Awareness of industries toward implementing Concurrent Engineering (CE) culture
Case Study: Jordanian Industries

Mohammad D. AL-Tahat*
Industrial Engineering Department
Hijjawi Faculty for Engineering Technology
Yarmouk University
Irbid 21163, Jordan
E-mails: mohammad.altahat@yu.edu.jo, altahat@ju.edu.jo, altahat@yahoo.com
*Corresponding author

Ala'a M. AL-Habashneh
Industrial Engineering Department.
School of Engineering
The University of Jordan
Amman 11942, Jordan
Habashneh_alaa@yahoo.com

Abstract

This paper investigates the level of awareness of Jordanian industries toward the implementations of Concurrent Engineering (CE), and to identify the most influential CE practices, a conceptual model is proposed. Related practices to CE are mapped into six areas namely; Customer Involvement, Organization Management, Information Infrastructure Systems, Supplier Involvement, Workflow Distribution, and Cross-Functional Teams. The interest of implementing such CE practices are investigated in the following Jordanian industrial sectors; Chemical and cosmetics industries, Engineering and electrical industries and information technology, Wood and furniture industries, and Construction industry. Hypotheses were formulated, a Structural Equation Model (SEM) is developed, random sampling was performed, and then primary data were collected through a five-point-Likert-scale. Model validity, reliability test, and fitness are checked. Consequently, analysis of variance (ANOVA) is conducted. Finally, the mentioned six mapped areas have positive effects on organization's awareness toward CE. This research will provide great feedback about the extent to which implementing CE improving performance. Moreover, it may support decision makers in identifying key factors for strengthening awareness of industries toward implementing CE culture.

Keywords
Concurrent engineering; Simultaneous engineering; parallel engineering; Product development; Sequential engineering.

1. Introduction and Literature Analysis

In response to fast growth of competitiveness, and rapidly changing and volatile customer demand, organizations have to be innovative, productive with the lowest possible product cost subjected to satisfactory product and process quality level, have the potential to ease and extent adjust to unpredictable and dynamically changing opportunities sophisticated customers, and to have the potential to implement and use modern methods of problems solving.

Concurrent Engineering CE is considered to be important for any organization wishing to survive in such continuing market pressure (Willaert, S.S.A. et al., 1998) because CE aims at improving the total value chain in product life cycle. In the literature several synonyms for CE are used like concurrent product development, simultaneous engineering (Bergstrom, 1989, Willaert, S.S.A. et al., 1998), or parallel engineering.
Many definitions of CE have been introduced in literature. Abdalla (Abdalla H. S., 1999) defined CE as "the consideration of the factors associated with the life cycle of the product during the design phase. These factors include product functionality, manufacturing, assembly, testing, maintenance, reliability, cost and quality". Yetukuri et. al stated that CE advocates a rapid, simultaneous approach, where concept development, design, manufacturing, and support are carried out in parallel, this allows simultaneous development and resolution of design and manufacturing steps. (Yetukuri N. B. et. al, 1996). Leppitt described CE as a collection of methods, practices, tools, and approaches aim at improving the total value chain in product development (Leppitt, 1993). CE is a management and engineering philosophy that enables organizations to produce better products and services at lower cost within shorter time (Godfrey, 1993). CE is a strategic concern that quickly and efficiently translating customer requirements into products or services by cross functional collaboration (Ellis, 1993). According to Cleetus "CE is a systematic approach to the integrated and concurrent development of a product and its related processes, that emphasizes response to customer expectations and embodies team values of cooperation, trust, and sharing in such a manner that decision making proceeds with large intervals of parallel working by all life-cycle perspectives, synchronized by comparatively brief exchanges to produce consensus" (Cleetus, 1992). Winner defined CE as "A systematic approach to the integrated, concurrent design of products and their related processes, including manufacturing and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements" (Dicesare, 1993). CE is a way of planning that suggests the need to consider design concerns simultaneously where they were considered sequentially in the earlier period. The traditional sequential approach to design and manufacturing engineering (Sequential Engineering (SE)) design process has been considered inefficient because of greater development time, greater cost, and lower overall design quality (Tang et al., 2000).
Practices of CE are can be implemented to many industrial sectors including automotive, aerospace, telecommunication, shipbuilding, information technology etc. Willaert (Willaert, S.S.A. et al., 1998) identified three main forces behind CE these are: reducing total cost all over the whole life cycle; achieving a satisfactory quality level; and reducing time-to-market, any other proposed objectives of CE may be carried back to these three driving forces. To achieve these objectives, an organization must first be efficient; consequently has to produce quality products, lastly has to be flexible. Drawbacks of CE mainly concerned with increasing possible risks (Willaert, S.S.A. et al., 1998) due to the allocation of extra resources at the beginning of the project where more problems are solved (Hudak, 1992), a correct implementation of CE minimizes the drawbacks. CE implies managing the design process using management tools that model the interface and dependencies among the decomposed phases of the design process (Tang et al., 2000). According to Tang the design process includes four major steps: model the structure of the design process with the related information structure; provide an execution planning system for the design tasks; the elimination of risk and amount of iteration between design tasks; and finally explore opportunities for achieving benefits of CE.
CE is useful, only when using the right analytic tools and procedures which operationalize its concepts. Therefore, this research is expected to provide an assessment tool to evaluate CE implementation in Jordanian enterprises.
Expected results of this research are: to involve specifying strengths, weaknesses, and opportunities facing organization's awareness toward implementing CE, it is expected that this work can act as a guide for the implementation of CE principles as well as a reference for future research in the field, therefore, the objectives of this work are;

1. To reveal a comprehensive information about Jordanian industries.
2. To study and to identify the most influential CE elements to Jordanian industries.
3. To present a reasonable method for the evaluation of Jordanian industries awareness toward implementing CE culture.

1.1 Dimensions of CE

According to Willaert et al., and AL-Tahat M. D. et al. (Willaert, S.S.A. et al., 1998 AL-Tahat M. D. et al., 2016,) CE culture can be implemented in terms of the following conceptual dimensions;

1. Customers Involvement (CI)

Surviving for engineering companies depends on getting to the market first with products that the customer wants (Anderson, 1993). Companies have found several ways to capture customer requirements, sharp market understanding, what customers in the showrooms are saying, Feedback from buyers, warranty, test a product on a test market to obtain a rapid market feedback, and adding customers to the product development team.

2. Organization Management (OM)

Organization and team-based approach to CE:

The most important items in relation to CE are management and teams (Brown, 1993). *Management:* Management's role in the CE philosophy is to keep the teams focused on their goals, to define and present the team goal, to make clear that they support and believe in the team, to set up a measurement system, teams' decisions must not be overridden. Company's reward system has to change when people are working in teams. The reward system should be based on the team result and the individual behavior in that team.

3. Cross Functional and Interdisciplinary teams of experts (CT)

A multidisciplinary team must balance all aspects of the Product Development (Sharples, 1993; Yeh, 1992). Therefore, team members must have a strong background in the product's design, manufacture, or support. A good team has synergy and the foresight to identify, address, and resolve issues through the entire product life-cycle Sharples, 1993). Teams with team leaders whose functional jobs and team responsibilities have a high degree of overlap tend to be the most successful. One pattern of team formation is known as 'Forming, storming, norming and performing', Team members should be multi-functional, experienced, disciplined, and open to negotiation. The team should be formed as early as possible in Product Development (Anderson, 1993). A workable team has between six and fifteen members depending on the size of project and complexity of the product (Baskerville, 1993). The team leader should have a broad-based background, diverse contacts, and technical expertise. Most importantly, he or she must have leadership abilities to successfully drive the project. A team member must have specific qualifications to work in a team. He or she must have technical skills (Anderson, 1993). More requirements for team work as well as team structure are found in (Starbek M., and Grum J., 2002).

4. Suppliers Involvement (SI)

It is not advisable to improve the design to manufacturing process without paying attention to the company's suppliers. Failing to communicate with suppliers can prove very costly. Good suppliers' involvements provide process knowledge and product component innovation, which is their real stock-in-trade. A successful supplier relationship implies; few suppliers, suppliers' involvements, environment of mutual trust, treated suppliers as an extension of the organization. A good supplier relationship supposed to be financially rewarding for both parties (Engel, 1991). One supplier relationship is also known as Just-In-Time II (JIT II). The key element of JIT II is having a supplier located inside, and having the supplier empowered within purchasing.

5. Work Flow and Distribution (WD)

Workflow management systems are "organizationally aware" the distribution of work to workers is based on explicit models of organizational structures and capabilities of workers. For the successful application of workflow, it is essential that there be a good fit between work practice and the models/mechanisms used by the workflow management system. A systematic concurrent workflow and distribution management consists of planning and scheduling teams' activities to support cooperative and concurrent works. WD process is based on an II including models of product requirements, enterprise organization and resources.

6. Information Infrastructure System (II)

When the information infrastructure is not balanced, the process of collaboration can break down, and the development teams can lose their effectiveness. To communicate successfully, ideas must be spoken out with voice or written up precisely, simplified by graphics and/or text, and launched by video capabilities. Successful communication is the foundation of rallying the team and makes working together successful (Godfrey, 1993). Communication involves identification and definition of mission-critical data. All members of the team need to have the same terminology (Beckert, 1993). This sharing of information is essential for CE therefore Information Technology (IT) is one main dimension of CE. According to Willaert et al., (Willaert, S.S.A. et al., 1998) information can be publicized using; virtual collocation tools like meeting on the network, electronic data interchange and electronic mail, coordination tools, and information access and corporate memory. Effective and integrated information technology tools, artificial intelligence constraint networks system, continuous feedback uses language and/or blackboard architecture from experts and advisors that surrounds the developed CE, expert system for information flow, and other information management approaches can be used also (Abdalla H. S., 1999). The lack of a well-integrated information infrastructure environment means that communication problems between departments will cause lengthy delays in development time and increased costs (Yetukuri N. B. and others, 1996). A team cannot exist without communication, to make the team concept work, technical information had to be more accessible to all parties involved (Anderson, 1993) accordingly each department can extract the information it needs. It is also vital to document every decision made during product development, after the project ends, and when team members often leave out. An electronic design notebook may use to store all the design choices. As a conclusion, a tailored Knowledge Management KM system for the needs of concurrent product development process is needed, the main functions of such KM system is to capture, organization, distribution and development of knowledge thought out the whole phases of concurrent product development process. One description of knowledge development and categorization is presented by Wunram (Wunram, 2003) as shown in figure 1.

2. Research Methodology

To achieve the goals of this work, the previously mentioned CE dimensions are hypothesized through the conceptual relationship model shown in figure 2 (AL-Tahat M. D. and AL-Habashneh, 2016). Consequently research hypothesis that proposing an assumed relationships among various-model latent are formulated as in table 1.

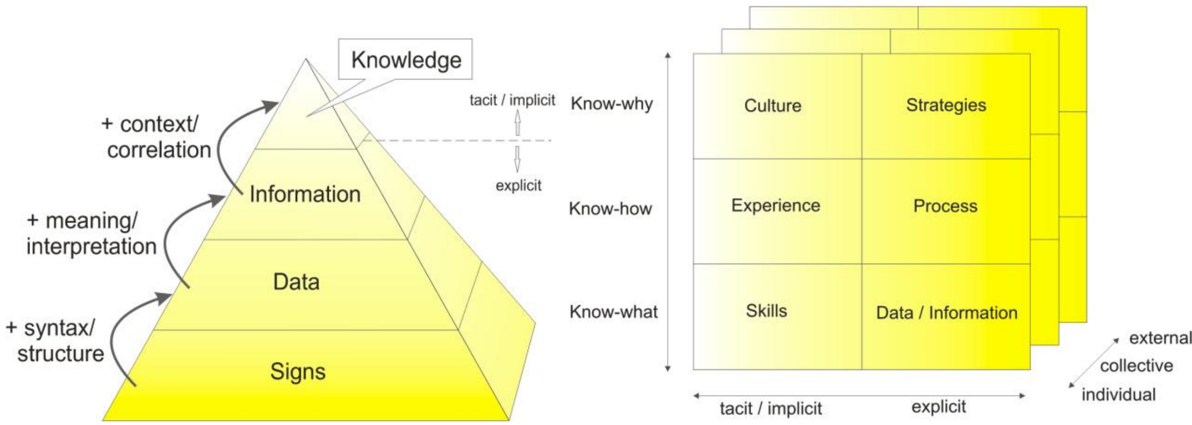

Figure 1. Knowledge development and categorization by Wunram (Wunram, 2003)

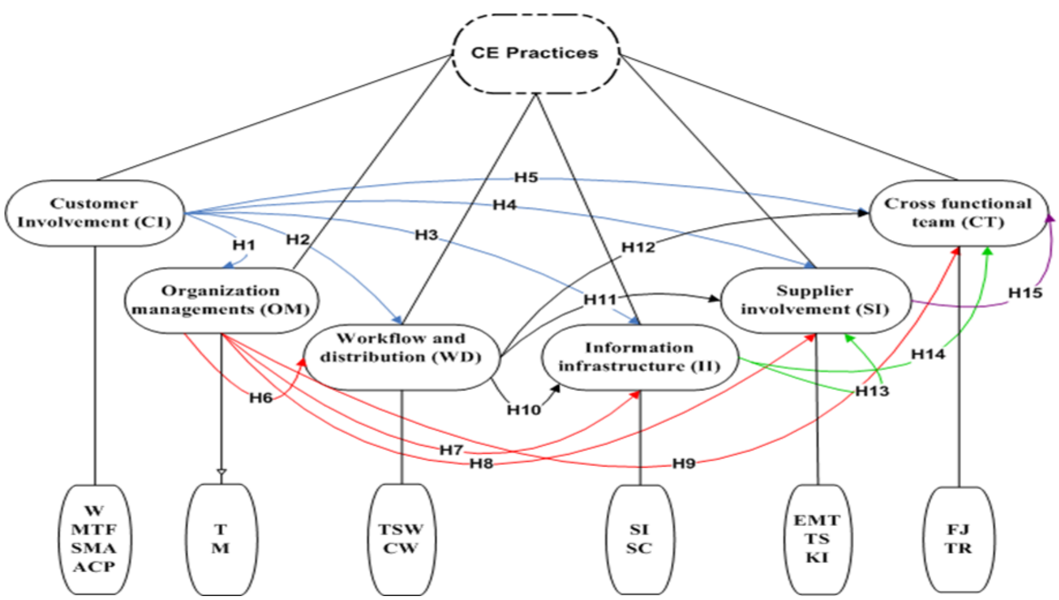

Figure.2. Proposed Conceptual Model of CE Practices and Research Hypotheses

In parallel to that, the targeted population is analyzed and identified, according to Jordan chamber of industry and commerce the following Jordanian industrial sector are categorized; (1) therapeutic industries and medical supplies, (2) plastic and rubber industries, (3) chemical and cosmetics industries, (4) engineering and electrical industries and information technology, (5) wood and furniture industries, construction industry, (6) packaging and paper industries, (7) food and agricultural industries, and the sample size will be determined and justified.

Only sectors shown in table 2 are considered for this work, population size of each sector is analyzed, convenience sampling is adopted, and accordingly a sample size, and number of respondents to invite are determined.

Table 1: Summary of the Proposed Hypotheses

H1	H10:CI has a significant positive effect on the development of OM
	$H1_1$:CI has no effect on the development of OM
H2	$H2_0$:CI has a significant positive effect on the development of WD
	$H2_1$:CI has no effect on the development of WD
H3	$H3_0$: CI has a significant positive effect on the development of II
	$H3_1$: CI has no effect on the development of II
H4	$H4_0$: CI has a significant positive effect on the development of SI
	$H4_1$:CI has no effect on the development of SI
H5	$H5_0$:CI has a significant positive effect on the development of CT
	$H5_1$:CI has no effect on the development of CT
H6	$H6_0$:OM has a significant positive effect on the development of WD
	$H6_1$:OM has no effect on the development of WD
H7	$H7_0$: OM has a significant positive effect on the development of II
	$H7_1$: OM has no effect on the development of II
H8	$H8_0$: OM has a significant positive effect on the development of SI
	$H8_1$: OM has no effect on the development of SI
H9	$H9_0$:OM has a significant positive effect on the development of CT
	$H9_1$:OM has no effect on the development of SI
H10	$H10_0$: WD has a significant positive effect on the development of II
	$H10_1$: WD has no effect on the development of II
H11	$H11_0$: WD has a significant positive effect on the development of SI
	$H11_1$: WD has no effect on the development of SI
H12	$H12_0$:WD has a significant positive effect on the development of CT
	$H12_1$:WD has no effect on the development of CT
H13	$H13_0$: II has a significant positive effect on the development of SI
	$H13_1$: II has no effect on the development of SI
H14	$H14_0$: II has a significant positive effect on the development of CT
	$H14_1$: II has no effect on the development of CT
H15	$H15_0$: SI has a significant positive effect on the development of CT
	$H15_1$:SI has no effect on the development of CT

Table 2: Industrial sectors included in the study and sampling characteristics.

Industries Sector Name	**Population Size (N)**	***Sample Size (n) E = 5%, α = 0.05**	***Number to invite Assuming Response rate = 60 %**	**Actual Number of respondents**	***Actual Margin of error**
Chemical and cosmetics industries	419`	201	335	410	5.26%
Engineering and electrical industries and information technology	2427	332	554	290	5.4%
Wood and furniture industries	1626	311	519	298	5.13%
Construction industry	1258	295	492	285	5.11%

* Calculated using Check Market tool (https://www.checkmarket.com/sample-size-calculator/)

Data collection methods are an important part of research design, Author decided to use a five-point Likert scale questionnaire. The questionnaire has been designed, tested, validated, and then distributed to each member that supposed to be invited as per the last column of table 3.

3. Statistical Analysis and Results Interpretation

Responses were collected, actual responding rate is computed, and accordingly actual margin error is evaluated as shown in table 2, average actual error is 5.225% that means 4.5% error division which is less than design error (5%), therefore author move forward the statistical analysis of the data.
Collected date is evaluated. Statistics of each CE dimension has been described for every industrial sector included in the study, such statistics are shown in Table 3. The overall awareness index of CE implementation is 60.5%, according to some experts in the field this reflects an acceptable awareness. Figure 3, illustrate the whole picture of variations of awareness index of CE implementation among the different stakeholders of this paper, the highest awareness index is (63.04%) found for WD in engineering and electrical industries and information technology sector, while the lowest is (58.6%) found for II in construction industry sector. Furthermore, Pearson Correlation Matrix is generated and presented by table 4.

Table 3: Statistics showing awareness indexes of CE among Industrial Sectors

Industrial Sector	CE Dimension	Mean	Standard deviation	Awareness Index %
Chemical and cosmetics industries	CI	3.000	0.518	60.00
	OM	3.089	0.546	61.78
	II	3.028	0.544	60.56
	SI	3.033	0.512	60.67
	WD	2.955	0.485	59.10
	CT	3.058	0.565	61.16
Overall		3.027	0.215	60.54
Engineering and electrical industries and information technology	CI	2.967	0.490	59.34
	OM	2.973	0.582	59.45
	II	2.935	0.545	58.69
	SI	2.971	0.552	59.42
	WD	3.152	0.468	63.04
	CT	3.113	0.439	62.25
Overall		3.019	0.173	60.37
Wood and furniture industries	CI	3.016	0.499	60.31
	OM	2.951	0.555	59.03
	II	3.042	0.538	60.83
	SI	3.090	0.486	61.80
	WD	3.015	0.547	60.30
	CT	3.097	0.517	61.93
Overall		3.035	0.196	60.70
Construction industry	CI	3.071	0.611	61.42
	OM	3.084	0.584	61.68
	II	2.903	0.528	58.06
	SI	3.039	0.486	60.77
	WD	2.990	0.431	59.80
	CT	3.034	0.460	60.67
Overall		3.020	0.200	60.40
Grand average				60.50

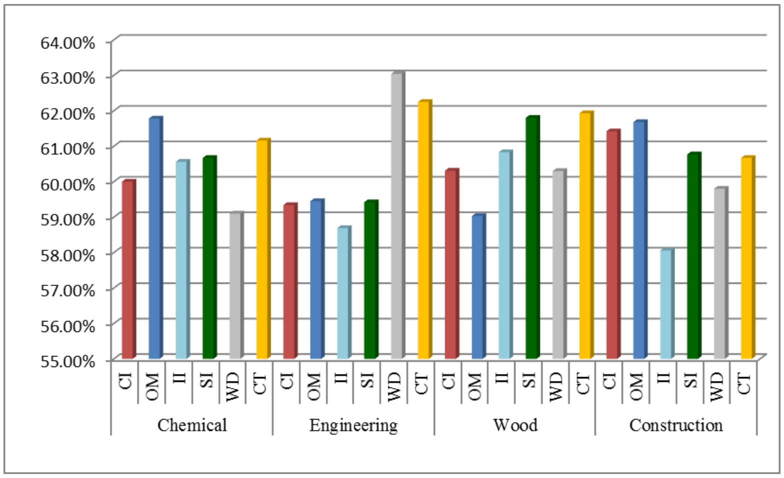

Figure 3. Variations of awareness index of CE implementation

Table 4: Pearson correlation matrix among model elements

	CI	**OM**	**II**	**SI**	**WD**	**CT**
CI	1	0.597*	0.499*	0.490*	0.607*	0.205*
OM	0.515*	1	0.481*	0.517*	0.630*	0.269*
II	0.504*	0.510*	1	0.590*	0.479*	0.173*
SI	0.177*	0.162*	0.165*	1	0.199*	0.181*
WD	0.291*	0.329*	0.227*	0.263*	1	0.227*
CT	0.528*	0.606*	0.509*	0.411*	0.609*	1

Note: * Correlation is significant at the .01 level (2-tailed)

4. Hypothesis testing and overall evaluation of the developed SEM

It is use to determine whether a particular hypothesis is a reasonable statement or not (Mason, et al., 1999). In order to test the developed hypotheses, ANOVA test and SEM analysis have been carried out using SPSS and AMOS software. The structural model is analyzed then the results are displayed in Table 5. Model fitness of the study is presented on table 6. Reference to table 5, the following results regarding CI are obtained:

- CI positively affects OM, because the corresponding p values of 0.011 is less than 0.05. It is noted that an increase of CI by one results in an increase of 1.3 in OM.
- CI positively affects WD, because the corresponding p values of 0. 026 is less than 0.05. It is noted that an increase of CI by one results in an increase of 1.01 in WD.
- CI positively affects II, because the corresponding p values of 0. 016 is less than 0.05. It is noted that an increase of CI by one results in an increase of 1.06 in II.
- CI positively affects SI, because the corresponding p values of 0. 02 is less than 0.05. It is noted that an increase of CI by one results in an increase of 0.7 in SI.
- CI positively affects CT, because the corresponding p values of 0. 022 is less than 0.05. It is noted that an increase of CI by one results in an increase of 1.11 in CT.

Similarly, results regarding OM, WD, II, SI, and CT can be obtained. According to Al-Refaie, A., and AL-Tahat, M.D. (Al-Refaie, A., AL-Tahat, M.D, 2014), the effect of CI on the overall awareness index is calculated as follows:

CI effect = (impact of CI on OM) × (impact of CI on WD) × (impact of CI on II))
+ (Impact of CI on SI) × (impact of CI on CT)
= (1.3) × (1.01) × (1.03) + (0.7) × (1.11)
= 1.05. That is mean, an increase of CI by one results in an increase of 1.05 the overall awareness index

Table 5: Hypotheses testing for structural model

Hypothesis	**Regression coefficient**	**Standard error**	**P-value**	**Decision**
$H1_0$	1.3	0.185	0.011	Reject null hypothesis
$H2_0$	1.01	0.157	0.026	Reject null hypothesis
$H3_0$	1.06	0.188	0.016	Reject null hypothesis
$H4_0$	0.7	0.196	0.020	Reject null hypothesis
$H5_0$	1.11	0.197	0.022	Reject null hypothesis
$H6_0$	0.77	0.098	0.023	Reject null hypothesis
$H7_0$	0.82	0.098	0.016	Reject null hypothesis
$H8_0$	0.54	0.112	0.028	Reject null hypothesis
$H9_0$	0.78	0.103	0.019	Reject null hypothesis
$H10_0$	1.43	0.140	0.011	Reject null hypothesis
$H11_0$	0.95	0.157	0.033	Reject null hypothesis
$H12_0$	1	0.331	0.019	Reject null hypothesis
$H13_0$	0.67	0.170	0.036	Reject null hypothesis
$H14_0$	1	0.168	0.020	Reject null hypothesis
$H15_0$	1.10	0.197	0.010	Reject null hypothesis

The statistical software AMOS, is used analysis of causal relationship for the developed structural equation model. The model is depicted graphically using AMOS, The results of AMOS computations for SEM are displayed shown in the figure 4. Results on figure 4 display the impact of every single question included in the questionnaire on the corresponding CE dimension, in addition to the impact of CE dimensions to each other.
The results in Table 6 indicate the validity of the overall model. Before drawing conclusions about model hypotheses, the fitness of the structural model in Figure 2 should be tested and achieved, results of fit summary for the structural model are also summarized in Table 6.

5. Conclusions

Through this work, brief information about Jordanian industries is revealed, and CE as well as the most influential CE elements to Jordanian industries have been studied and identified, it is concluded that operationalizing CE is a reasonable approach that can improve productivity.
A reasonable model for the evaluation of Jordanian industries' awareness, toward implementing CE culture, in four Jordanian industrial sectors, namely: construction industry, engineering and electrical industries and information technology, chemical and cosmetics industries, and wood and furniture industries, is successfully presented. Results reveal that the awareness of Jordanian industrial sectors toward implementing CE is 60% to 80%, alternatively this conclusion can be formulated as; 60% to 80% of Jordanian industrial enterprises are familiar with CE culture. Future avenues to this research may be to bridge CE with lean management methodologies, or with the 20 keys to workplace improvement and business excellence that been published in 1988 by Iwao Kobayashi (Javier Santos et al. 2006).

Acknowledgements

This paper is part of a research project entitled "Studying the principles of concurrent engineering in Jordanian industries", which is being conducted during a sabbatical leave granted to Prof. Dr. Mohammad D. AL-Tahat, from the University of Jordan, during the academic year 2016/2017. Deanship of scientific research at the University of Jordan is supported this research.

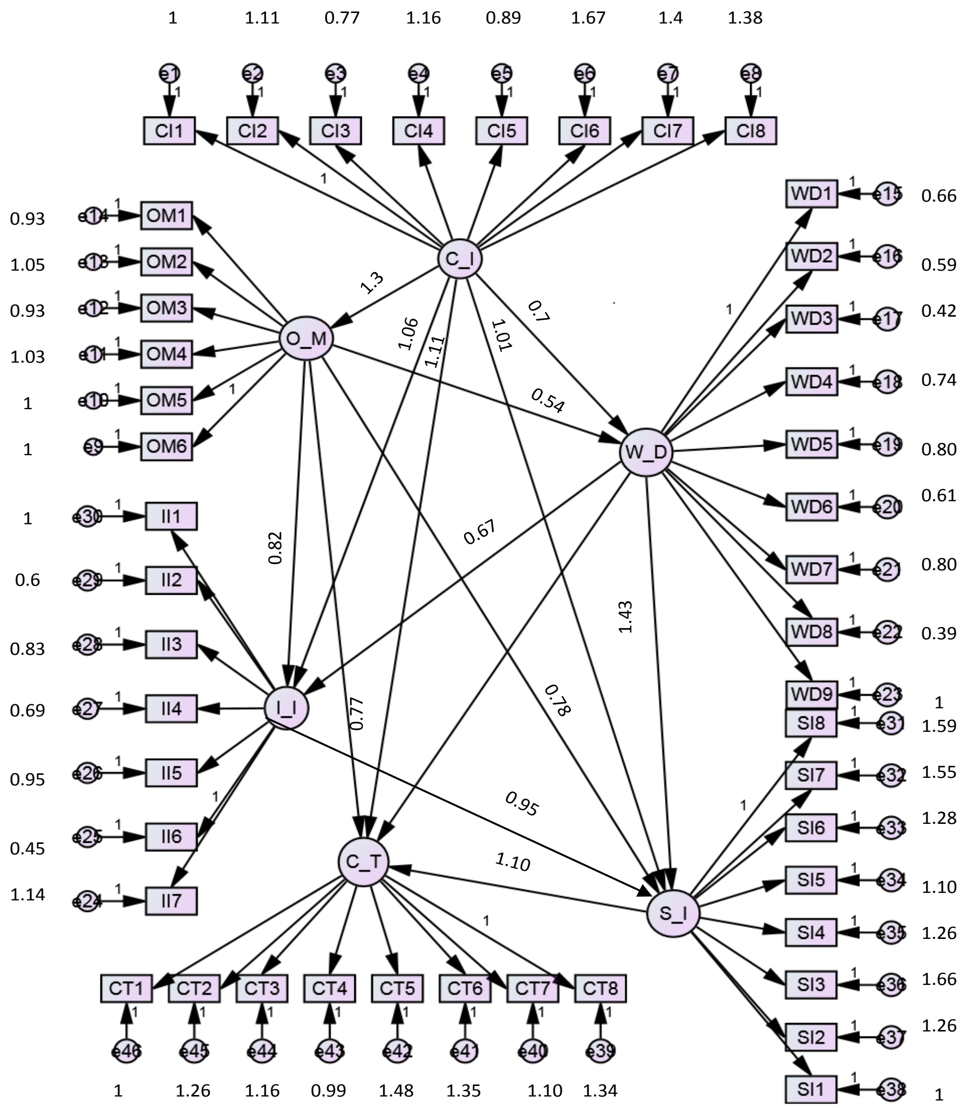

Figure 4. Graphical depiction and results computations for SEM using AMOS

Table: 6 Model fitness of the study

CE Dimension	X^2	X^2/DF	P-value	Goodness Fit Index (GFI)	Comparative fit index CFI	RMSEA
CI	153.802	4.72	0.022	0.683	0.607	0.078
OM	123.284	3.14	0.037	0.691	0.718	0.054
II	160.283	4.00	0.023	0.794	0.798	0.070
SI	149.335	3.733	0.038	0.825	0.725	0.053
WD	175.233	3.380	0.031	0.952	0.745	0.065
CT	121.703	3.04	0.036	0.762	0.718	0.062
Overall	114.425	2.335	0.029	0.927	0.932	0.074

References

Abdalla H. S. (1999). Concurrent engineering for global manufacturing. Int. J. Production Economics 60 - 61, 251-260.

Al-Refaie, A., AL-Tahat, M.D. (2014) "Effects of Knowledge Management and Organization Learning on Firms' Performance ", The Journal of Nature Science and Sustainable Technology (JNSST), Vol. 8, Issue 3. ISSN: 1933-0324.

AL-Tahat M. D. and AL-Habashneh A.M. (2016). Studying the level of implementing concurrent engineering fundamentals in Jordanian Industries. Master thesis in industrial engineering, Faculty of graduated studies, the University of Jordan.

Anderson, J. C., and Gerbing, D. W. (1993), Structural equation modeling in practice: A review and recommended two-step approach, Psychological bulletin, 103(3): 411.

Baskerville, D.M., 1993. Why business loves work teams. Black Enterprise 23 (9), 85–90.

Beckert, B., 1993. Technology for the experts. Machine Design 65 (15), SS18–SS25.

Bergstrom, R.P., 1989. Assembly: Sometimes great notions work. Production 101(10), 54–58.

Brown, D.H., 1993. PIM: A tool for Concurrent Engineering. CAE: Computer-Aided Eng. 12 (4), 64.

Cleetus, J., 1992. Definition of Concurrent Engineering. CERC Technical Report CERC-TR-RN-92-003. Concurrent Engineering Research Center, West Virginia University, Morgantown, WV.

Dicesare, F.P., 1993. Re-engineering to achieve a Concurrent Engineering environment. J. Design and Manufacturing 3, 2. 75–89.

Ellis, D., 1993. Concurrent Engineering—a success story. IEE Colloquium on 'Concurrent Engineering', 20–26.

Engel, J., 1991. Simultaneous engineering and the outside equipment vendor. Manufacturing Systems 9 (10), 36–40.

Godfrey, D., 1993. Incorporating value analysis through a Concurrent Engineering program. Production 105 (9), 44–47.

Hudak, G.J., 1992. Concurrent Engineering: what are the risks and benefits? Proceedings of the Technical Program. NEPCON West '92, Anaheim, CA, USA, pp. 362–372.

Javier Santos, Richard Wysk, and Jose Manuel Torres (2006), Improving Production with lean Thinking. John Wiley & sons Inc.

Leppitt, N., 1993. Concurrent Engineering—a key in business transformation. Eng. Manage. J. 3 (2), 71–76.

Mason, R. D., Lind, D. A., and Marchal, W. G. (1999), Statistical Techniques in Business and Economics, 10th Edition, McGraw-Hill International Edition.

Sharples, S., 1993. Concurrent Engineering—why do it at all? IEE Colloquium on 'Concurrent Engineering', London, UK, 4–11.

Starbek M., Grum J., (2002). Concurrent engineering in small companies. International Journal of Machine Tools & Manufacture 42, 417–426.

Tang D., Zheng L., Li Z., Li D. , Zhang S. (2000). Re-engineering of the design process for concurrent engineering. Computers & Industrial Engineering 38 479±491.

Wunram, M. (2003). "Practical Methods and Tools for Corporate Knowledge Management – Sharing and Capitalizing Engineering Know-How in the Concurrent Enterprise", Verlag Mainz.

Willaert, S.S.A., Graaf R. D., and Minderhoud S. (1998). Collaborative engineering: A case study of Concurrent Engineering in a wider context. Journal of Engineering and Technology Management (15), 87–10.

Yeh, R.T., 1992. Notes on Concurrent Engineering. IEEE Trans. on Knowledge and Data Eng. 4 (5), 407–414.

Yetukuri N. B., Yetukuri V. N., and Fischer W. G. (1996). SPAW: A design tool for planning a manufacturing process in a concurrent engineering environment. Computers in Industry 32, 79-93.

Biography

Prof. Dr. Mohammad D. AL-Tahat is a University full professor of Industrial Engineering (IE) with the University of Jordan, where he teaches and conducts several research works in the area of Industrial and Manufacturing Engineering. He received his BSc. MSc. and Ph.D. in industrial engineering. His articles appeared in many reputable international journals. He has taught many IE courses in the University of Jordan, in Jordan University of science and technology, and in University of Tabuk, for both undergraduate and postgraduate programs. He worked as the dean assistant, and as a chair of the IE department at the University of Jordan, currently he is in a sabbatical leave working for industrial engineering with Yarmouk University/ Jordan.

Ala'a AL-Habashneh a graduate student of Industrial Engineering, received her master degree in industrial engineering from the University of Jordan in 2016.