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RESEARCH ARTICLE

IMPACT AND ASSESSMENT OF THE SUSTAINED CSC RISK FACTORS ON THE CONSTRUCTION INDUSTRY

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ABSTRACT

Supply chain management becomes a global trend in different disciplines. Construction industry occupies a huge sector of these disciplines. From this point of view, the interest of construction supply chain management becomes very important to maximize the profits of the organizations and minimize their losses to the lowest level. In thispaper, sustained CSC risk factors which have a significant effect on the construction industry in Egypt are investigated and assessed through a survey conducted with association of governmental agencies, construction firms and consulting companies. CSC risk factors are detected and categorized based on ESG metrics and also based on their type as well.

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INTRODUCTION

Supply chain has become an important and practical issue for the firms and organizations in order to maximize their profits to the highest level and minimize their losses to the lowest level. Good command of supply chain management requires a proper and optimum management of the supply chain process which begins from the manufacturer and ends to the customer. During this risky trip, the construction supply chain process passes by several stages including: requirement, design, procurement, construction and fabrication, transportation and site storage.

REVIEW OF LITERATURE

Construction industry as one of the industrial disciplines has an impact on the environment. Nowadays, modern globalization concerns with sustainability and aims to get the majority of the industrial activities to be sustained. According to this global direction, the impact of the construction activities during the construction supply chain process needs to be well managed in order to comply with sustainability obligations and achieve the organization targets at the same time. To obtain and achieve this equation, it's important to study and investigate the risk factors that could affect the "CSCM" during its life cycle and to assess these risk factors. The objectives of construction project are mainly including time, cost and quality. These can be considered as the main frame of any construction project. Earned value measures (EVMs) are considered important indicators that can assess the ability for achieving these objectives. And also (EVMs) can play a crucial role for assessing the risk factors that can affect them and subsequently affect the supply chain management.

Earned value measures (EVMs) indicate the deviations between planned and actual time schedule and can expect if we are ahead or behind schedule. In addition, earned value measures (EVMs) distinguish the variance between actual and planned cost and predict if the project will be over or under budget. Earned value measures (EVMs) provide organizations with methodology needed to integrate the management of project scope, schedule and cost. EVMs can play a crucial role in answering management questions**.**

Supply Chain Management: The idiom of "supply chain" refers to the process generated from the companies and organizations to deliver a product or a service to the customer. In general supply chain management deals with the flow of materials, information and even the cash flow network. According to this, the proper management of supply chain will have to deal with suppliers, materials, transporters, logistics and even customers themselves. In conclusion, the complete process includes: products, design, procurement, planning and forecasting, production, distribution, and fulfillment after sales support as shown in **Figure (1):**

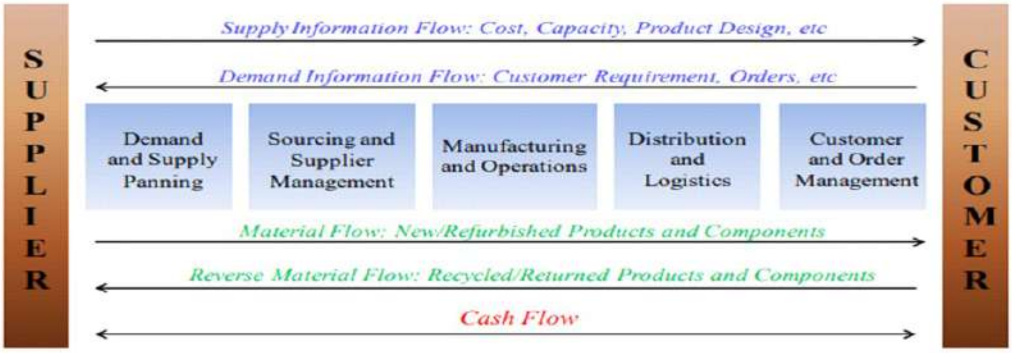


Figure (1). Supply Chain Process

Based on these principles, the aim of "SCM" is to minimize the cost of these elements and achieve the aims of: "zero-stock", "just-in-time deliver" and customer satisfaction. In this art review, we will expose to the studies and researches which detect and investigate the assessment of risk factors that could affect the supply chain in the construction industry.

Supply Chain Management in Construction Industry: Supply chain in the construction industry has become very important and plays a crucial role in the modern construction industry. By searching and reading the academic papers and researches which are concerning with the construction supply chain risks from years "2006 to 2022" the distribution of these papers are shown in **Figure (2):**

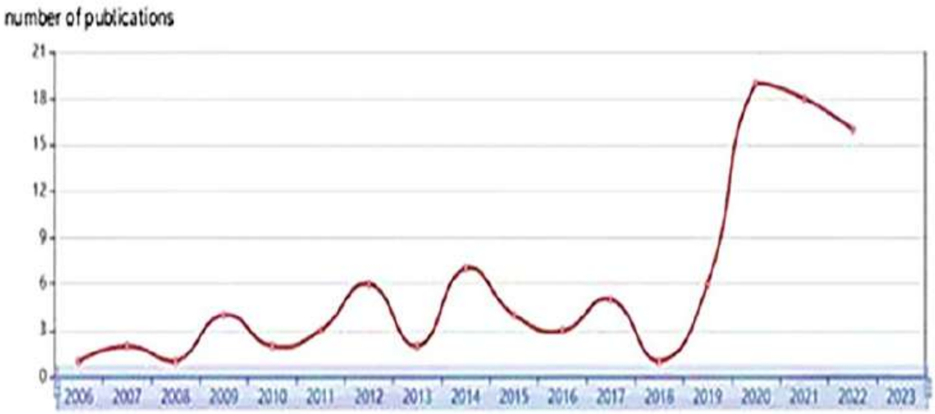


Figure (2). 2006 – 2022 Number of papers related to construction supply chain risks quantity line

According to the distribution shown in **Figure (2),** it's clearly obvious that studying "CSC" risks has no-longer revealed till the beginning of this century. By the time, and because of several reasons including: pandemic, environmental, political and economic reasons the number of published papers has significantly grown up. The great downturn and the market globalization for the construction industry, made the supply chain process from the manufacturer to the customer critical and fragile. As a result, more and more papers and researches became very important to help in understanding and identifying most of the supply chain risks in the construction industry. Life cycle and stages of the construction supply chain is different comparing with manufacturing and fabrication supply chain life cycle in the way of its organization. Manufacturing and fabrication supply chain depends on the flow of materials from the suppliers to the customers through its life cycle. However, in the construction supply chain the resources and the materials are casted in place and the workers move around them, see **Figure (3).**

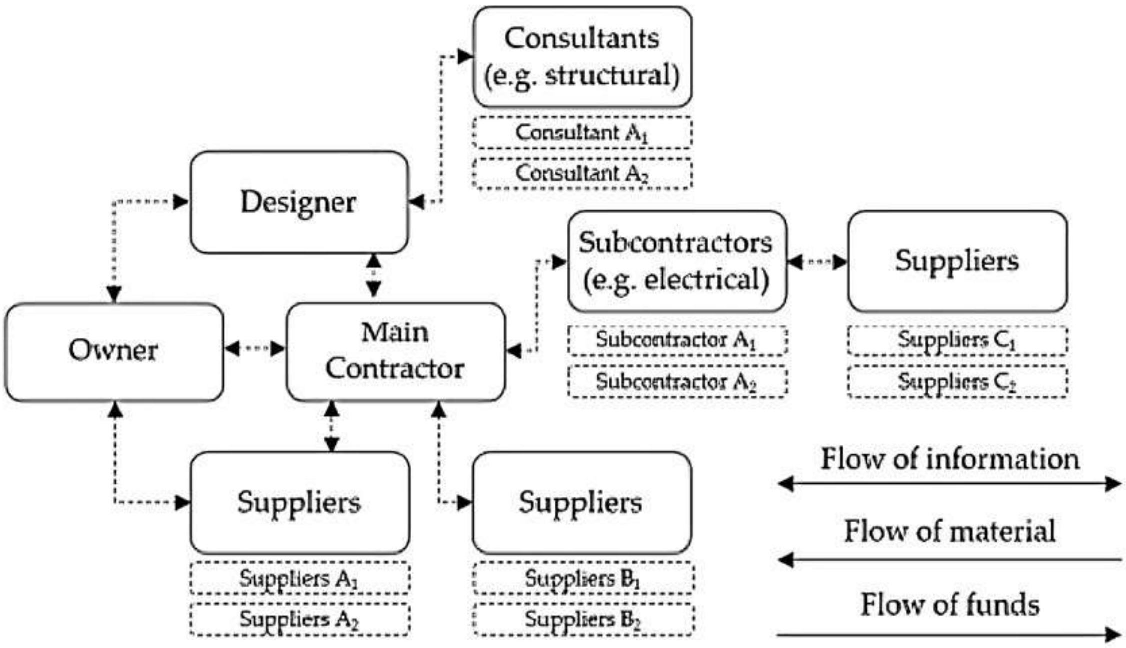


Figure (3). A Typical construction supply chain

Construction supply chain "CSC" includes all construction processes from requirements, design, procurement, construction and fabrication, transportation and site storage**.** From this point of view, we can define construction supply chain as all activities involved in the construction industry including sourcing, producing, transporting and distributing construction materials – including equipment and services.

The importance of SCM in Construction Industry: Construction industry depends basically on SCM to ensure the delivery of goods, materials and information from the supplier to the customer on time. This has a significant and direct impact on project cost, on-time completion and success. We can summarize the importance of the construction SCM in the following targets:

Timely project completion: SCM ensures the arrival and delivery of goods, resources and information on time. That will lead to reduce the indirect costs of the missed deadlines which have significant impacts on the labor expenses and the failure of the project due to the late of materials delivery.

Cost efficiency: SCM ensures financial efficiency as a result of reduces the extra inventory, inefficiencies and improving transportation.

Risk mitigation: Good command management of construction supply chain "CSC" helps to reduce risks which could affect the construction activities such as: labor shortages, information risks, logistic risks, supply risks, product/service risks, weather risks and governance regulation risks to the lowest limits.

Resource allocation: Good command management of construction supply chain "CSC" makes resources allocation more effective. Understanding the objectives, demands and the targets of the project and matching them with the available resources can help to prevent the resources shortages and overages.

Customer satisfaction: On-time completion and high quality results are the main factors which lead to customer satisfaction. Proper management of CSC can ensure the achievement of these factors to hit the customer satisfaction.

Collaboration: Effective SCM ensures the collaboration between all stakeholders including: suppliers, contractors and customers.

Competitive advantage: Strong SCM in construction gives the companies flexibility to change and adapt conditions to comply with market demands. This gives the companies and organizations competitive advantages and good reputation.

Sustainability: CSCM can comply with sustainability goals. CSCM can adapt the supply chain cycle and adapt transportation routes to make the carbon footprint to comply with sustainability goals.

Essential components of construction supply chain management CSCM: To ensure an effective SCM, the components of SCM should be integrated and work in harmony. The good knowledge of the SCM components will result in speed up procedures, obtaining significant results and minimize costs to the lowest limits. Here, we will illustrate briefly the components of SCM.

Supplier management: Strong and effective supply chain depends on effective supplier management. It's very important to select dependable and various suppliers. This will help to prevent and minimize the risk of materials delay and materials shortages, also this will help to offer good and trusted opportunities of negotiations with suppliers.

Inventory management: An effective SCM should achieve the equation of being balanced between the surplus inventories and keeping the adequate resources in hand to mitigate the projects' demands. Just-in-time techniques help to achieve the project objectives without spending money and extra costs on storage or locking up resources in excess materials. Firms and organizations can maximize their profits by precisely estimation of the materials requirements.

Logistics and transportation: Effective logistics and transportation are very important to ensure the arrival of resources and supplies on time, which is very significant factor in the effective supply chain management. Decreasing transit times and the related expenses can be achieved by optimizing the logistics and routes. By optimum management of logistics and transportation, the risk of delay can be prevented and the on time completion can be achieved.

Demand forecasting: The risk of materials shortages can be decreased by the appropriate forecasting of the resources requirements of the project. Organizations can precisely predict their needs from the previous project plans, from the experts and from similar projects.

Risk management: Strong and effective SCM depends on the good command of risk management. Effective risk management can be obtained by definition of all possible risks which could affect the supply chain and precautions and preventive procedures which can be detected. In this literature review, we will illustrate all possible risk factors which could affect the CSC and their impact.

METHODOLOGY

Framework of Risk Assessment in Construction Supply Chain CSC: The suggested framework of risk assessment of the construction supply chain with its conceptual approach is introduced in detail. The framework consists of 4 stages. The risk register stage is presented to identify and classify the risk factors that affect the construction supply chain CSC. The risk assessment stage is presented through a survey that is conducted on a wide and various cluster samples to assess the risk factors impact. Qualitative and quantitative analysis is presented through the risk analysis stage. Finally, the stage of monitoring and evaluation is presented using the analytical model that is generated by using spss and excel programs.

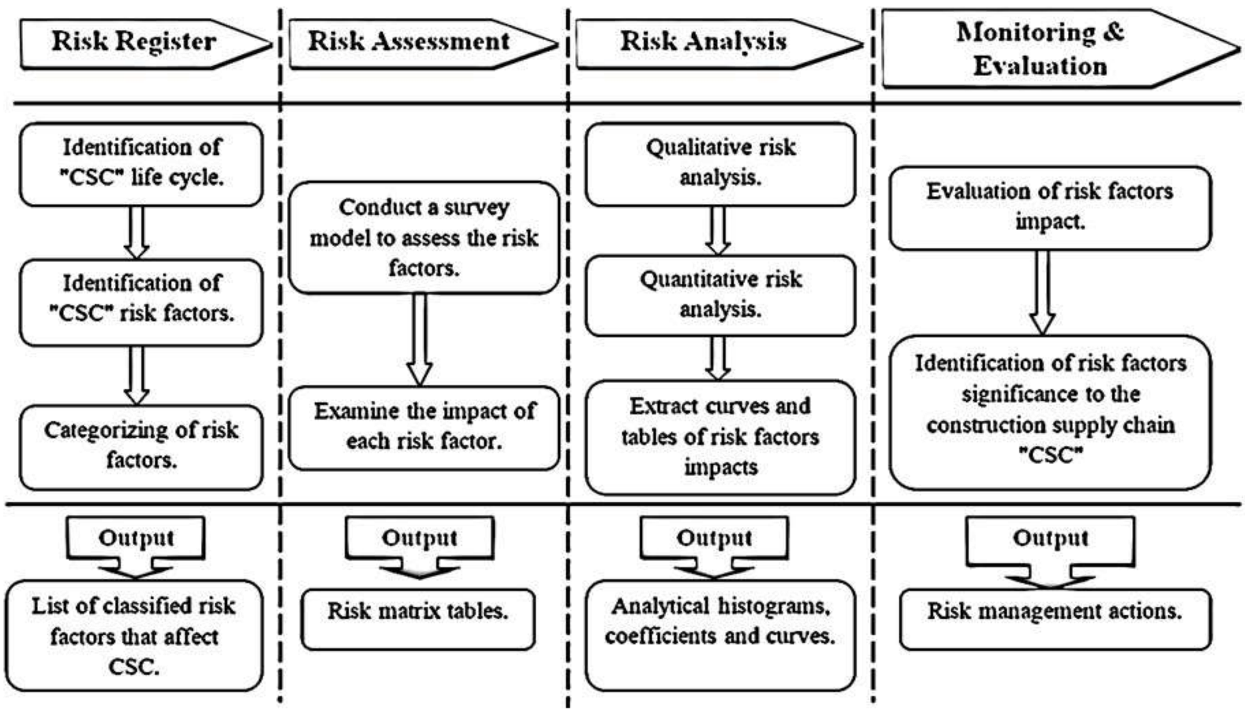


Figure (4) Components of the framework

The suggested framework of the construction supply chain "CSC" risk assessment and its work flow are shown in **Figure (4**) and **Figure (5)** with four main stages as follows: (1) risk register; (2) risk assessment; (3) risk analysis; and (4) monitoring and evaluation.

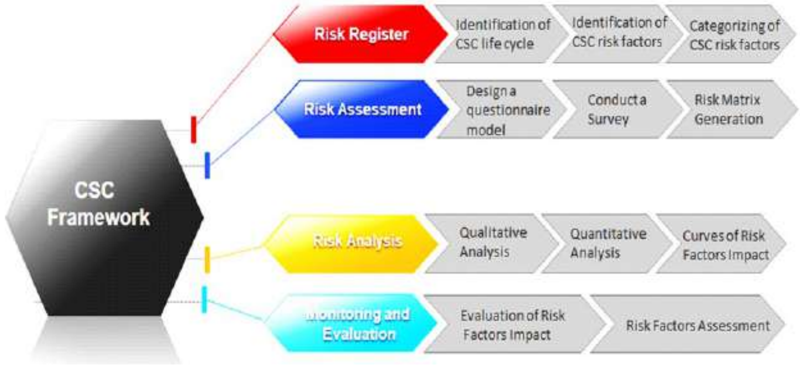


Figure (5). CSC Framework

Risk Register: The risk register stage is very important to identify all possible risk factors that could affect the construction supply chain "CSC". It consists of three steps as follows:

Identification of the construction supply chain "CSC" life cycle: The first step in the risk register stage is very crucial to identify the construction supply chain life cycle. The construction supply chain life cycle includes requirements, design, procurement, construction and fabrication, transportation and site storage as shown in **Figure (6):**

Figure (6) Construction supply chain life cycle

Identification of the construction supply chain "CSC" risk factors: An extensive study of construction supply chain literature was performed in order to identify all possible risk factors that could affect the construction supply chain. A list of 47 risk factors was detected. These detected risk factors are the risks that could affect the CSC on its life cycle stages.

Categorizing of the construction supply chain risk factors

In this step, the 47 risk factors categorized according to 2 basic concepts. First concept is categorizing the risk factors according to the type of the risk factor into macro level risks, demand management risks, supply management risks, production/service management risks and information management risks as shown in tables from **Table (1)** to **Table (5)**, **Figure (7)** indicates the types of CSC risk factors as shown:

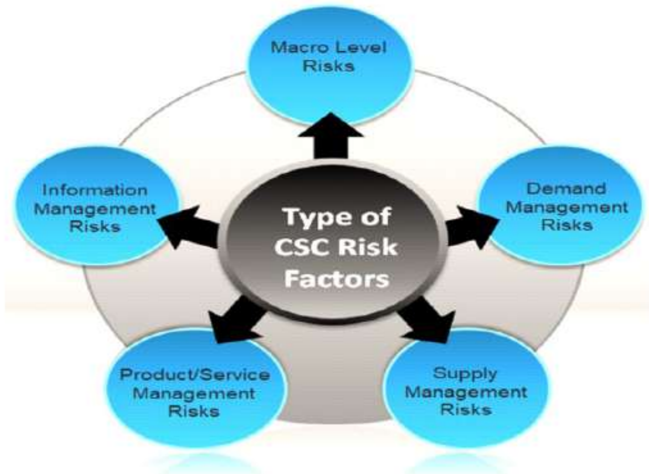


Figure (7). Types of CSC Risk Factors

Table (1). Macro level risks

No.	Type of Risk
a.	Weather Change (e.g., precipitations, Temperature(
b.	Natural Disasters (e.g., Earthquakes, Tsunami)
c.	Diseases (e.g., SARS, bird flu)
d.	Political unrest (e.g., Civil unrest)
e.	Terrorism (e.g., 9/11)
f.	Currency fluctuations
g.	Government regulations (e.g., Environmental laws)
h.	IT breakdown (e.g., Virus, Internet disruption)
i.	Labor strikes
j.	Lack of skilled personnel
k.	Immigration related workforce shocks

Table (2). Demand management risks

No.	Type of Risk
a.	Sudden loss of demand due to an economic downturn
b.	Volatile demand / decline in demand
c.	Receivable losses caused by delinquent customers
d.	Changes in customer tastes
e.	Failed communication with the customers
f.	Increase in customers' bargaining power

Table (3) Supply management risks

.No	Type of Risk
.a	Delays in the availability of materials from suppliers, leading to shortage
.b	Suppliers’ bankruptcy
.c	Failed communication with the suppliers
.d	Breach of partnership (e.g., violation of company information, integrity of cargo due to loss)
.e	Delays in material flow due to the inability of suppliers to respond to changes in demand (through high capacity utilization at the supply source)
.f	Delay in material flow due to the inability ofsuppliers to respond to changes in demand due to any other cause of inflexibility at the supply source
.g	Delay in material flow due to poor quality of yield at the supply source
.h	Delay in material flow due to excessive handling(such as at border crossings and change in transportation modes)
.i	Procurement risks stemming from exchange rate fluctuations (which may increase the cost of procurement)
.j	Procurement risks stemming from the percentage of a key component or raw material procured from a single source
.k	Procurement risks stemming from industry-wide capacity utilization
.l	Procurement risks stemming from price increases by suppliers
.m	Risks stemming from JIT program: Increased downtime
.n	Risks stemming from JIT program: Pull inventory at higher freight costs
.o	Risks stemming from JIT program: Pay higher prices to suppliers who can deliver faster

Table (4) Product/Service management risks

No.	Type of Risk
a.	Risks stemming from an excessive inventory: Product Obsolescence
b.	Risks stemming from an excessive inventory: Inventory holding costs
c.	Risks stemming from an excessive inventory: Product Value (Holding excessive inventory for products with high value or short life cycles can get expensive)
d.	Risks stemming from an excessive inventory: Demand and Supply uncertainty leading to an inventory becoming expensive
e.	Risks stemming from underutilized capacity: Cost of capacity (investment in capacity)
f.	Risks stemming from underutilized capacity: Capacity flexibility (agility towards changes in demand)
g.	Risks stemming from underutilized capacity: Risks in recovering expenses
h.	Risks due to dependability and conformance to delivery schedule

Table (5) Information management risks

.No	Type of Risk
.a	Risks in forecasting: Inaccurate forecasts due to long lead times, seasonality, product variety, short life cycles, small customer base
.b	Risks in forecasting: Information distortion due to sales promotions, incentives, lack of supply-chain visibility and exaggeration of demand in times of product shortage
.c	Risks due to intellectual property: Reduced vertical integration of supply chains leading to more information collaboration
.d	Risks due to intellectual property: Globalization of supply chains leading to outsourcing to same manufacturers used by competitors
.e	Risks due to the failure of IT systems: Information infrastructure breakdown
.f	Risks due to the failure of IT systems: System integration of extensive systems networking
.g	Risks due to the failure of IT systems: E-commerce

Second concept is categorizing the risk factors according to the sustainability regulations into environmental, social and governance as shown in **Table (6)**:

Table (6) Classification of risk factors according to sustainability regulations

No.	ESG category	Type of risk factor
1	Environment	Weather Change (e.g., precipitation, Temperature)
2		Natural Disasters (e.g., Earthquakes, Tsunami)
3	Social	Diseases (e.g., SARS, bird flu)
4		Labor strikes
5		Lack of skilled personnel
6		Volatile demand / decline in demand
7		Receivable losses caused by delinquent customers
8		Changes in customer tastes
9		Failed communication with the customers
10		Increase in customers' bargaining power
11		Delays in the availability of materials from suppliers, leading to shortage
12		Suppliers' bankruptcy
13		Failed communication with the suppliers
14		Breach of partnership (e.g., violation of company information, integrity of cargo due to loss)
15		Delays in material flow due to the inability of uppliers to respond to changes in demand (through high capacity utilization at the supply source)
16		Delay in material flow due to the inability ofsuppliers to respond to changes in demand due to any other cause of inflexibility at the supply source
17		Delay in material flow due to poor quality of yield at the supply source
18		Delay in material flow due to excessive handling(such as at border crossings and change in transportation modes)
19		Procurement risks stemming from exchange rate fluctuations (which may increase the cost of procurement)
20		Procurement risks stemming from the percentage of a key component or raw material procured from a single source
21		Procurement risks stemming from industry-wide capacity utilization
22		Procurement risks stemming from price increases by suppliers
23		Risks stemming from JIT program: Increased downtime
24		Risks stemming from JIT program: Pull inventory at higher freight costs
25		Risks stemming from JIT program: Pay higher prices to suppliers who can deliver faster
26		Risks stemming from an excessive inventory: Product Obsolescence
27		Risks stemming from an excessive inventory: Inventory holding costs
28		Risks stemming from an excessive inventory: Product Value (Holding excessive inventory for products with high value or short life cycles can get expensive)
29		Risks stemming from an excessive inventory: Demand and Supply uncertainty leading to an inventory becoming expensive
30		Risks stemming from underutilized capacity: Cost of capacity (investment in capacity)
31		Risks stemming from underutilized capacity:Capacity flexibility (agility towards changes indemand)
32		Risks stemming from underutilized capacity: Risks in recovering expenses
33		Risks due to dependability and conformance to delivery schedule
34		Risks in forecasting: Inaccurate forecasts due to long lead times, seasonality, product variety, short life cycles, small customer base
35		Risks in forecasting: Information distortion due to sales promotions, incentives, lack of supply-chain visibility and exaggeration of demand in times of product shortage
36		Risks due to intellectual property: Reduced vertical integration of supply chains leading to more information collaboration
37		Risks due to intellectual property: Globalization of supply chains leading to outsourcing to same manufacturers used by competitors
38		Risks due to the failure of IT systems: Information infrastructure breakdown
39		Risks due to the failure of IT systems: System integration of extensive systems networking
40		Risks due to the failure of IT systems: E-commerce
41	Governance	Political unrest (e.g., Civil unrest)
42		Terrorism (e.g., 9/11)
43		Currency fluctuations
44		Government regulations (e.g., Environmental laws)
45		IT breakdown (e.g., Virus, Internet disruption)
46		Immigration related workforce shocks
47		Sudden loss of demand due to an economic wnturn

Risk Assessment: This stage consists of 2 steps. The first step is designing a questionnaire model and conducting a survey to assess the impact of each risk factor of the 47 risk factors. The questionnaire model detects the probability and the severity of each risk factor occurrence.

The second step is to examine the impact of each risk factor. The risk matrix action zone is derived according to the equation (Impact = probability x severity). According to this equation, a matrix of risk action zones that valued from 1 to 9 is derived a shown in **Table (7)**. The different kinds of risk action zones are defined as follows: a green zone, a yellow zone and a red zone. If the value of the risk factor is equal to 1 to 2, the risk factor then belongs to the green zone; if the value of the risk factor is greater than 2 and less than 5, then the risk factor belongs to the yellow zone; if otherwise, then it belongs to the red zone.

Table (7) Matrix of Risk Action Zone

		Probability		
		Low	Medium	High
Severity	Low	1	2	3
	Medium	2	4	6
	High	3	6	9

Risk Analysis: In this stage, qualitative and quantitative risk analysis is conducted and analytical histograms, coefficients and curves will be generated.

Monitoring and Evaluation: In this stage and according to the analysis of risk factors' impacts, the monitoring and the evaluation of the risk factors can be assessed and the risk management action can be done. According to the literature review and the intensive study it is found that, the construction supply chain management plays a crucial role in the modern construction industry. From this point of view, it was necessary to investigate and assess the risk factors that could affect the CSC. In this research, all possible risk factors that could affect the CSC and have a significant impact were investigated. By intensive study, 47 risk factors that could affect the CSC were detected and classified according the CSC life cycle and according to the sustainability compliance. To get the impact of these 47 risk factors and asses their significance to the CSC, a questionnaire model was designed and a survey was conducted. The survey was administrated to a total sample of 130 firms, governmental organizations and construction experts.

Survey Process: The survey process in this research consists of 8 steps: 1) create a survey project plan, 2) Develop a survey questionnaire, 3) Pilot survey, 4) Implement the survey, 5) Analyze the survey results, 6) Create a survey report, 7) Review the survey results and 8) Develop an action plan as shown in **Figure (8)**:

Figure (8). Survey Process.

Sample Size Calculation: In order to determine how large a sample size should be to achieve confident results, an empirical sample size equation is applied to get the appropriate sample size based on the confidence level required as follows:

$$N = Z^2 \times \acute{p}\,(1-\acute{p}) \;/\; \grave{\varepsilon}^2$$

Where,

N: is the sample size.
Z: is the Z score related to the confidence level.
Ṕ: is the firms proportion (to be assumed = 0.50).
ὲ: is the margin of error.

Cluster Sample Classification: The questionnaire was administrated to a total number of (130) firms and governmental organization. The cluster sample is classified as shown in **Table (8)**; **Figure (9)** indicates the percentage of each cluster type and its distribution in the sample as shown:

Table (8). Cluster Sample Classification

No.	Type of the cluster sample	Total Number	(%) Percentage of the Cluster Sample Type
A.	New Urban Communities Authorities (NUCA).	43	33.08%
B.	Construction Companies.	50	38.46%
C.	Consultants & Academic Organizations.	37	28.46%

New Urban Communities Authority (NUCA) which consists of (43) cities, includes around (10) projects for each city. This means that the actual sample for this cluster is (43 * 10 = 430) samples. The cities involved by NUCA are illustrated as shown in **Table (9)**:

Table (9). New Urban Communities Authorities Cities

NO.	NUCA Governorates	NO.	NUCA Governorates
1	New Administrative Capital	23	New Sohag City
2	6th October city	24	New Tiba City
3	Hadayek October	25	New Akhmim City
4	New October City	26	New Aswan City
5	El-Sheikh Zayed City	27	New Fayioum City
6	New Zayed City	28	New Qena City
7	New Sphinx City	29	Touristic Villages City
8	New Alamin City	30	New Menia City
9	Hadayek El Asema	31	Sharq El Owaynat City
10	El Oubour City	32	New Suez City
11	El Sherouk City	33	New Port Said City
12	Badr City	34	Gharb Asiut City
13	10th of Ramdan City	35	Gharb Qena City
14	El Sadat City	36	New Toshka City
15	New Nubaria City	37	New Luxor City
16	New Borg El Arab City	38	New Alexandria City
17	15th may City	39	New Rashid City
18	New Damietta city	40	New Fashn City
19	New Salheia City	41	New Malawy City
20	New Beni Sweif City	42	New Obour City
21	New Cairo City	43	New Mansoura City
22	New Assiut City	44	

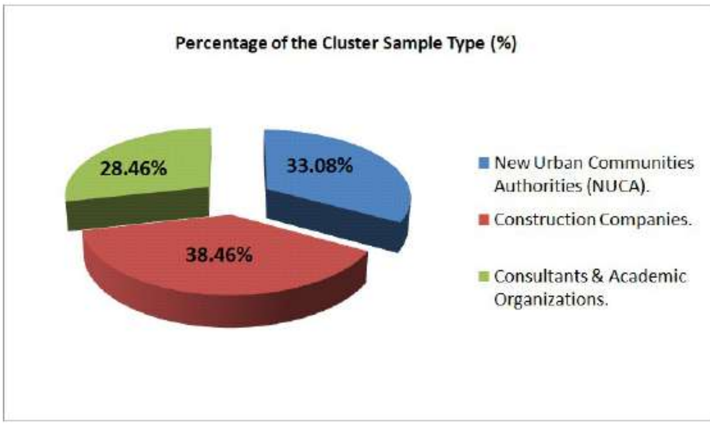


Figure (9). Cluster Sample Distribution

RESULTS AND DISCUSSION

Firms and organizations under the survey completed the questionnaire model according to each stage of the CSC life cycle. The impact of each risk factor is detected according to the risk impact equation (impact = Probability x severity). Based on this equation, risk action zones are generated and valued from 1 to 9.

Risk Action Zones: Risk action zones are classified into 3 zones; green zone with value from 1 to 2, yellow zone with values greater than 2 and less than 5 and red zone with values greater than 5. Each risk factor is classified during the CSC life cycle stages and the impact of each risk factor is classified to the suitable risk action zone based on the impact equation. The average risk action zones for the CSC life cycles stages of each risk factor is derived according to the survey results and based on the impact equation as shown in **Table (10)**.

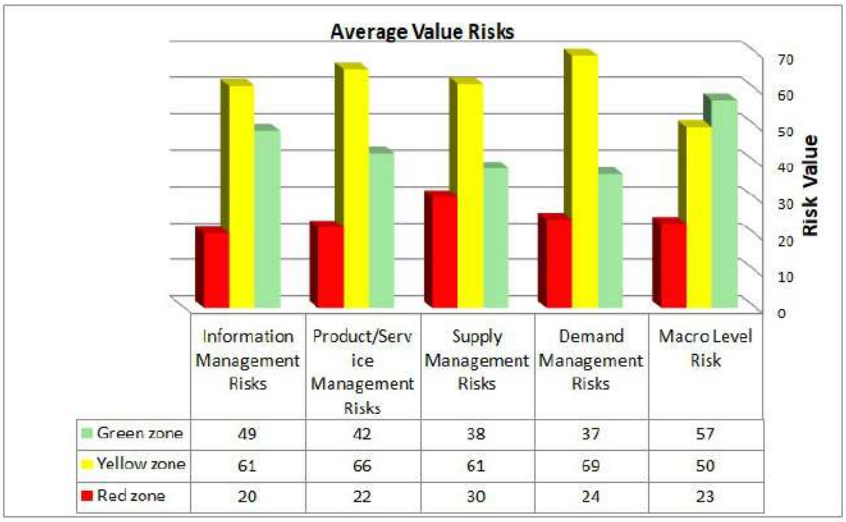
Table (10). Average Risk Action Zones of the CSC life cycles stages

No.	Type of risk factor	Risk Action Zones		
		Green Zone	Yellow Zone	Red Zone
1	Weather Change (e.g., precipitation, Temperature)	38	67	26
2	Natural Disasters (e.g., Earthquakes, Tsunami)	96	26	9
3	Diseases (e.g., SARS, bird flu)	80	43	8
4	Labor strikes	75	47	9
5	Lack of skilled personnel	27	71	33
6	Volatile demand / decline in demand	34	77	20

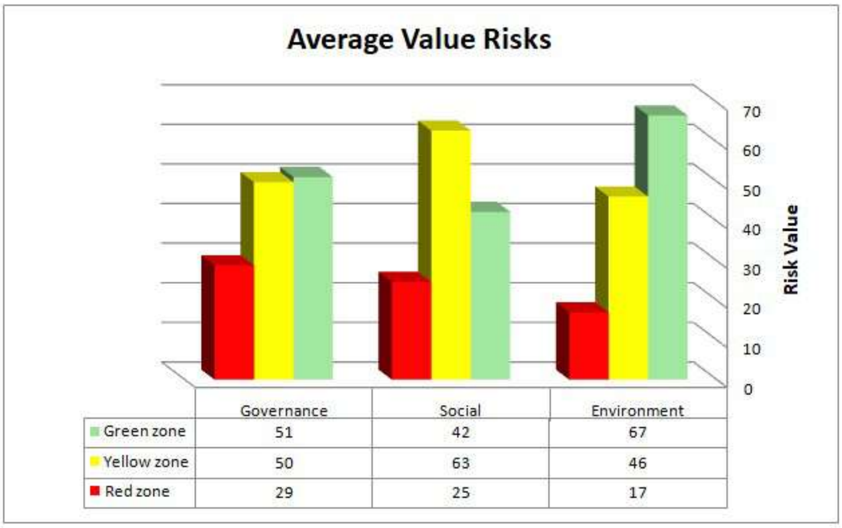
Continue ….

7	Receivable losses caused by delinquent customers	28	73	30
8	Changes in customer tastes	27	70	34
9	Failed communication with the customers	57	65	9
10	Increase in customers' bargaining power	30	77	23
11	Delays in the availability of materials from suppliers, leading to shortage	30	68	33
12	Suppliers' bankruptcy	57	53	21
13	Failed communication with the suppliers	63	56	12
14	Breach of partnership (e.g., violation of company information, integrity of cargo due to loss)	74	47	10
15	Delays in material flow due to the inability of suppliers to respond to changes in demand (through high capacity utilization at the supply source)	42	70	19
16	Delay in material flow due to the inability ofsuppliers to respond to changes in demand due to any other cause of inflexibility at the supply source	37	70	23
17	Delay in material flow due to poor quality of yield at the supply source	44	64	23
18	Delay in material flow due to excessive handling(such as at border crossings and change in transportation modes)	28	60	43
19	Procurement risks stemming from exchange rate fluctuations (which may increase the cost of procurement)	16	47	68
20	Procurement risks stemming from the percentage of a key component or raw material procured from a single source	29	62	40
21	Procurement risks stemming from industry-wide capacity utilization	43	66	22
22	Procurement risks stemming from price increases by suppliers	16	58	57
23	Risks stemming from JIT program: Increased downtime	36	69	25
24	Risks stemming from JIT program: Pull inventory at higher freight costs	32	67	32
25	Risks stemming from JIT program: Pay higher prices to suppliers who can deliver faster	31	68	31
26	Risks stemming from an excessive inventory: Product Obsolescence	54	59	18
27	Risks stemming from an excessive inventory: Inventory holding costs	49	63	19
28	Risks stemming from an excessive inventory: Product Value (Holding excessive inventory for products with high value or short life cycles can get expensive)	36	74	21
29	Risks stemming from an excessive inventory: Demand and Supply uncertainty leading to an inventory becoming expensive	47	58	26
30	Risks stemming from underutilized capacity: Cost of capacity (investment in capacity)	38	66	27
31	Risks stemming from underutilized capacity:Capacity flexibility (agility towards changes indemand)	40	74	17
32	Risks stemming from underutilized capacity: Risks in recovering expenses	47	62	22
33	Risks due to dependability and conformance to delivery schedule	31	70	29
34	Risks in forecasting: Inaccurate forecasts due to long lead times, seasonality, product variety, short life cycles, small customer base	43	62	26
35	Risks in forecasting: Information distortion due to sales promotions, incentives, lack of supply-chain visibility and exaggeration of demand in times of product shortage	38	67	25
36	Risks due to intellectual property: Reduced vertical integration of supply chains leading to more information collaboration	57	58	15
37	Risks due to intellectual property: Globalization of supply chains leading to outsourcing to same manufacturers used by competitors	50	61	19
38	Risks due to the failure of IT systems: Information infrastructure breakdown	53	59	19
39	Risks due to the failure of IT systems: System integration of extensive systems networking	53	58	20
40	Risks due to the failure of IT systems: E-commerce	48	62	21
41	Political unrest (e.g., Civil unrest)	59	58	14
42	Terrorism (e.g., 9/11)	76	41	14
43	Currency fluctuations	15	41	75
44	Government regulations (e.g., Environmental laws)	39	63	29
45	IT breakdown (e.g., Virus, Internet disruption)	59	49	23
46	Immigration related workforce shocks	67	45	19
47	Sudden loss of demand due to an economicdownturn	45	55	31

The 47 risk factors categorized according to 2 basic concepts. First concept is categorizing the risk factors according to the type of the risk factor into macro level risks, demand management risks, supply management risks, production/service management risks and information management risks. The average risk values of each risk action zone during the CSC life cycle stages are derived based on the previous surveying results, and according to the classification of risk factors mentioned above as shown:



Second concept is categorizing the risk factors according to the sustainability regulations into environmental, social and governance. The average risk values of each risk action zone during the CSC life cycle stages are derived based on the previous surveying results, and according to the classification of risk factors mentioned above as shown:



Reliability Analysis: The first concept is assessing the reliability of the risk factors based on categorizing the risk factors according to the type of the risk factor into macro level risks, demand management risks, supply management risks, production/service management risks and information, and then generating the average value of risk action zone.

Using (SPSS) program, the Cronbach's alpha was conducted to assess the reliability of each risk factor based on this classification. Alpha values over 0.7 indicate that all scales can be considered reliable**.**

Case Processing Summary

		N	%
Cases	Valid	3	100.0
	Excluded[a]	0	.0
	Total	3	100.0

- List wise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.961	5

Cronbach's alpha is (0.961) which exceeds (0.7); this means the scales for the five factors in the first concept are reliable. The second concept is assessing the reliability of the risk factors regarding the sustainability regulations into environmental, social and governance, and then generating the average value of risk action zone. Using (SPSS) program, the Cronbach's alpha was conducted to assess the reliability of each risk factor based on this classification. Alpha values over 0.7 indicate that all scales can be considered reliable.

Case Processing Summary

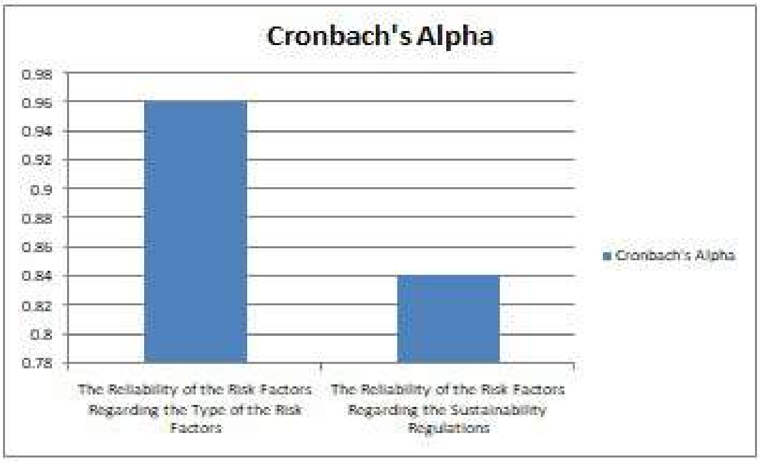
		N	%
Cases	Valid	3	100.0
	Excluded[a]	0	.0
	Total	3	100.0

- List wise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.841	3

Cronbach's alpha is (0.841) which exceeds (0.7); this means the scales for the three factors in the second concept are reliable.



Correlation Analysis: The correlation analysis is conducted to study the correlation between the variables for the 2 – classification concepts. The first concept is assessing the correlation of the risk factors based on categorizing the risk factors according to the type of the risk factor into macro level risks, demand management risks, supply management risks, production/service management risks and information. Using (SPSS) program, the correlation analysis is conducted to assess the correlation between each risk factor based on this classification. Correlation degree ranges from (-1.0) to (+1.0).

Correlations

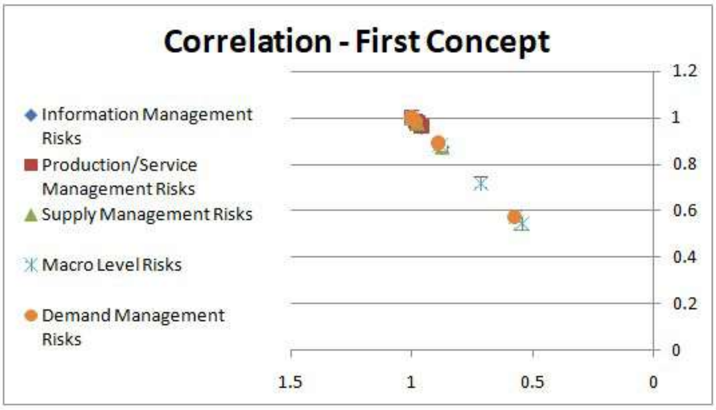
		Macro_Level_Risks	Demand_Management_Risks	Supply_Management_Risks
Macro_Level_Risks	Pearson Correlation	1	.574	.547
	Sig. (2-tailed)		.610	.632
	N	3	3	3
Demand_Management_Risks	Pearson Correlation	.574	1	.999*
	Sig. (2-tailed)	.610		.021
	N	3	3	3
Supply_Management_Risk	Pearson Correlation	.547	.999*	1
	Sig. (2-tailed)	.632	.021	
	N	3	3	3
Production_Service_Management_Risks	Pearson Correlation	.716	.983	.976
	Sig. (2-tailed)	.492	.119	.140
	N	3	3	3
Information_Management_Risks	Pearson Correlation	.885	.890	.874
	Sig. (2-tailed)	.309	.302	.323
	N	3	3	3

		Production_Service_Management_Risks	Information_Management_Risks
Macro_Level_Risks	Pearson Correlation	.716	.885
	Sig. (2-tailed)	.492	.309
	N	3	3
Demand_Management_Risks	Pearson Correlation	.983	.890
	Sig. (2-tailed)	.119	.302
	N	3	3
Supply_Management_Risks	Pearson Correlation	.976	.874
	Sig. (2-tailed)	.140	.323
	N	3	3
Production_Service_Management_Risks	Pearson Correlation	1	.959
	Sig. (2-tailed)		.183
	N	3	3
Information_Management_Risks	Pearson Correlation	.959	1
	Sig. (2-tailed)	.183	
	N	3	3

*. Correlation is significant at the 0.05 level (2-tailed).

By analysis, Pearson correlation shows a strong direct correlation for macro level risks with Production Service Management Risks (0.716) and Information Management Risks (0.885). And also shows a strong direct correlation for demand management risks with supply management risks (0.999), production management risks (0.983) and information management risks (0.890). Pearson correlation also shows a strong direct correlation for supply management risks with production/service management risks (0.976) and information management risks (0.874). It also shows strong direct correlation for production/service management risks with information management risks (0.959).

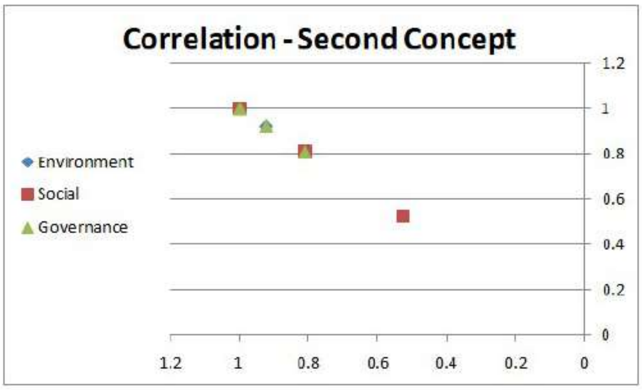
Pearson correlation shows a moderate direct correlation between macro level risks, demand management risks and supply management risks (0.574).



The second concept is assessing the correlation of the risk factors according the sustainability regulations into environmental, social and governance. Using (SPSS) program, the correlation analysis is conducted to assess the correlation between each risk factor based on this classification. Correlation degree ranges from (-1.0) to (+1.0).

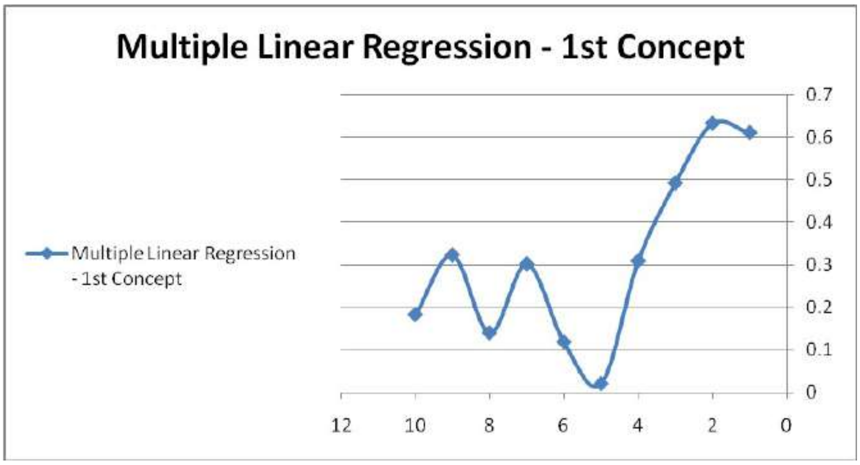
Correlations				
		Environment	Social	Governance
Environment	Pearson Correlation	1	.527	.924
	Sig. (2-tailed)		.647	.249
	N	3	3	3
Social	Pearson Correlation	.527	1	.811
	Sig. (2-tailed)	.647		.398
	N	3	3	3
Governance	Pearson Correlation	.924	.811	1
	Sig. (2-tailed)	.249	.398	
	N	3	3	3

By analysis, Pearson correlation shows a strong direct correlation for environment risk factors with governance risk factors (0.924). It also shows a strong direct correlation between social risk factors and governance risk factors (0.811). However, Pearson correlation shows a moderate correlation between environmental and social risk factors (0.527).



Regression Analysis – Multiple Linear Regressions: By performing a multiple linear regression analysis using SPSS program, the significant impact of each risk factor's category on each other will be investigated. For the first concept, there are 10 hypotheses as the following:

N.	Hypothesis	Description
1	H1	The impact of macro level risks and demand management risks.
2	H2	The impact of macro level risks and supply management risks.
3	H3	The impact of macro level risks and production/service management risks.
4	H4	The impact of macro level risks and information management risks.
5	H5	The impact of demand management risks and supply management risks
6	H6	The impact of demand management risks and production/service management risks.
7	H7	The impact of demand management risks and information management risks.
8	H8	The impact of supply management risks and production/service management risks.
9	H9	The impact of supply management risks and information management risks.
10	H10	The impact of production/service management risks and information management risks.

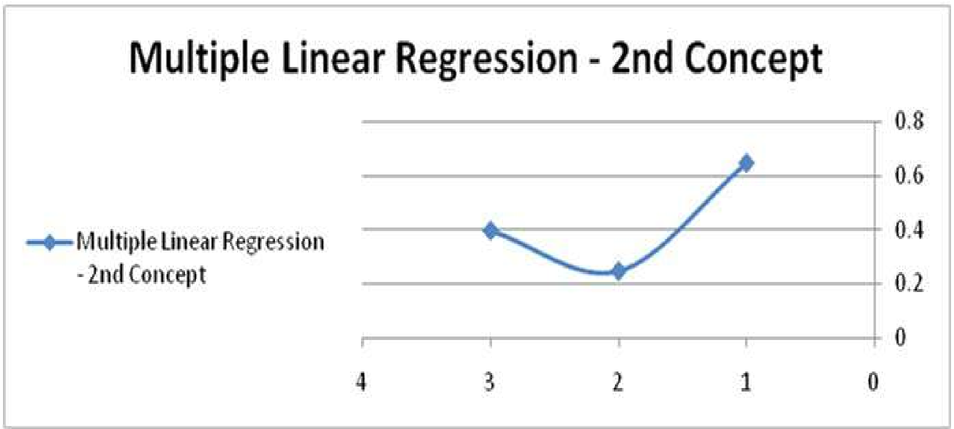


Hypothesis	Beta coefficient	R^2	F	T - Value	P - Value	Hypothesis Support
H1	0.574	0.33	0.492	0.702	0.610 > .001	No
H2	0.547	0.299	0.427	0.653	0.632 > .001	No
H3	0.716	0.513	1.054	1.027	0.492 > .001	No
H4	0.885	0.783	3.604	1.898	0.309 > .001	No
H5	0.999	0.999	900.527	30.009	0.021 > .001	No
H6	0.983	0.966	28.034	5.295	0.119 > .001	No
H7	0.890	0.792	3.798	1.949	0.302 > .001	No
H8	0.976	0.952	20.002	4.472	0.14 > .001	No
H9	0.874	0.764	3.236	1.799	0.323 > .001	No
H10	0.959	0.920	11.445	3.383	0.183 > .001	No

From the first concept regression analysis, it was found that there is no significant impact of the risk factors category on each other as all the P values > .001. By performing a regression analysis using SPSS program, the significant impact of each risk factor's category on each other will be investigated. For the second concept, there are 3 hypotheses as the following:

N.	Hypothesis	Description
1	H1	The impact of Environmental risks and social risks.
2	H2	The impact of Environmental risks and Governance risks.
3	H3	The impact of social risks and Governance risks.

Hypothesis	Beta coefficient	R^2	F	T - Value	P - Value	Hypothesis Support
H1	0.527	0.278	0.384	0.620	0.647 > .001	No
H2	0.924	0.855	5.877	2.424	0.249 > .001	No
H3	0.811	0.658	1.925	1.387	0.398 > .001	No



From the second concept regression analysis, it was found that there is no significant impact of the risk factors category on each other as all the P values > .001.

CONCLUSION

SCM is very important and plays a crucial role in construction industry. For a proper and accurate management of construction supply chain, it's very important to detect and assess the risk factors that have a significance effect on the CSC.

The importance and effect of each risk factor depends on the classification of the risk factors and the position of each risk factor in the risk action zone matrix based on its probability and severity as indicated.

Limitations of the Study

Although all possible sides of the risk factors which could have a significance effect on the CSC process are detected and assessed, there are limitations in this study which include the following:

- The study includes projects on progress and terminated projects only.
- High currency fluctuation in short time.
- Poor coordination between clusters.
- Lack of trust.
- Poor knowledge information management.
- Lack of information technology.

Recommended and farther studies

In order for accurate assessment of CSC risk factors, future researches are recommended in the following

- More and wider sectors of different construction aspects needed to be detected and investigated.
- Applying the designed assessment model on new starting projects.
- All detected risk factors in this study should be assessed step by step on new starting projects for each stage of CSC life cycle.

Abbreviations

SCM: Supply Chain Management.
CSC: Construction Supply Chain.
NUCA: New Urban Communities Authorities.
ESG: Environment, Social and Governance.
EVMs: Earned Value Measures.

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