5	33		x		x		x	x		x						
Business Climate/Organizational Culture	4	27	x		x										x		x
Mutual Respect	4	27	x											x	x	x	

Table 2 Continued

Factors Impacting Collaboration in Health Care	Total	% of times factor has been quoted														
			Alpay and Littleton (2001)	Baggs, J.D (1994)	Doherty <i>et al.</i> (1996)	Gregson, B.A et al. (1992)	Henneman et al. (1994)	Hojat, M. and Gonnella, J.S. (2011)	Jirotko et al. (2005)	McCaffrey et al. (2010)	Nathanson et al. (2011)	Risser <i>et al.</i> (1999)	Rosenstein and O'Daniel (2005)	Tang, C.J et al. (2013)	Weller et al. (2011)	Yeager (2005)
Joint Planning	3	20	x			x										x
Commitment	2	13								x						x
Psychological Factors	2	13			x											x
Shared Goals	2	13							x							x
Willing Participation	2	13					x									x
Sharing Resources	1	7	x													

4.3.1 Analysis

The majority of the researchers (87%) quoted that open communication was necessary in health care collaboration (Table 2, Figure 2). This was required to have a clear flow of information to avoid issues and further assist in making appropriate decisions. The other factors which were quoted in 40%-55% of the research papers are having a clear knowledge of individual's roles and responsibilities, information or knowledge sharing between the collaborative members, coordination and trust between the individuals who are collaborating (Table 2, Figure 2). These five factors may be identified as the key factors impacting collaboration in health care, and may be regarded as the critical factors since they have been quoted most frequently.

The other factors that guided collaboration in health care were cooperation, joint or collaborative decision making, business climate or organizational culture and mutual respect for the collaborative team members. These were the next most frequently quoted factors accounting for 25%-35% of the papers (Table 2, Figure 2); hence, it may be determined that in addition to the five key factors, these identified factors are also important for collaboration in health care.

Additional factors identified were joint planning between the members, commitment, psychological factors, having shared goals, willingness of the individuals to participate in collaboration and sharing the available resources. These factors were quoted in 7%-15% of the papers and were found to be cited a limited number of times (Table 2, Figure 2).

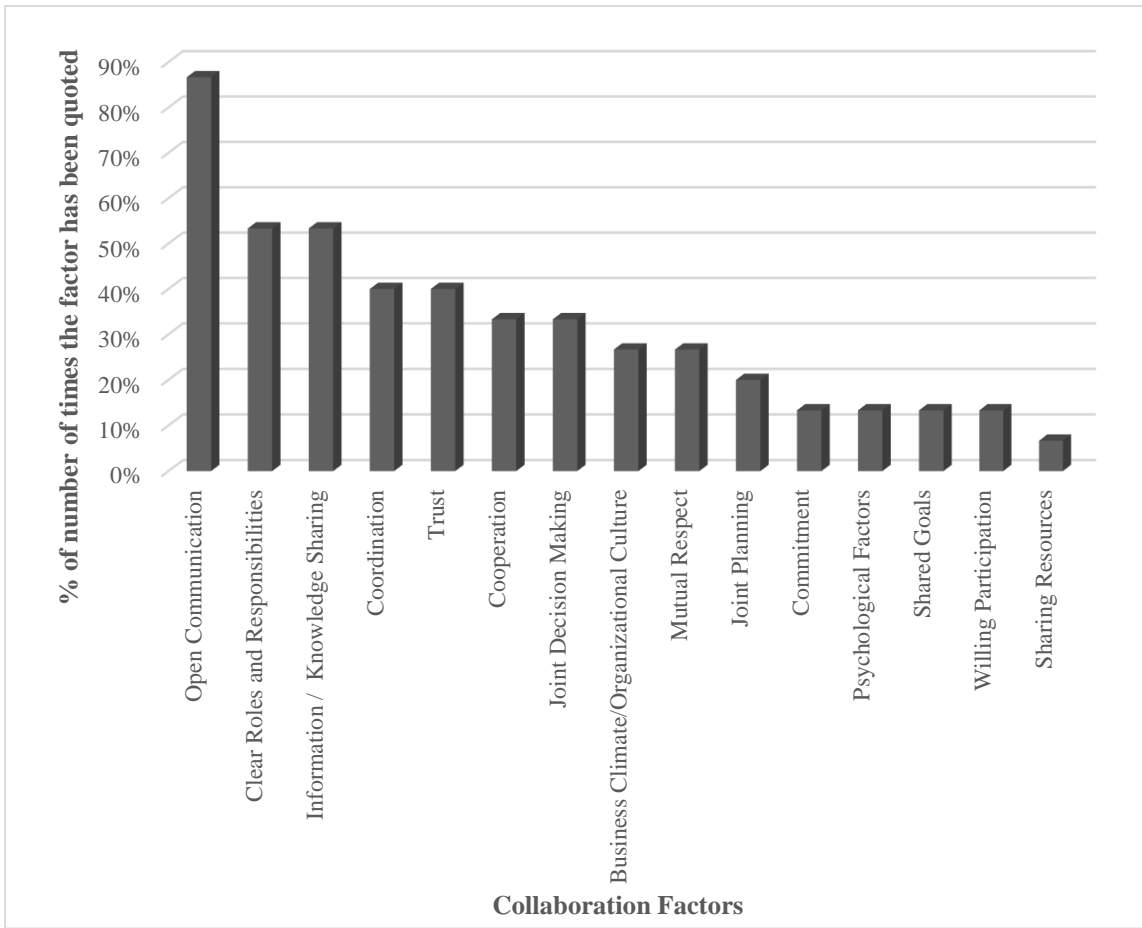


Figure 2: Pareto Chart Representing Factors Impacting Collaboration in Health Care

4.4 Collaboration Factors in Supply Chain Management

It was observed that plenty of research has been done in the field of supply chain collaboration. It may be interpreted that collaboration plays a major role in supply chain management.

In supply chain management, collaboration is important between the supply chain partners as it results in reduced costs, greater technological improvements, enhanced performance, enhanced product quality and quicker product development (Walter, 2003; Hudnurkar et al. 2014).

The factors that impact collaboration in supply chain management were identified as information or knowledge sharing, trust, joint decision making, joint collaborative effort, commitment, joint planning, incentivizing and sharing rewards, sharing resources, open communication, having shared goals, management support, implementing technology, having legal collaborative agreement, interpersonal relationship, business climate or organizational culture, cooperation and coordination as seen in Table 3.

Table 3: Factors Impacting Collaboration in Supply Chain Management

Factors Impacting Collaboration in Supply Chain Management	Total	% of times factor has been quoted	Angerhofer and Angelides (2006)	Baihaqi and Sohal (2012)	Barratt (2004)	Cai <i>et al.</i> (2010)	Cao and Zhang (2011)	Chen <i>et al.</i> (2011)	Fawcett <i>et al.</i> (2012)	Forusland and Jonsson (2009)	Fynes <i>et al.</i> (2005)	Gopal Kumar, Rabindranath (2014)	Hudnurkar <i>et al.</i> (2014)	Kwon and Suh (2004)	Nyaga (2010)	Simatupang <i>et al.</i> (2002)	Simatupang <i>et al.</i> (2004)	Simatupang and Sridharan (2002)	Simatupang and Sridharan (2004)	Simatupang and Sridharan (2005)	Simatupang and Sridharan (2008)	Tim <i>et al.</i> (2002)	Walter (2003)	Wenfa Hu (2008)	Zacharia (2009)
Information/ Knowledge Sharing	18	78	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x	x		x	x	
Trust	16	70	x	x	x		x	x	x	x		x	x	x		x		x				x	x	x	x
Joint Decision Making	10	43				x	x					x	x			x		x				x			x
Joint Collaborative Effort	10	43							x	x	x	x	x		x		x		x	x	x				
Commitment	8	35		x			x				x	x	x										x		x
Joint Planning	8	35		x									x			x		x		x	x			x	

Table 3 Continued

Factors Impacting Collaboration in Supply Chain Management	% of times factor has been quoted																						
	Total	Angerhofer and Angelides (2006)	Baihaqi and Sohal (2012)	Barratt (2004)	Cai <i>et al.</i> (2010)	Cao and Zhang (2011)	Chen <i>et al.</i> (2011)	Fawcett <i>et al.</i> (2012)	Forusland and Jonsson (2009)	Fynes <i>et al.</i> (2005)	Gopal Kumar, Rabindranath (2014)	Hudnurkar <i>et al.</i> (2014)	Kwon and Suh (2004)	Nyaga (2010)	Simatupang <i>et al.</i> (2002)	Simatupang <i>et al.</i> (2004)	Simatupang and Sridharan (2002)	Simatupang and Sridharan (2004)	Simatupang and Sridharan (2005)	Simatupang and Sridharan (2008)	Tim <i>et al.</i> (2002)	Walter (2003)	Wenfa Hu (2008)
Incentives/ Shared Rewards	7	30				x					x			x		x		x	x		x		
Sharing Resources	6	26				x	x			x	x	x	x										
Open Communication	5	22		x		x		x	x		x												
Shared Goal	5	22	x	x		x		x			x												
Management Support	4	17		x			x				x												x
Tools-Implementing Technology	4	17	x	x							x												x
Collaborative agreement (legal)	3	13		x	x						x												

Table 3 Continued

Factors Impacting Collaboration in Supply Chain Management			%																							
	Total	of times factor has been quoted	Angerhofer and Angelides (2006)	Baihaqi and Sohal (2012)	Barratt (2004)	Cai <i>et al.</i> (2010)	Cao and Zhang (2011)	Chen <i>et al.</i> (2011)	Fawcett <i>et al.</i> (2012)	Forusland and Jonsson (2009)	Fynes <i>et al.</i> (2005)	Gopal Kumar, Rabindranath 2014	Hudnurkar <i>et al.</i> (2014)	Kwon and Suh (2004)	Nyaga (2010)	Simatupang <i>et al.</i> (2002)	Simatupang <i>et al.</i> (2004)	Simatupang and Sridharan (2002)	Simatupang and Sridharan (2004)	Simatupang and Sridharan (2005)	Simatupang and Sridharan (2008)	Tim <i>et al.</i> (2002)	Walter (2003)	Wenfa Hu (2008)	Zacharia (2009)	
Interpersonal Relationship	3	13			x	x							x													
Business Climate/ Organizational culture	2	9			x								x													
Cooperation	2	9								x		x														
Coordination	2	9										x												x		

4.4.1 Analysis

The most frequently quoted factors in supply chain collaboration were information or knowledge sharing and trust. These factors were quoted in 78% and 70% of the research papers (Table 3, Figure 3). Information sharing has a noteworthy impact on supply chain collaboration and results in cost reduction, improvement of performance and aids in attaining a competitive advantage (Hudnurkar et al. 2014). Trust between the team members is considered essential for effective and successful collaboration.

In addition to information sharing and trust, it was observed that there were other factors quoted frequently such as joint decision making, having a joint collaborative effort, commitment to collaborate and joint planning among the supply chain partners. These factors were quoted in 35%-45% of the papers (Table 3, Figure 3). These factors seem to have a noteworthy impact on supply chain collaboration. The six most frequently quoted factors may be identified as the key factors impacting collaboration in supply chain management.

The other factors impacting collaboration in health care were incentivizing and sharing rewards among the supply chain partners, sharing the available resources, open or collaborative communication, sharing the collaborative goals, support from the management, and enabling technology as a tool for better management and efficiency. These factors were quoted in 15%-30% papers (Table 3, Figure 3). It may be determined that in addition to the six key factors, these identified factors are also important for collaboration in supply chain management.

Additional factors identified were having a legal collaborative agreement, interpersonal relationship between the supply chain partners, business climate or organizational culture, cooperation and coordination among the partners. These factors were quoted a limited number of times in 8%-15% of the papers (Table 3, Figure 3).

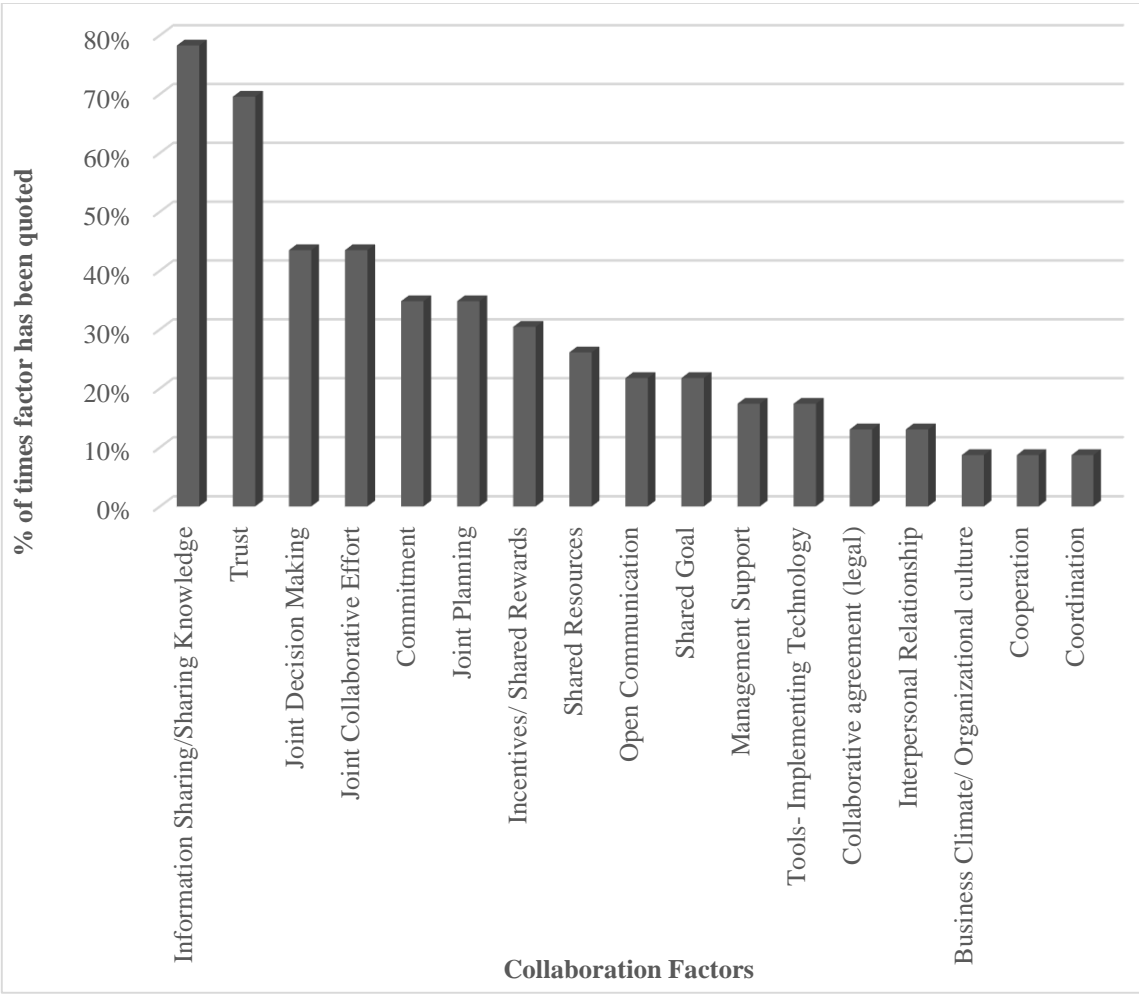


Figure 3: Pareto Chart Representing Factors Impacting Collaboration in Supply Chain Management

4.5 Collaboration Factors in Psychology

The factors that impact collaboration as mentioned in psychology were team composition and diversity, information or knowledge sharing, support from management, organizational structure, business climate or organizational culture, incentivizing and sharing rewards, having a clear specification of roles and responsibilities, joint decision making between collaborative group members, individual and team performance, implementing technology, training, trust, environment, open communication, psychological factors, having shared goals, sharing available resources and coordination and can be seen in Table 4.

Table 4: Factors Impacting Collaboration in Psychology

Factors Impacting Collaboration in Psychology	Total	% of times factor has been quoted	Campion <i>et al.</i> (1993)	Cuevas <i>et al.</i> (2006)	Cummings and Kiesler (2005)	Edwards and Wilson (2004)	Hackman (1990)	Hammond <i>et al.</i> (2001)	Hammond <i>et al.</i> (2005)	Mattessich and Monsey (1992)	O'Driscoll and Cooper (1996)	Payne (1996)	Salas <i>et al.</i> (2005Bb)	Steiner (1972)	Unsworth and West (2000)	West (1996)	Wilson <i>et al.</i> (2003)	Wilson (2006)	Wilson <i>et al.</i> (2009)
Team Composition and Diversity	8	47	x		x	x	x			x			x		x				
Information Sharing/ Sharing Knowledge	6	35	x			x	x			x							x	x	
Management Support	6	35	x			x	x	x					x		x				
Organizational Structure	6	35	x			x	x					x				x	x		
Business Climate/Organizational Culture	5	29				x	x					x			x	x			
Incentives/Shared Rewards	5	29				x	x			x			x		x				
Clear Roles and Responsibilities	4	24					x			x	x								x
Joint Decision Making	4	24							x					x	x	x			
Performance	4	24				x	x						x						x

Table 4 Continued

Factors Impacting Collaboration in Psychology	Total	% of times factor has been quoted	Campion <i>et al.</i> (1993)	Cuevas <i>et al.</i> (2006)	Cummings and Kiesler (2005)	Edwards and Wilson (2004)	Hackman (1990)	Hammond <i>et al.</i> (2001)	Hammond <i>et al.</i> (2005)	Mattessich and Monsey (1992)	O'Driscoll and Cooper (1996)	Payne (1996)	Salas <i>et al.</i> (2005Bb)	Steiner (1972)	Unsworth and West (2000)	West (1996)	Wilson <i>et al.</i> (2003)	Wilson (2006)	Wilson <i>et al.</i> (2009)
Tools- Implementing Technology	4	24			x			x	x										x
Training	4	24			x	x							x		x				
Trust	4	24			x			x										x	x
Environment	3	18			x						x						x		
Open Communication	3	18	x		x								x						
Psychological Factors	3	18											x	x					x
Shared Goals	3	18			x	x				x									
Shared Resources	3	18					x	x		x									
Coordination	1	6					x												

4.5.1 Analysis

The most frequently quoted factor in psychology was team composition and diversity. This factor was found to be quoted in 47% of the research papers. Most research papers stated that heterogeneous teams exhibit better performance (Table 4, Figure 4).

A few other frequently quoted collaboration factors identified were information or knowledge sharing, management support, organizational structure, business climate or organizational culture, incentivizing and sharing rewards. These factors were quoted in 29%-35% of the papers reviewed and presented (Table 4, Figure 4). It may be determined that these factors may have a notable impact on collaboration. The most frequently quoted five factors may be identified as the key factors impacting collaboration with regard to psychology.

The other factors impacting collaboration in this discipline were found to be joint decision making among team members, having a clear specification of roles and responsibilities, individual and team performance, tools- implementing technology, training and trust. These factors were quoted in 24% of the papers (Table 4, Figure 4). It may be determined that these identified factors are also important for collaboration in this discipline as they were quoted several times.

Additional factors identified were environment, open communication, psychological factors, having shared goals and sharing available resources. These factors were quoted in 18% of the papers (Table 4, Figure 4). It was observed that coordination was quoted only in 8% of the papers. From this, it can be inferred that coordination is not quoted much in this discipline. It can also be observed that coordination was not quoted

much in supply chain collaboration either. However, coordination was observed to be most frequently quoted in health care.

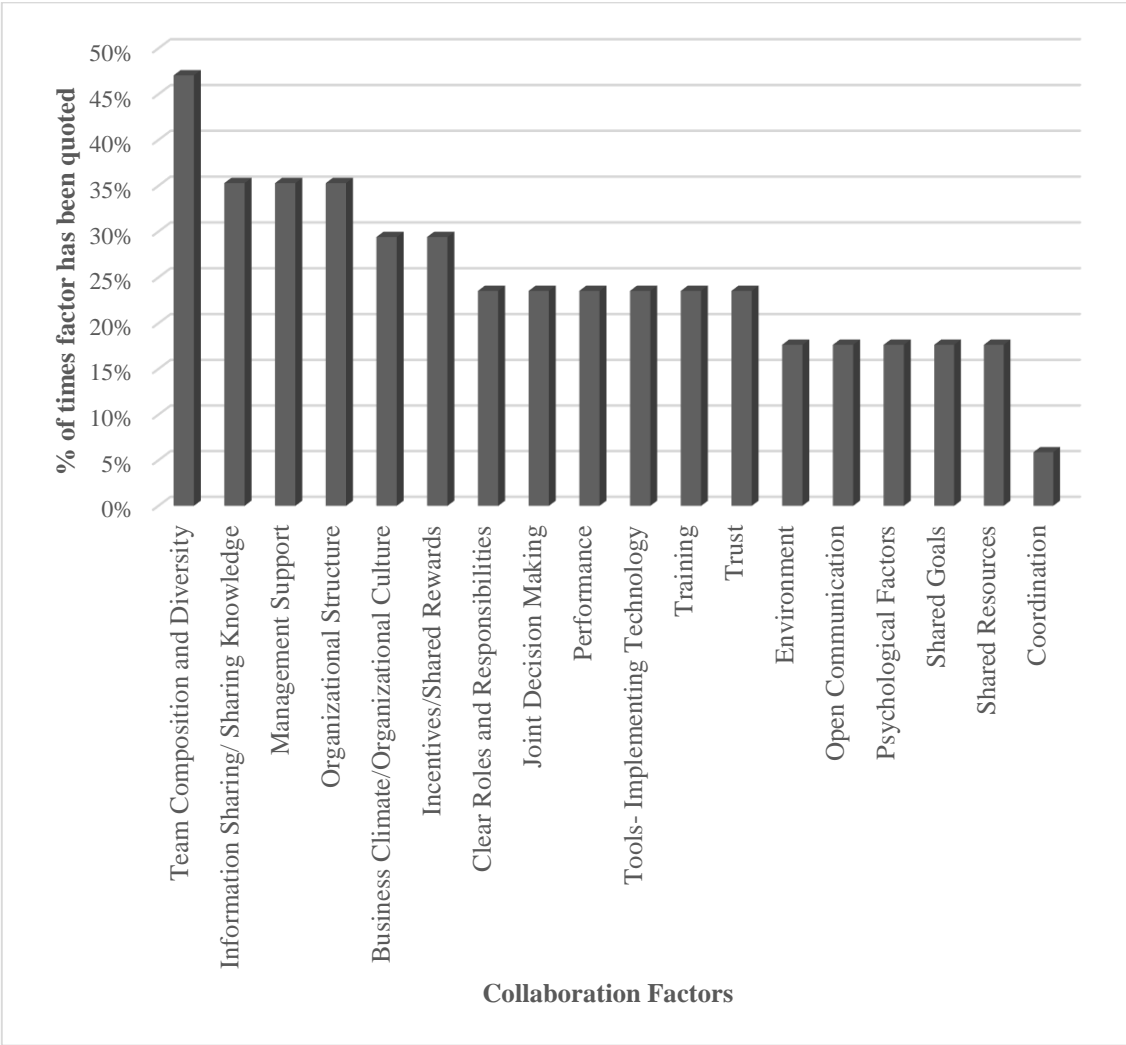


Figure 4: Factors Impacting Collaboration in Psychology

4.6 Collaboration Factors in Business and Engineering Management

The factors that impact collaboration in business and engineering management were found to be team composition and diversity, information or knowledge sharing, open communication, tools- implementing technology, business climate or organizational culture, coordination, joint decision making between collaborative group members, psychological factors, trust, environment, support from management, organizational structure, having shared goals, sharing available resources and training and can be seen in Table 5.

Table 5: Factors Impacting Collaboration in Business & Engineering Management

Factors Impacting Collaboration in Business and Engineering Management	Total	% of times factors has been quoted	Bornemann <i>et al.</i> (2003)	Denise (1999)	Devine and Banahan (1999)	Fasel (2001)	Gutwin and Greeberg (2000)	Hansen and Nohria (2004)	Harvey and Koubeck (1998)	Knutilla <i>et al.</i> (2000)	McNeese and Rentsch (2001)	Walsh and Maloney (2007)	Waugh (2005)	Wood and Gray (1991)	Weiseth <i>et al.</i> (2006)
Team Composition and Diversity	7	54		x	x			x	x		x	x			x
Information Sharing/ Sharing Knowledge	5	38	x		x			x						x	x
Open Communication	5	38		x			x		x			x			x
Tools-Implementing Technology	4	31							x	x	x				x
Business Climate/Organizational Culture	3	23	x		x										x
Coordination	3	23			x		x								x
Joint Decision Making	3	23			x									x	x
Psychological Factors	2	15				x		x							
Trust	2	15				x						x			
Environment	1	8			x										
Management Support	1	8			x										
Organizational Structure	1	8													x
Shared Goals	1	8			x										
Shared Resources	1	8											x		
Training	1	8													x

4.6.1 Analysis

The analysis has been done with regard to Table 5 and Pareto chart represented in Figure 5. The most frequently quoted collaboration factor in business and engineering management was team composition and diversity. This factor was found to be quoted in 54% of the research papers. Most research papers stated that heterogeneous teams exhibit better performance. It can be observed that this factor is the most important one in psychology as well.

It was observed that there are factors such as information or knowledge sharing, open communication and implementing technology that impact collaboration in this discipline. These factors were quoted in 30%-40% of the papers reviewed. The four most frequently quoted may be identified as the key factors impacting collaboration in business and engineering management.

The other factors impacting collaboration in this discipline were organizational culture, coordination and joint decision making between the collaborative group members. These factors were quoted in 23% of the papers. It may be determined that in addition to the four key factors, these identified factors are also important for collaboration in this discipline as they were quoted a few times.

Additional factors identified were psychological factors, trust, environment, management support, organizational structure, shared goals, shared resources between the team members and training given to the members participating in collaboration. These factors were quoted a limited number of times in 8%-15% of the papers.

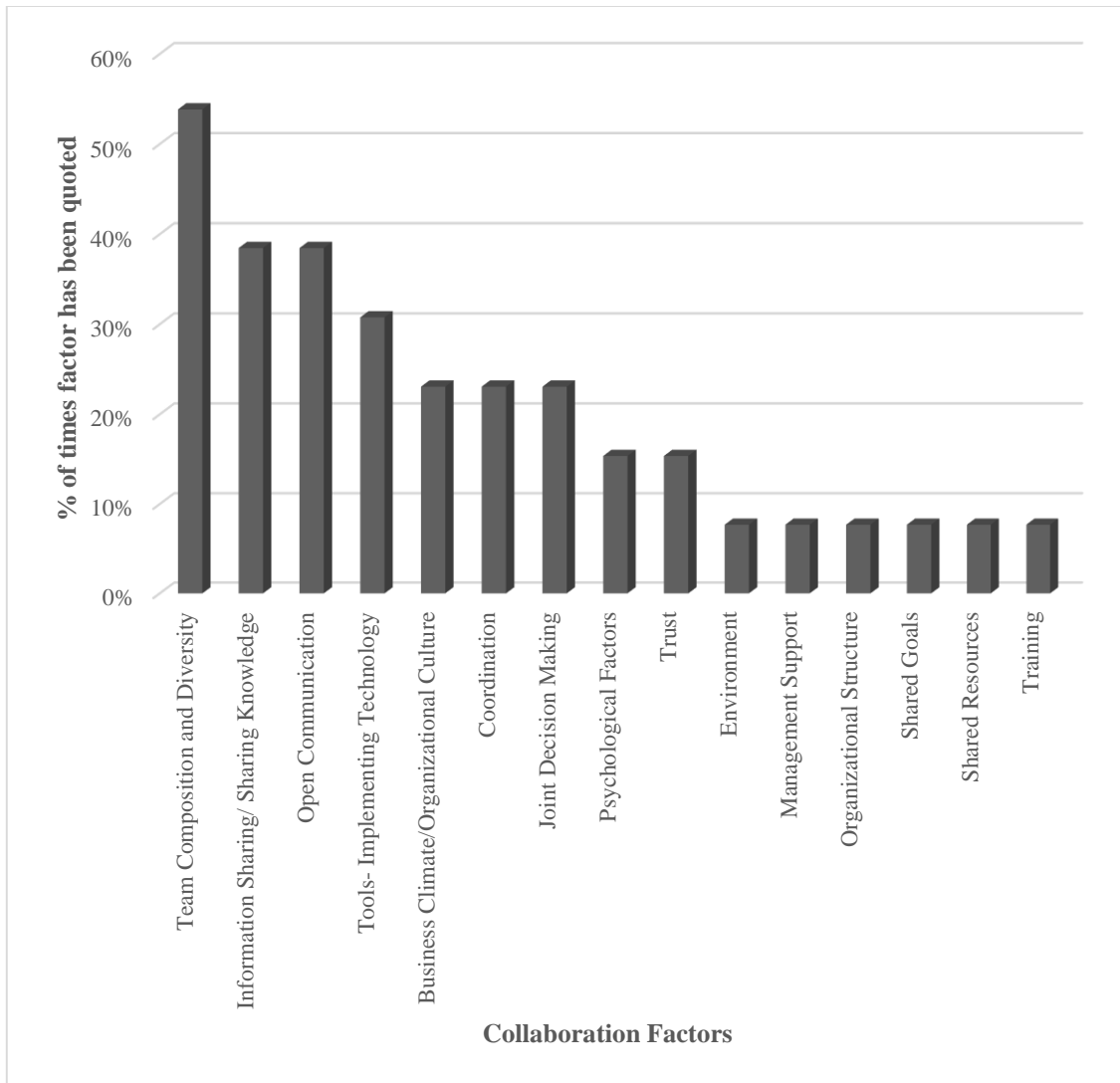


Figure 5: Factors Impacting Collaboration in Business & Engineering Management

4.7 Development of a Unified Pareto Chart of Collaboration Factors

In the previous section, the factors impacting collaboration in each discipline were found individually and tabulated. In this section, the previously tabulated work has been put together, resulting in a table exhibiting all the factors, with respect to the above five disciplines studied. This has been shown in Table 6, Appendix B. Using this data, a unified Pareto chart has been prepared and can be seen in Figure 6.

4.7.1 Analysis

The unified Pareto chart is a good representation of majority of the factors impacting collaboration and can be used as a basis by individuals and firms to develop collaboration measurement tools and could serve as a framework to assess collaboration. The frequently quoted factors with respect to various disciplines have been studied and presented. Since, they are arranged in the decreasing order of the total number of citations, it provides an easier understanding of most quoted to least quoted collaboration factors. It can be seen that information sharing, trust, open communication and joint decision making are most frequently quoted, and team productivity and willing participation are quoted in the least number of papers researched.

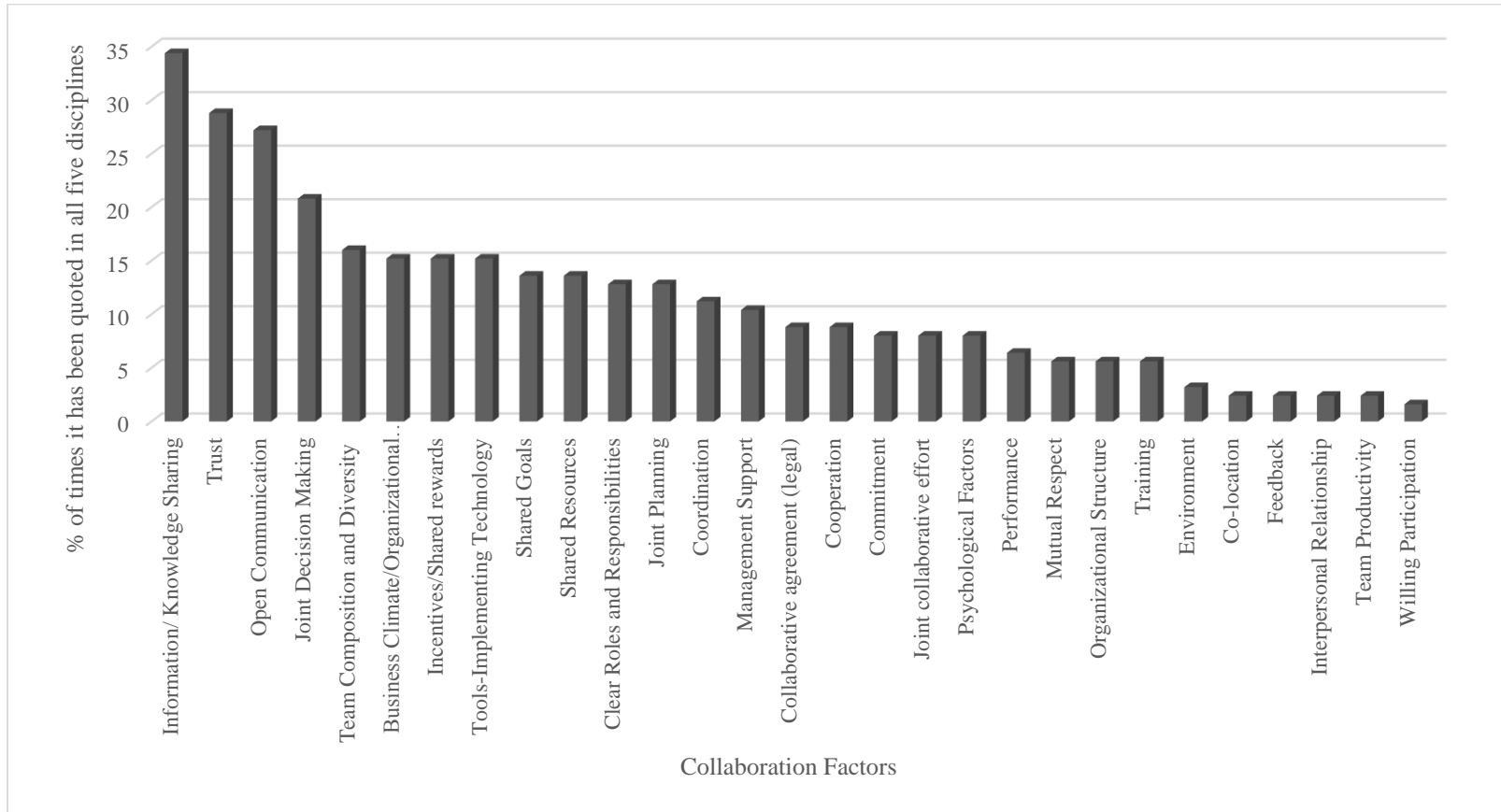


Figure 6: Unified Pareto Chart Representing Factors Impacting Collaboration

4.8 Comparative Analysis

A comparative analysis of the unified Pareto chart (Figure 6) and the Pareto chart developed for identifying factors in construction (Figure 1) has been done. It can be observed that majority of the factors (twenty four out of twenty seven) which impact collaboration in general, were also found to impact construction collaboration. However, a discrepancy was observed in the order of arrangement of the factors in the two Pareto charts. The three factors that were not quoted in construction collaboration were joint collaborative interaction, joint collaborative effort and willing participation. These collaboration factors were found to be quoted in other disciplines.

It can be observed that the most frequently quoted factor with respect to all disciplines studied was information or knowledge sharing whereas the most frequently quoted factor in construction is having a legal collaborative agreement. Trust and open communication were the next most frequently quoted factors in both the disciplines. Incentivizing and sharing rewards and implementing technology such as BIM has been quoted more frequently in construction than all disciplines put together. In the general analysis of collaboration factors using the unified Pareto chart, it can be observed that joint decision making and team composition and diversity are more frequently quoted than in papers related to construction. The least quoted factors in construction collaboration were management support, training and psychological factors. However, when compared to the unified Pareto chart, it can be observed that these factors are more frequently quoted and the least quoted factors with respect to the five disciplines put together were interpersonal relationship, team productivity and willing participation.

4.9 Multi-Disciplinary Comparative Analysis

The unified Pareto chart can be used in general to identify collaboration factors and not restricted to only construction industry. A more accurate analysis for each discipline can be ascertained and for this purpose, a graph representing the collaboration factors with respect to all disciplines studied has been presented in this section.

The results from the Pareto charts developed individually for each of the disciplines have been compared to identify the frequency of the factors in each discipline. This has been put together in the form of a graph. The abscissa represents all identified factors that impact collaboration in the five disciplines studied; the ordinate represents the percentage of the number of times the factor has been quoted in each discipline. This has been represented in Figure 7.

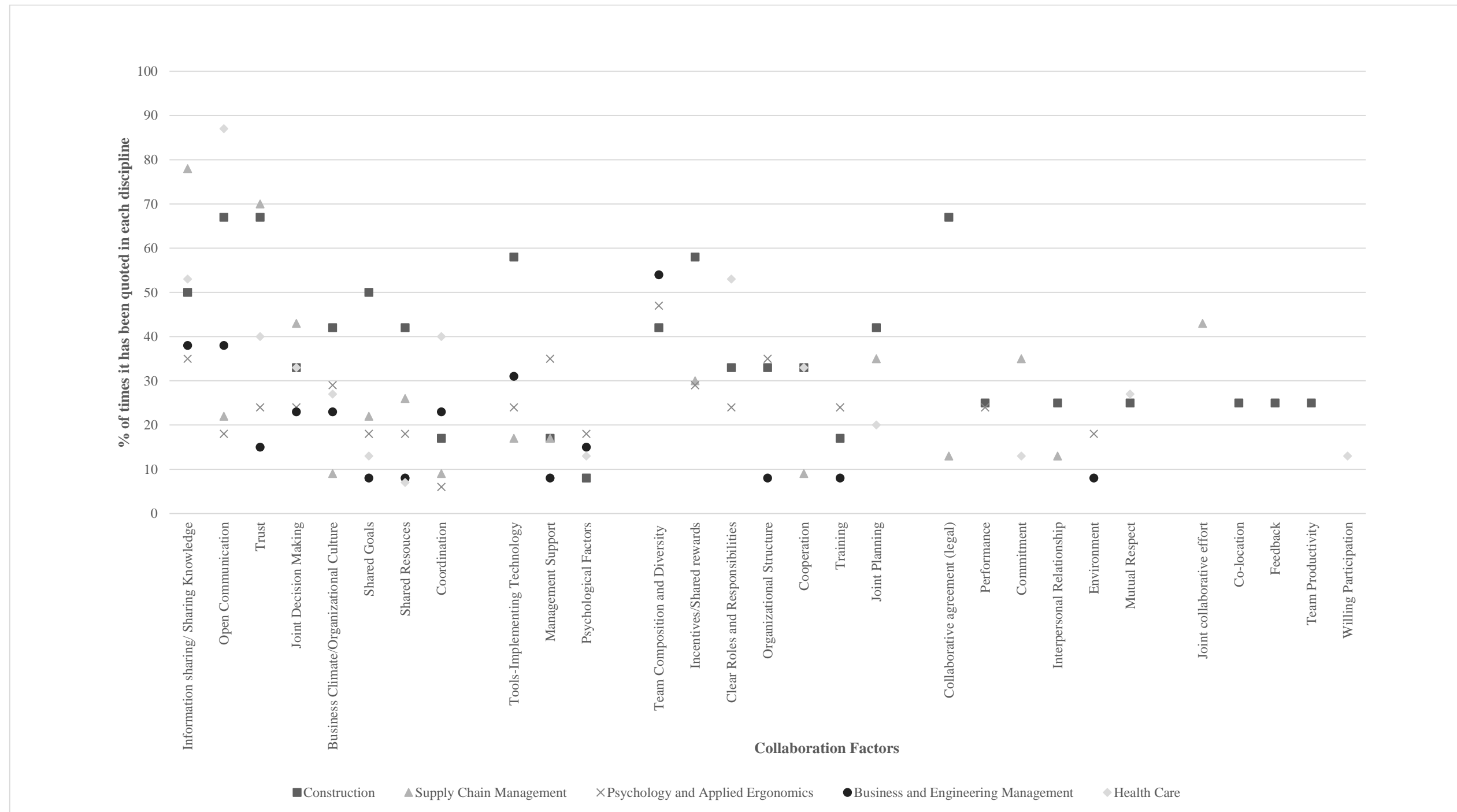


Figure 7: Consolidated Graph Representing Collaboration in Each of the Five Discipline

4.9.1 Analysis

It can be observed that the factors quoted in all five disciplines are not the same and only a few factors were found to be common. For better comparison, the graph can be divided into sections. It can be noted that the factors ranging from information or knowledge sharing to coordination have been quoted in all the five disciplines. The factors such as implementing technology, management support and psychological were quoted in four of the five disciplines. The factors ranging from team composition and diversity to joint planning have been quoted in three of the five disciplines studied. Furthermore, the factors extending from having a legal collaborative agreement to mutual respect between the team members were quoted in any two of the disciplines and the rest of the factors were quoted in any one of the disciplines.

This implies that the graph can be exclusively used to determine the percentage of number of times the factor has been quoted in every discipline. For example, from the graph, it can be concluded that information sharing has been most frequently quoted in supply chain management and is quoted least in psychology. Similarly, joint or collaborative planning has been quoted maximum number of times in construction and least in healthcare. Hence, for the same factor, the percentage of number of times it has been quoted in different disciplines can be compared. The graph can also be used to identify all the factors that impact collaboration in a particular discipline.

4.10 Assessing Construction Collaboration

To assist in developing or assessing the construction collaboration measurement tools, the unified Pareto chart can be used in conjunction with the consolidated graph for the most efficient outcomes. This can be applied to other disciplines studied in this research.

When developing or assessing a collaboration measurement tool, the importance of the factor displayed by percentage of number of times the factor being quoted with respect to construction or the concerned discipline (any of the other four disciplines studied) can be considered from the consolidated graph. This can be compared to the same factor on the Pareto chart that provides a general analysis. This would result in a more specific idea about the importance of the factor being considered and would be helpful in making a judgment regarding the factor and its inclusion in the measurement tool.

In conclusion, Pareto chart can be used as a basis for creating a new collaboration measurement tool and the consolidated graph can be used to fine tune this support system by comparing it with a similar field.

4.11 Analysis of Existing Construction Collaboration Tools

Two existing tools have been analyzed using the unified Pareto chart and consolidated graph of collaboration factors for all five disciplines.

4.11.1 Tool 1

The construction collaboration measurement tool presented in this section was provided by Cima Strategic Services. This tool has been analyzed to identify the factors mentioned and determine if there is any potential for improvement. The tool has been represented in Figure 8. The collaboration factors addressed by this tool have been identified and are stated in the same order. The factors are (from Figure 8):

- Team Productivity
- Interpersonal Relationship and Open Communication
- Interpersonal relationship and Willing Participation
- Team Productivity
- Training
- Performance
- Organizational Culture
- Psychological Factor
- Joint Collaborative Effort
- Feedback
- Feedback

Collaboration Feedback Invitation

ID: 2733

Category	Question
✔ Productivity	How well did the team apply innovative productivity improvement methods?
✔ Helpfulness	How well did the team create an environment that promoted asking for help when needed?
✔ Helpfulness	How well did the team create an environment that promoted offering of help even when not asked?
✔ Functional Improvement	Evaluate the rate at which we have improved the function of our team.
✔ New Habits	How well has the team adopted and advanced new habits (such as the relationship placemat, the pride curve, ground rules, etc.)?
✔ Goal Progress	Please evaluate the rate at which the team increased earnings per headcount.
✔ Wall Busting	How well has the team encouraged team members to remove impediments to collaboration by eliminating legacy structures?
✔ Acts of Kindness	How well have team members integrated genuine acts of kindness into their interactions on the project?
✔ Collaboration Gauge	Based on our common definition of collaboration, where would you place the team on the Collaboration Gauge right now? A collaborative project represents a "peak experience" on a project.
✔ Peak Experience	What is one success from the best project you have ever worked on, that we could apply to this project and create a "peak experience"?
✔ Other Comments	Please share any other comments or feedback below.

Figure 8: Collaboration Measurement Tool Provided by Cima Strategic Services
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4.11.1.1 Analysis

These factors have been represented on the unified Pareto chart and consolidated graph as represented in Figure 9 and Figure 10. It can be observed that team productivity,

interpersonal relationship and feedback have been stressed upon in this collaboration measurement tool.

Pareto chart gives a general idea regarding the most frequently quoted collaboration factors. From the Pareto chart (Figure 9), it can be observed that only two factors that are more frequently quoted have been mentioned. These are open communication and team composition and diversity. The factors have also been identified on the consolidated graph (Figure 10) and this gives a better understanding of the factors with respect to construction. It can be observed that joint collaboration effort and willing participation were not mentioned in papers related to construction collaboration. Further, amongst the most frequently mentioned factors in literature, only open communication has been mentioned in this tool.

Most of the factors mentioned in this tool such as joint collaboration effort, psychological factors, performance, feedback, interpersonal relationship, team productivity and willing participation were quoted only a limited number of times and can be seen in both Pareto chart (Figure 9) and consolidated graph (Figure 10).

To enhance the efficiency of this tool, most frequently quoted factors in consolidated graph and unified Pareto chart may be included. Factors such as legal collaborative agreement, information sharing, trust, joint decision making, shared goals, sharing rewards, sharing resources, implementing technology as a tool can be mentioned in this tool. In conclusion, the tool may be revised with more frequently quoted collaboration factors for better assessment of collaboration.

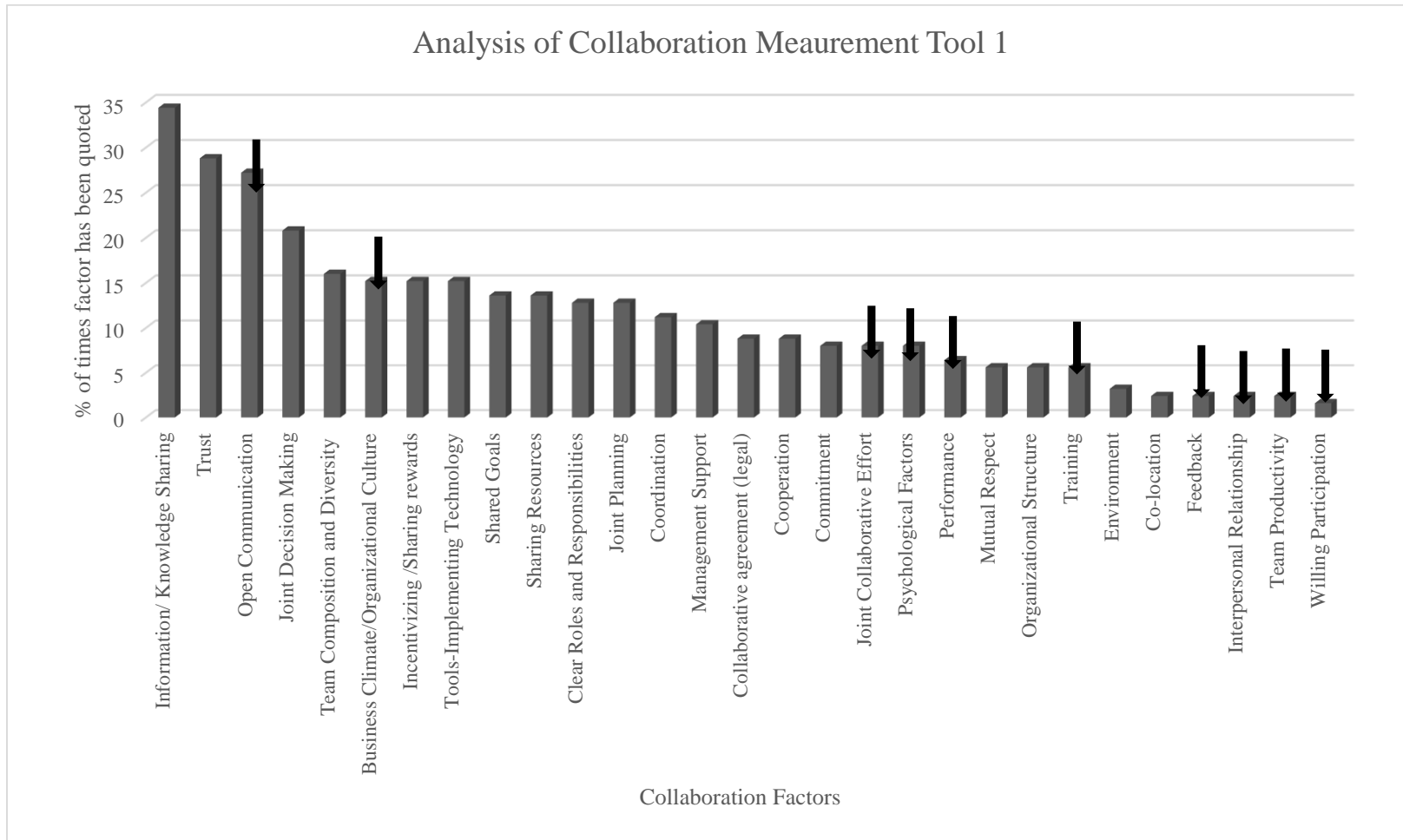


Figure 9: Pareto Chart Representing Collaboration Factors Mentioned in Tool 1

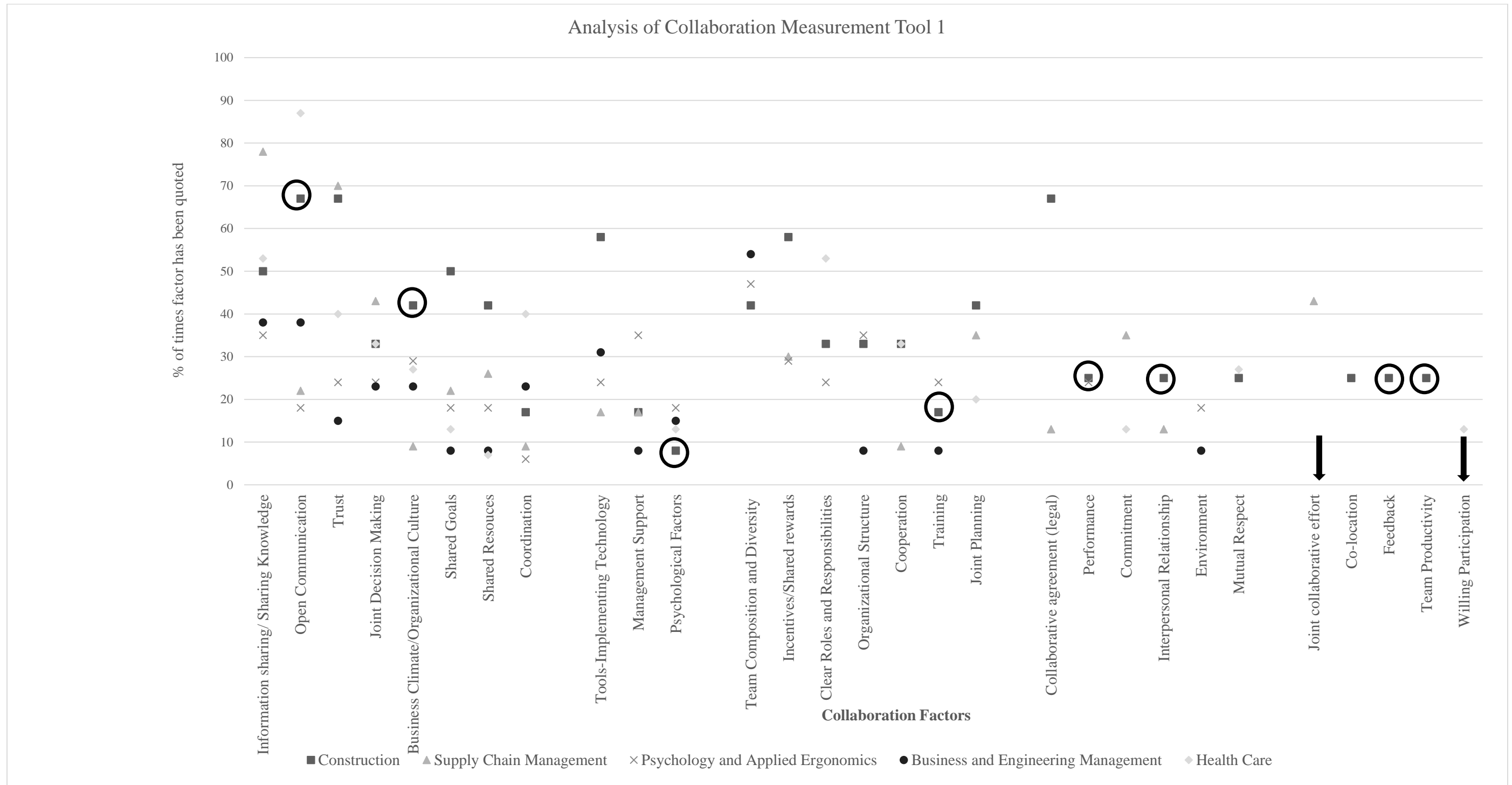


Figure 10: Consolidated Graph Representing Collaboration Factors Mentioned in Tool 1

4.11.2 Tool 2

The collaboration measurement tool presented in this section was prepared by Construction Industry Institute and can be seen in Figure 11. It measures the alignment or collaboration during pre-project planning. The tool has been analyzed to identify the factors mentioned in it and to determine if there exists any scope for further improvement.

The collaboration factors addressed by this tool are as follows:

1. Organization Structure
2. Clear Specification of Roles and Responsibilities
3. Information or Knowledge Sharing
4. Open Communication
5. Team Productivity
6. Trust and Mutual Respect
7. Sharing Resources
8. Incentivizing or Sharing Rewards
9. Training
10. Joint Planning and Tools- Implementing Technology

4.11.2.1 Analysis

The factors mentioned in this tool can be identified on the unified Pareto chart (Figure 12) and the consolidated graph (Figure 13). From the Pareto chart (Figure 12), it can be observed that this tool has a balanced mix of the factors represented throughout the chart. The most frequently quoted factors such as information or knowledge sharing, trust and open communication have been mentioned. The tool also identifies other frequently quoted factors impacting collaboration such as incentivizing and sharing rewards, tools-implementing technology, sharing resources, having a clear knowledge of roles and responsibilities, joint planning. The tool further identifies factors that have been quoted a limited number of times such as mutual respect, organizational structure, training and team productivity.

Additionally, for better analysis, the findings of the Pareto chart can be compared with the consolidated graph (Figure 13) as the graph provides a better understanding of the factors with respect to each construction. From the graph it can be observed that, open communication, trust, tools such as implementing technology, incentivizing or sharing rewards and having a legal collaborative agreement are the most important factors of construction collaboration. This tool includes majority of the most frequently quoted factors that impact construction collaboration with the exception of having a legal agreement to collaborate.

For better measurement of construction collaboration, this tool can further include factors such as interpersonal relationships, team composition and diversity, organizational culture and having shared goals as these factors have been quoted several times.

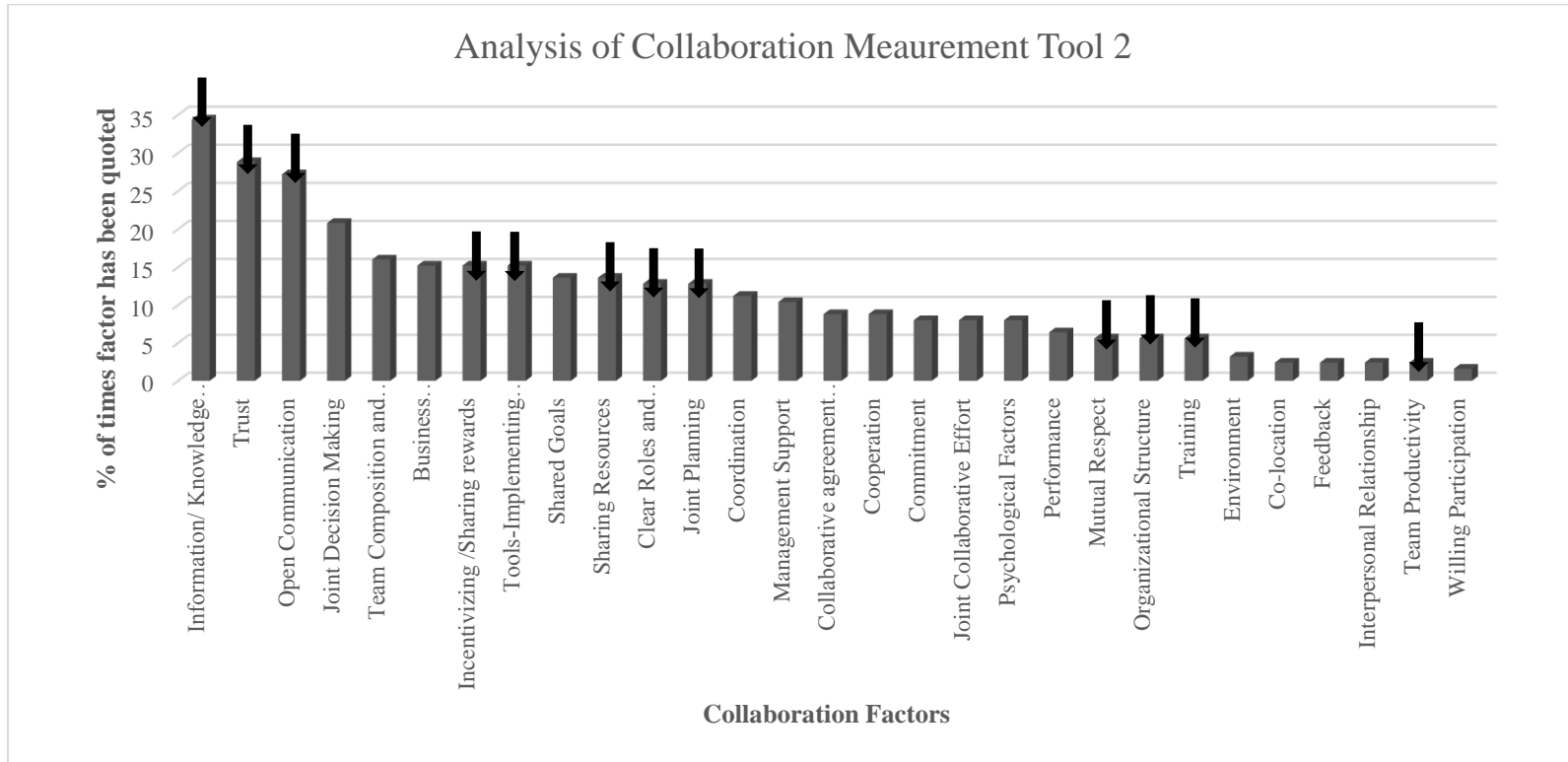


Figure 12: Pareto Chart Representing Collaboration Factors Mentioned in Tool 2

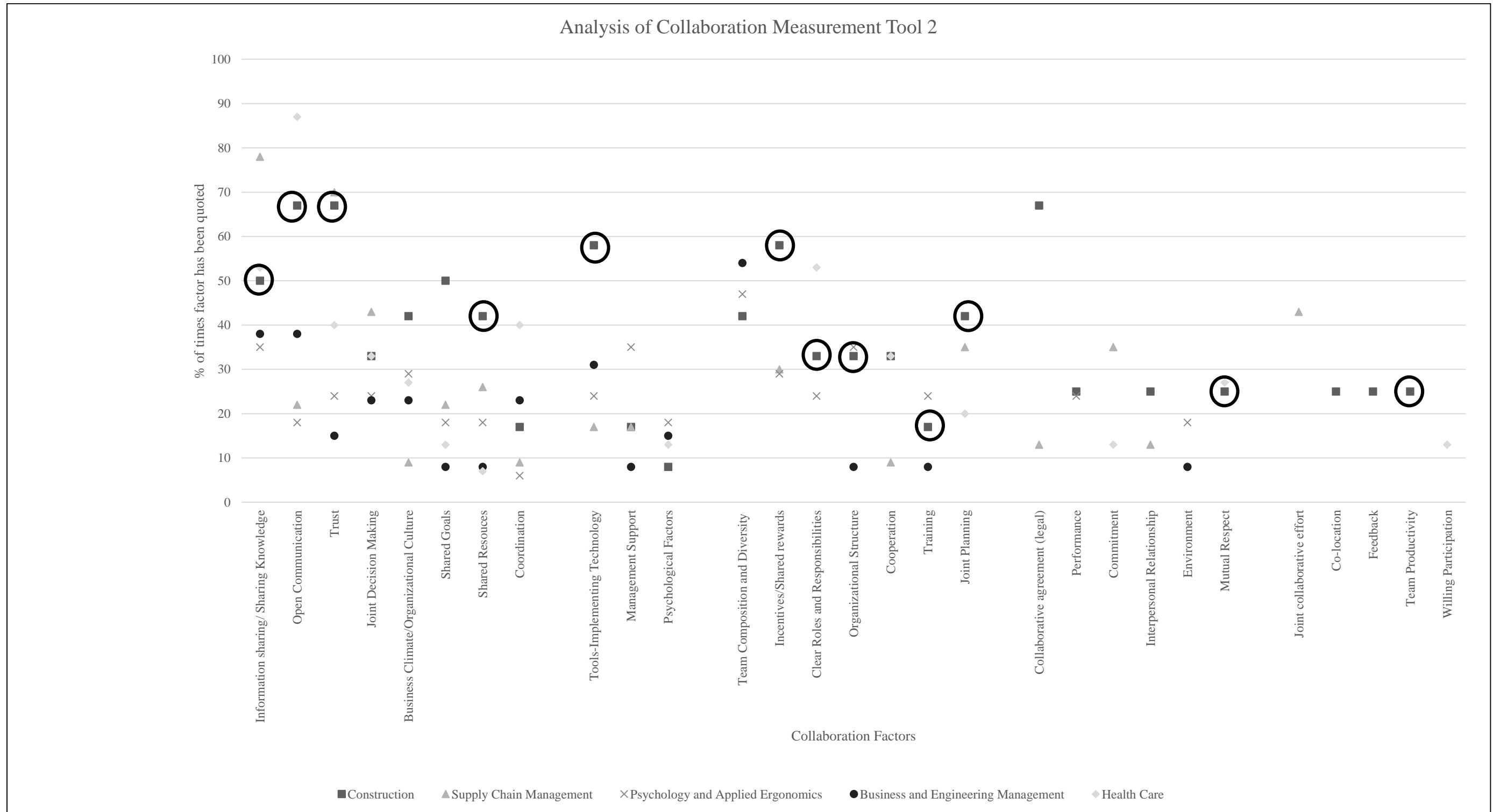


Figure 13: Consolidated Graph Representing Factors Mentioned in Tool 2

5. CONCLUSION AND FUTURE WORK

Construction industry involves many trades working together to deliver the final product and with the industry transitioning to Design-Build and IPD, the success of the project depends greatly on collaboration between the individuals, team players and key project participants. Hence, collaboration is essential and it is further necessary to assess it continuously. Therefore, this paper focuses on identifying the factors that impact collaboration through an extensive multi-disciplinary literature review and through this, developing a comprehensive framework to assess collaboration. The literature related to collaboration in disciplines other than construction can benefit the system by aiding in improving collaborative performance. A multi-disciplinary study provides a broad outlook and reflects the factors and metrics used by construction and non-construction disciplines to assess collaboration among team players.

The framework of metrics developed as a result of this research can be used to validate collaboration measurement tools. The factors mentioned in the tools can be compared with respect to the unified Pareto chart and consolidated graph developed in this research to assess the tools. The most frequently cited factors that impact collaboration in general and with respect to construction are found to be interpersonal relationship, trust, open communication, having a legal collaborative agreement, having common shared goals, joint decision making and team composition and diversity.

Development of the framework opens a whole new scope for future research on collaboration. Many of the identified metrics in the framework are extracted from non-

construction related literature; it should be investigated if these metrics reflect and measure collaboration in the construction industry effectively.

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APPENDIX A

Definitions

Business Climate/ Organizational Culture: “Organizational culture emerges from organization’s overall vision and objectives and comprises the attitudes, beliefs and values shared by employees. This can influence the ‘openness’ of communication channels, willingness to change, organizational trust and effectiveness” (Patel et al. 2012).

Clearly Specified Roles and Responsibilities: “The collaborative partners clearly understand their roles, rights, and responsibilities; and how to carry out those responsibilities” (Mattessich and Monsey, 1992).

Collaborative Agreement (legal): It refers to situation wherein collaboration is a requirement and no longer a choice. This agreement is legally signed as a contract between two collaborating parties (Abdirad and Pishad-Bozorgi, 2014).

Co-location: It refers to the situation wherein the collaborative team members are present in the same location and can meet face to face on a regular basis. This facilitates ease in the flow of communication and collaboration between the group members. Further, co-location assists in increased discussion of the project related concerns, resulting in an increase in the number of on-site meetings and decreased efforts in arrangement of such meetings (Abdirad and Pishad-Bozorgi, 2014).

Commitment: It refers to the willingness of the team members or collaborative partners to put forth effort on behalf of the relationship and henceforth, suggesting a

future orientation wherein firms attempt to build a relationship that could be sustained in face of unanticipated problems (Hudnurkar et al. 2014)

Cooperation: “Co-operation refers to situations in which firms work together to achieve mutual goals” (Hudnurkar et al. 2014). Tjosvold and Tsao (1989) assert that cooperation occurs when the goals of the people are positively linked and attaining one’s goal can help the others to attain their respective goals.

Coordination: Coordination is essential to achieve collaborative goals and it involves managing and integrating people and information; planning and managing time schedules, division of resources and tasks and standardizing processes (Hackman, 1990; Patel et al. 2012; Weiseth et al. 2006).

Environment: Environment constitutes the physical space that individuals and collaborative teams work in which may include organization of space, light, temperature, noise, and safety; socio-cultural aspects of the workplace, and work organization (Edwards and Wilson, 2004; Patel et al. 2012; Wilson et al. 2003).

Feedback: Merriam Webster dictionary defines feedback as “helpful information or criticism that is given to someone to tell what can be done to improve a performance, product, etc.”

Incentive or Shared Rewards: Incentive alignment refers to the process of sharing the costs, risks and benefits among the collaborative group members. Incentivizing the team members, provides them motivation to work better and collaborate at a higher level. (Cao et al. 2009).

Information Sharing: It is defined as the act of capturing and disseminating timely, relevant and accurate information for decision makers or collaborative members to plan and control the work (Simatupang and Sridharan, 2005).

Interpersonal Relationship: Interpersonal relationship refers to the informal and personal relationships between the members of the team and it further constitutes the exchanges of favors that dominate business activities (Cai et al. 2010).

Joint Collaborative Effort: Joint collaborative effort such as planning, goal setting, performance measurement, and problem solving, is necessary for effective and successful collaborative relationships (Hudnurkar et al. 2014).

Joint Decision Making: The process wherein the collaborative group members orchestrate decisions that optimize the benefits and it involves and supports both intellectual and judgment tasks (Cao et al. 2009, Patel et al. 2012).

Joint Planning: Joint or collaborative planning refers to collaboration among the members to develop various plans to be executed to fulfill the desired objectives (Cai et al. 2010).

Management Support: “. Management support refers to clear directions and guidance to individuals and collaborative group members and communication of expectations, goals and objectives and ensuring delivery of good quality work. Support from management is associated with improved work productivity, team effectiveness, employee satisfaction, and plays a large role in success or failure of collaborative projects” (Patel et al. 2012).

Mutual Respect: “Members of collaborative group share an understanding and respect for each other and their respective organizations: how they operate, their cultural norms and values, limitations, and expectations” (Mattessich and Monsey, 1992). The extent to which team members appreciate each other's competence and show personal consideration for each other (Wells et al. 2006).

Open Communication: “Collaborative group members interact often, update one another, discuss issues openly, and convey all necessary information to one another and to people outside the group” (Mattessich and Monsey, 1992).

Organizational Structure: Organizational structure defines the various departments, tasks, processes, culture and norms, trust, policies, procedures, learning and incentive for participation. Further, the organization structures and work conditions, should promote and facilitate collaborative work (Patel et al. 2012).

Performance: “Evaluating collaborative performance may involve assessing individual as well as collective efforts, depending on the type of task, as both can have an important influence on overall performance. Team performance will be influenced by type of task, levels of trust between members, the autonomy afforded to the team, training, and quality of management” (Patel et al. 2012)

Psychological Factors: Patel et al. (2012) state that the psychological characteristics of individuals, the combination of these in the collaborative group and the levels of compatibility can all impact on collaboration. Further, they may be moderated by results of collaboration success or failure. Psychological factors stated by Patel et al. (2012) include:

“Needs, biases, perceptions, mood, motivation, attitudes, values, beliefs, expectations, preferences, personality, ambitions, confidence.

Cognitive factors: attention, perception, memory, mental models, reasoning, thinking styles etc. Social interactions, culture, motivation and emotions can all influence cognition.

Aspects of mental workload, situation awareness, working style and behavior.”

Shared Goals: The collaborative groups have a shared goal, when they share the same vision and defined objectives, that are clear to all the members, and which can be realistically attained (Mattessich and Monsey, 1992).

Sharing Resources: The collaborative group members require access to suitable resources which could include finance, time, physical space, materials, equipment, tools, and appropriate skilled personnel in order to perform their tasks. Any lack of commitment to share these essential resources is a barrier to effective collaboration and may hinder the management of resource use according to demand (Mattessich and Monsey, 1992; Patel et al. 2012).

Team Composition and Diversity: Team composition refers to the heterogeneity and size of the team (Patel et al. 2012). Team diversity includes diversity in skills, education, experience, organizational roles and positions, personalities, strengths, attitudes and professional and ethnic backgrounds (Abdirad and Pishad-Bozorgi, 2014, Patel et al. 2012).

Team Productivity: It can be defined as measurement of team efficiency based on the output produced by the team with respect to given input.

Tools- Technology: Technology eases information transfer, improves detailing and aids in improving skills and knowledge of the collaborative members. Additionally, enabling technology results in cost benefits and better deliverables (Abdirad and Pishad-Bozorgi, 2014).

Training: “Training provides opportunities for team members to acquire new skills or improve existing skills and develop shared mental models, and thus can improve overall organizational effectiveness. Organizations should be aware of the skills and behaviors required to perform particular collaborative tasks or functions and base training on task analyses” (Patel et al. 2012).

Trust: “A positive belief, attitude, or expectation of one party concerning the likelihood that the action or outcomes of another will be satisfactory” (Hudnurkar et al. 2014).

Willing Participation: Willing participation refers to the readiness, enthusiasm and willingness of the collaborative group members to participate in the collaboration process.

