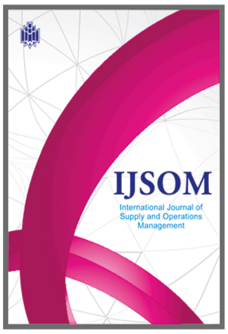
International Journal of Supply and Operations Management

IJSOM

May 2016, Volume 3, Issue 1, pp. 1112-1125
ISSN-Print: 2383-1359
ISSN-Online: 2383-2525
www.ijsom.com



An Integrated Enterprise Resources Planning (ERP) Framework for Flexible Manufacturing Systems Using Business Intelligence (BI) Tools

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Abstract

Nowadays Business intelligence (BI) tools provide optimal decision making, analyzing, controlling and monitoring of operations in enterprise systems like enterprise resource planning (ERP) and mainly refer to strong decision making methods used in online analytical processing, reporting and data analysis, such as improving internal processes, analysis of resources, information needs analysis, costs reduction and revenue increase. The main purpose of the paper is creating a unified framework for the application of BI in ERP systems which results of value-added inflexible manufacturing systems (FMS). In this paper, business process system and interaction between technology and environment by applying BI in ERP systems of companies that use flexible manufacturing systems have been presented. This paper is a comprehensive review of recent literature that examined the effects of BI systems on the four levels of Tenhiala *et al.*' Model. This model based on cross-sectional data from 151 manufacturing plants proved that ERP is essential for the FMS. According to results of this paper, the answer to this question is important “How can we use the potential data and intelligence of BI in ERP systems for the effective flexible manufacturing systems?” This study has four hypotheses to answer this question and based on results, all four hypotheses were confirmed. Finally, a model has been developed to determine the relationship between BI (as enabler of ERP) and FMS.

Keywords: Business Intelligence (BI); Enterprise Resource Planning; flexible manufacturing systems (FMS); Smart Management; Decision Support Systems.

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1. Introduction

Nowadays, technological advances are growing at a high rate and organizations need a strategic approach for analyzing problems in complex systems (Zali *et al.*, 2014). Also, manufacturing industries Are looking for the most up-to-date Technologies in order to in order to meet the challenges and customer-driven market considering the fact that today's customers want the diverse products with the lowest price and as highest quality as possible. Therefore, manufacturing industry needs to provide advantages such as flexibility and decrease production lag time to deal with the market changes.And to maintain market share, improving productivity and reducing prices.

Given that the enterprise resource planning (ERP) systems are including a range of different activities that will improve the performance of an organization and all data and processes of an organization with a linguistic information processing will be integrated with using ERP, So many of manufacturing systems have resorted to using ERP and source localization (Liao *et al.*, 2007, Lubbe *et al.*, 2006). ERP software provides different tools that can support supply chain integration (Kelle and Akbulut, 2005), knowledge and user competencies (Worley *et al.*, 2005), mutually desirable goals (Wang and Chen, 2006).

Many researchers argue that the information processing capabilities of ERP systems are crucial for organizations that face dynamic market requirements and also the criticized procedures and constraints actually support process reengineering (Tenhiala *et al.*, 2015, Movahedi and Koupaei, 2011, Sanchez *et al.*, 2015). The argument that organizations can use the benefits of discipline and simplicity by Implementing ERP systems can be based on Rigid Flexibility Theory (Gosling *et al.*, 2010, Collins and Schmenner, 1993). Though this Theory was first proposed over half a century ago, it has been used in the contemporary operations management research (e.g. Goodale *et al.*, 2011, Jacobs. M., 2008, Huang *et al.*, 2010, Jiang. W., 2014, Zhang *et al.*, 2012). According to this theory, Tenhiala et al.' proposed a model that proved ERP is essential for the FMSin 2015. They use cross-sectional data from 151 manufacturing plants to examine which factors is more important in the flexible manufacturing systems. Due to the theoretical backing, the results strongly favor the use of ERP systems under dynamic market requirements. Although Utilizing ERP in FMS is of great strategic and tactical advantages but it is necessary to be added an intelligent tool to this software package to increase the ability of flexibility system such as: analysis and query, Report Builder, online analytical processing (OLAP), business intelligence, operational business intelligence, open source business intelligence, business intelligence sharing and regional intelligence. Using business intelligence tools can be provided a combination of advanced analytics, such as: data mining, predictive analytics, text mining, statistical analysis and macro analysis of the data. Most organizations still experience a lack of Business Intelligence (BI) in their production planning processes when using ERP (Ghazanfari *et al.*, 2011).

Consequently, there have been various methods introduced to evaluate and assess the intelligence-level of enterprise systems to improve production planning processes and decision support system. This paper proposed BI tools as an intermediary for the ERP systems implementation on manufacturing systems, and combines a comprehensive review of recent literature with statistical methods for factor analysis.

In addition, we will discuss the BI tools related findings and observations in productivity promotion of production and automobile export optimized through the methods, techniques, and experiences of Iran Khodro Company (IKCO) experts by using statistical methods and data mining techniques. Finally, a framework is proposed for determining relationship between BI and flexible manufacturing systems (FMS).

2. Literature review

Flexible manufacturing system allows companies to change production processes between multiple products (Mohammadi and Jafari, 2010) and respond to customer needs quickly and effectively (Rafie-Majd*et al.*, 2015). However, it is not possible to use this method in some industries but successful companies, including major automotive manufacturers have attempted to implement FMS. To achieve the proper functioning of FMS, it is necessary to create a system that make a right decision at the right time according to conditions of FMS (Naderi and Azab, 2015).Considering that ERP systems use an integrated database to consolidate data and provide local and global information for effective decision-making, in recent years, several researches have been conducted to investigate the effects of ERP systems in FMS. Critics claim because those ERP systems are procedures and constraints on organizations that make production processes inflexible to change. Therefore, they are surely detrimental to organizations that face dynamic market requirements. In contrast, proponents argue that the information processing capabilities of ERP systems are crucial for organizations that face dynamic market requirements and also the criticized procedures and constraints actually support process reengineering (Tenhiala et al., 2015). Due to advances in technology, to develop a fully automated and integrated flexible manufacturing system using an integrating ERP and physical operational systems are important (Jiang. P.*et al.*, 2015).Implementation of ERP systems can increase the flexibly of manufacturing system (Powell*et al.*, 2013).Given the importance of using ERP systems in flexible manufacturing systems, Tenhiala *et al.* (2015) proposed a model based on cross-sectional data from 151 manufacturing plants that said ERP is essential for the FMS. This model based on Rigid Flexibility Theory presented (Gosling *et al.*, 2010, Collins and Schmenner, 1993). The Tenhiala et al.' Model (2015) conducted at four levels: Materials planning, Materials management, Capacity planning and Shop-floor control.

3. Tenhiala et al.' Model (2015)

This model explains the activities and their input information flows from the other business functions of a firm. This model suggests that successful implementation of ERP is dependent on the implementation of the following 4 levels. Each of these 4 levels has some of criteria that used to assess the level.

- **Materials planning:** Demand information, Product specifications, Bills of materials, Cost centers
- **Capacity planning:** Cost centers, Routings/recipes, Work centers and resources, Shift schedules
- **Materials management:** Vendor data, Goods receipts, Goods issues, Accounts payable, General ledger
- **Shop-floor control:** Order confirmations, Maintenance and repair, Staffing decisions

Based on the descriptions of the critical success factors and the definitions of the Tenhiala et al. framework elements, the 15 critical success factors (CSFs) are classified into the Tenhiala et al. framework (see Fig. 1).

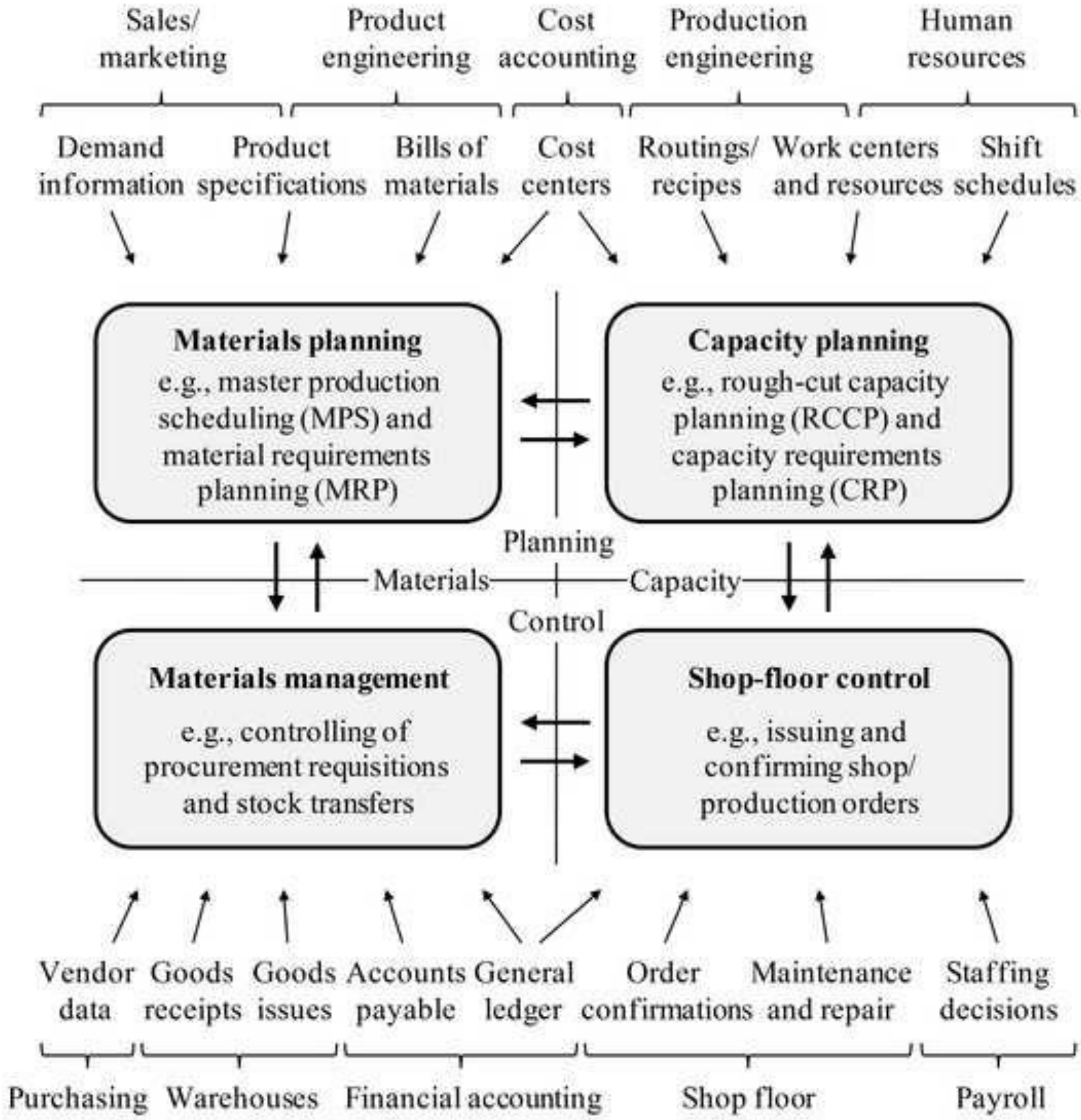

Figure 1. Tenhiala et al.' Model (2015)

In the future, smart manufacturing systems must not only integrate real-time data from system operations, but also formulate and solve the optimal-control analyze quickly and efficiently (Sprock and McGinnis, 2015). Therefore, this paper proposes BI tools as an intermediary for the ERP systems implementation on Improving Tenhiala et al.' Model (2015) and combines a comprehensive review of recent literature with statistical methods for factor analysis.

To illustrate the flexibility of a manufacturing systems implementation, Tenhiala *et al*. (2015) take the chartering phase of such an implementation as an example (arrow numbers from Fig. 1 are indicated in brackets). When a company has a flexible manufacturing system, it is necessary to improve the technological infra-structure, which is ERP system, then all other four elementary levels to be adapted as well. The findings of the study indicated a conceptual model that shows ERP systems can be used as an enabler in flexible manufacturing systems.

Today, BI plays an essential role in the creation of information and decision making (Popovič *et al*., 2010). In addition, BI can be used to support a wide range of business decisions ranging from operational to strategic. Basic operating decisions include product positioning or pricing. Strategic business decisions include priorities, goals and directions at the broadest level. In all cases, BI is most effective when it combines data derived from the market in which a company operates (external data) with data from company sources internal to the business such as financial and operations data (internal data)(Cheng *et al.*, 2009).

This paper investigates the role of advantages of BI as a mediator for the implementation of ERP systems on Improving Tenhiala et al.' Model. The findings of this paper will explain how the combination of BI and ERP systems can be used as an enabler for flexible manufacturing systems. So the theoretical model in this study is shown below:

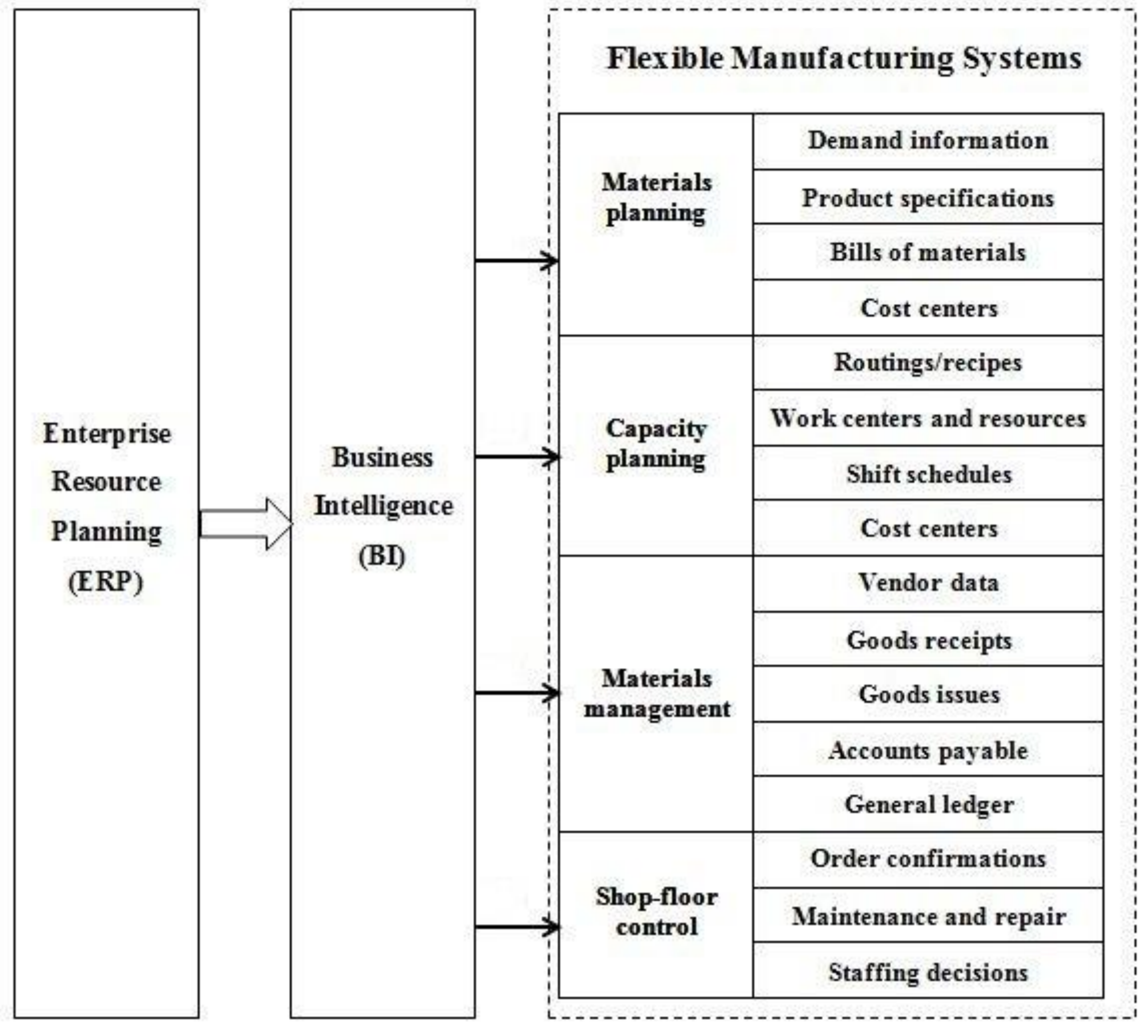

Figure 2. The combination of BI and ERP Systems as an enabler on Tenhiala et al.'s Model.

BI tools can play a major role in analyzing forecasts, analyzing of financial data and empowerment smarter decisions. Sometimes these smart business decisions are associated with immediate response and it is often used to reduce the time and improvement decision making methods. But in all cases, using BI is proactive (Negash, 2004). A well-designed business intelligence solution ensures that information across the organization is available in a consistent, reliable manner. Figures can be aggregated and compared in different business units, assuring the validity of data comparisons, and that's all management reports offer operations leaders and top management with the information they need to steer the business properly. Also, BI increased flexibility in the manufacturing systems by identifying new customers, new markets and offer new products to new customers. By combining business intelligence (BI), a flexible manufacturing data can be collected and analyzed and decision making process can be facilitated. On the business side, less time is spent in data analysis and preparation as management reports are created directly from the BI dashboards.BI tools can analyze the business scenarios in long and short term by using existing data in enterprise information systems. In addition, it can add some features such as prediction of the required information and indicators to ERP's modules. Several quality indicators exist for ability prediction of process and machine ability, which can prevent future errors in the system and product. Business intelligence can help organizations predict these quality indicators for the future. Thus, this paper investigates using a combination of BI and ERP systems based on Tenhiala et al.' Model. Therefore, suggested model can improve flexible manufacturing systems (FMS).

BI can be used in the decision process of ERP. These methods can increase accuracy, flexibility and improvement decision-making information. The hybrid systems that contain two or more intelligence methods have also been investigated (Kahraman *et al.*, 2011). These systems leverage the large data infrastructure investments (e.g. ERP systems) made by firms, and have the potential to realize the substantial value locked up in a firm's data resource (Elbashir *et al*., 2008; Azma and Mostafapour, 2012).

Also custom BI solutions merge ERP data with other transaction data outside of the ERP solution, allowing executives to analyze data from multiple sources. Although these studies review different dimensions of ERP systems, but none of these studies have reviewed the effect of BI as an enabler of ERP in flexible manufacturing systems (FMS).This paper produces a framework for applying BI as an enabler of ERP in FMS in Tenhiala *et al.*' Model. The scientific basis of this research is very strong and developed based on Tenhiala et al.' Studies.

4. The proposed study

Hypothesis of research

According to the proposed model of this research, the research hypothesis will be refined after the literature review and baseline study as bellows:

1. Hypothesis H1. Using Business Intelligence (BI) in ERP systems impacts on Materials Planning of FMS.
2. Hypothesis H2: Using Business Intelligence (BI) in ERP systems impacts on Capacity Planning of FMS.
3. Hypothesis H3: Using Business Intelligence (BI) in ERP systems impacts on Materials Management of FMS.

4. Hypothesis H4: Using Business Intelligence (BI) in ERP systems impacts on Shop-floor Control in FMS.

These hypotheses are shown in the following proposed model:

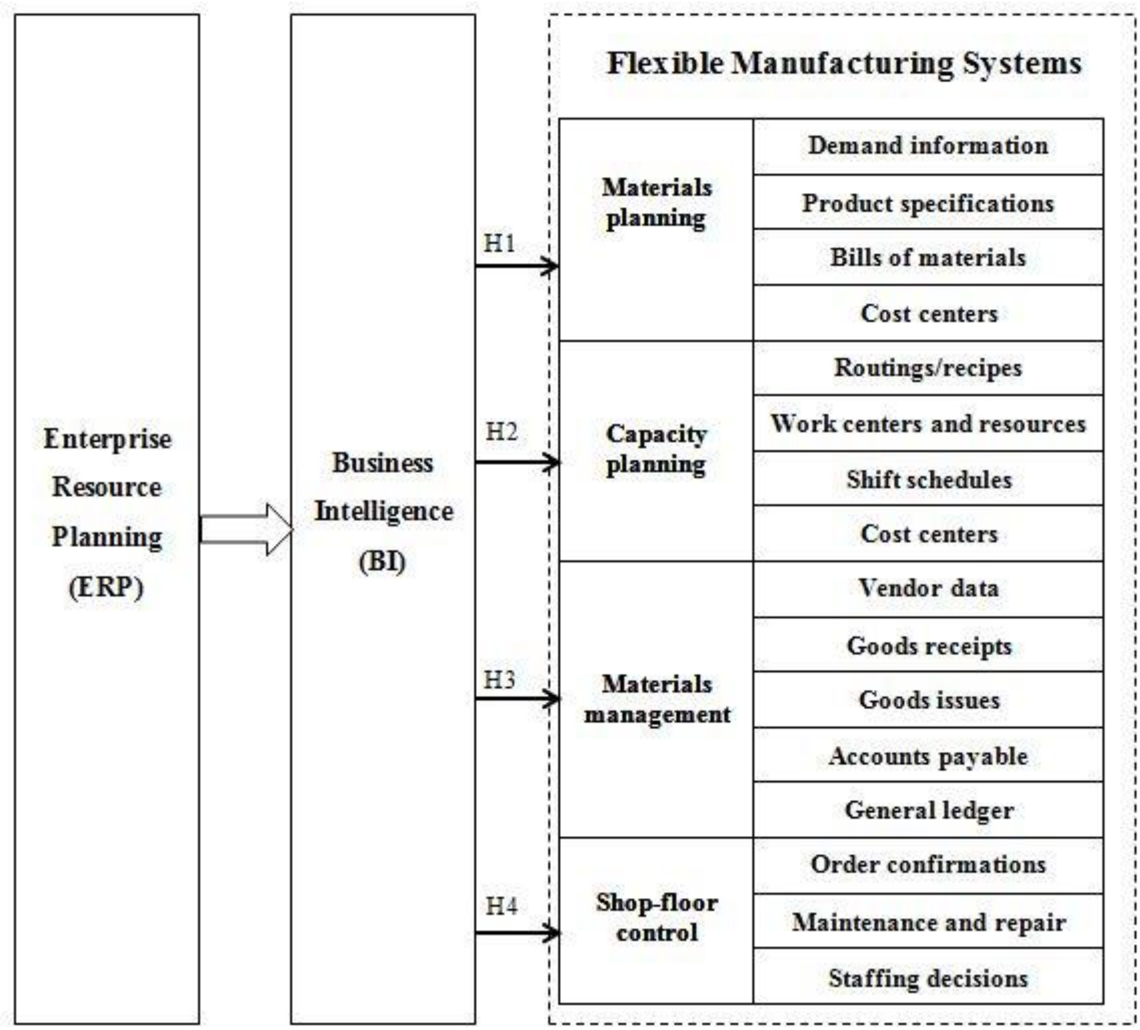

Figure 3. The conceptual model: The impacts of BI (in ERP systems) on Tenhiala et al.' Model (2015)

5. Statistical community and Sample size

The objective of this paper is to investigate the perceptions and attitudes in the region of Iran, that use Business Intelligence (as an enabler of ERP systems) on the operations of Flexible Manufacturing Systems (FMS). Our main goals are to identify the main advantages that an FMS can derive from the usage and implementation of an Enterprise Resource Planning (ERP) with the capabilities of business intelligence.

In order to measure the above mentioned, 24 firms of Iran were examined, during August and September 2015. The majority of the firms (68.35%) are manufacturing sector, and31.65% are commercial firms. More than one out of two firms (62.36%) employ more than 40 employees. In addition, we examine the results of model on IranKhodro Company (IKCO). Therefore, at present research the statistical society consists of the managers, supervisors, experts and sales and marketing staff of IranKhodro Company. The data collection method is using the questionnaires.

Managers and users of ERP systems were personally interviewed, with the use of a structured questionnaire divided in 4 sections: Materials planning, Capacity planning, Materials management, Shop-floor control. All questions were taken from relevant literature hypotheses, and were presented using the Likert scale from 1 (totally disagree) to 5 (totally agree). In order to identify the relationship between the advantages yielded by the usage of business intelligence features as an enabler of ERP in FMS based on Tenhiala et al.' Model, various statistical tests were as employed as the non-parametric test of Kruskal-Wallis, the Spearman correlation coefficient and the Kolmogorov–Smirnov non parametric test.

6. Validity and reliability

In this paper, data were collected using a questionnaire. For this purpose, a questionnaire was adjusted based on the assessment criteria of ERP and FMS. To obtain a high degree of validity and reliability in this paper, different measures have been undertaken. We use of multiple sources of information and opinions of experts and professors.Then Content Validity Ratio (CVR) method was used to assess the content validity. This formula is as follows:

$$CVR = \frac{n_e - \frac{N}{2}}{\frac{N}{2}} \qquad (1)$$

In this formula: n_e is number of SME (subject matter expert raters) indicating "essential", and N is total number of SME. CVR were calculated for all parameters and variables.

The content validity will be optimal for the indicators or factors, if CVR is greater than 0.75 as the significant level of 0.05 (Wisdom Source, 2004).

7. The results

Iranian companies have only 10 years began adopting ERP systems in their daily operations. The companies in the sample examined have been using ERP systems for an average of approximately 5 years with a standard deviation of 3.14 years. The advantages of using ERP systems identified by the respondents relate to data integration (39.00%), reducing manufacturing costs, maintenance records and transportation costs (27.50%), flexible manufacturing processes and flexible decision making (24.50%), improve efficiency and controlling activities (9.00%) which are all related to business intelligence features of ERP systems.

In Table 1 the factors affecting the successful adoption of ERP systems based on Tenhiala *et al*.' Model (2015) are presented. The reliability of respondents' answers has been tested, using Cronbach’s alpha reliability test, for all sections of the questionnaire with values higher than 0.7, reaching 0.954 for the questions of whole the questionnaire. Specifically, for the questions of Table 1 the value of Cronbach an indicator is 0.725, and the Kolmogorov-Smirnov test shows that answers do not follow the normal distribution.

Table 1. Factors affecting the successful of ERP systems based on Tenhiala et al.' Model (2015)

	Average	Median	S.D.	D (sig.p.)
Demand information in ERP system	3.78	4	0.945	D(37)=0.465, p=0.00
Product specifications in ERP system	4.25	5	0.922	D(37)=0.465, p=0.00
Bills of materials in ERP system	3.98	5	0.867	D(37)=0.465, p=0.00
Cost centers in ERP system	4.28	5	0.886	D(37)=0.465, p=0.00
Routings/recipes in ERP system	4.63	4	0.903	D(37)=0.465, p=0.00
Work centers and resources in ERP system	3.86	5	0.794	D(37)=0.465, p=0.00
Shift schedules of the ERP system	4.47	5	0.868	D(37)=0.465, p=0.00
Vendor data of the ERP system	4.57	4	1.02	D(37)=0.465, p=0.00
Goods receipts of the ERP system	3.93	4	0.993	D(37)=0.465, p=0.00
Goods issues of the ERP system	4.32	4	0.905	D(37)=0.465, p=0.00
Accounts payable of the ERP system	4.56	5	0.759	D(37)=0.465, p=0.00
General ledger of the ERP system	4.09	4	0.875	D(37)=0.465, p=0.00
Order confirmations with ERP system	4.68	4	0.977	D(37)=0.465, p=0.00
Maintenance and repair with ERP system	3.74	5	1.03	D(37)=0.465, p=0.00
Staffing decisions with ERP system	4.19	5	0.967	D(37)=0.465, p=0.00
Total Average:	**4.22**		**0.91**	

The relationship between the characteristics of firms and the benefits derived by ERP implementation is tested using the non-parametric test of Kruskal-Wallis as the responses are not normally distributed. The variable used is the mean value of all the responses, while the independent variables are the: a) the process of materials planning using ERP in which the firm operates, b) the process of capacity planning using ERP in which the firm operates, c) materials management using ERP in which the firm operates. And d) the Shop-floor control using ERP. The results are shown in Table 2.

Table 2. Results of perceptions of managers concerning benefits of ERP systems

	Kruskal-Wallis $\chi2$	Df	Significance
the process of materials planning using ERP in which the firm operates	8.28	4	0.033**
the process of capacity planning using ERP in which the firm operates	7.64	5	0.042**
materials management using ERP in which the firm operates	0.38	4	0.086
the Shop-floor control using ERP	5.73	4	0.931

*** Significant for 0.05*

According to the results of the test the perceptions of managers concerning benefits of ERP implementation differ tow across sectors with as the value of the test is $\chi2$ (3, N=24) = 8.277, p = 0.033 < 0.05 probability and $\chi2$ (3, N=24) = 7.639, p = 0.042< 0.05 probability. Figure 2 depicts that the firms of the sample in the Demand information, Product specifications, Bills of materials, Cost centres, Routings/recipes, Work centres and resources and Shift schedules more uniformly, while commercial firms' perceptions of benefits of ERP implementation differ significantly.

Business Intelligence is the focus of the 4th section of the questionnaire examining 15 business intelligence capabilities of ERP systems in flexible manufacturing systems. The average value for the total of the 15 variables is 4.11 with a standard deviation of 0.88. Cronbach a value for the questions of Table 3 is 0.903 and the Kolmogorov-Smirnov test shows that answers do not follow normal distribution.

Table 3. Factors affecting the successful of Business intelligence (as an enabler of ERP systems) based on Tenhiala et al.'s Model (2015).

	Average	Median	S.D.	D (sig.p.)
Demand information using integrated of BI and ERP in flexible manufacturing system	3.04	4	0.769	D(37)=0.486, p=0.00
Product specifications using integrated of BI and ERP in flexible manufacturing system	4.35	5	0.810	D(37)=0.345, p=0.00
Bills of materials using integrated of BI and ERP in flexible manufacturing system	3.98	5	0.844	D(37)=0.388, p=0.00
Cost centers using integrated of BI and ERP in flexible manufacturing system	3.75	5	0.883	D(37)=0.454, p=0.00
Routings/recipes using integrated of BI and ERP in flexible manufacturing system	3.67	4	1.071	D(37)=0.455, p=0.00
Work centers and resources using integrated of BI and ERP in flexible manufacturing system	3.91	5	1.032	D(37)=0.473, p=0.00
Shift schedules using integrated of BI and ERP in flexible manufacturing system	4.16	5	0.819	D(37)=0.398, p=0.00
Vendor data using integrated of BI and ERP in flexible manufacturing system	3.96	4	0.833	D(37)=0.404, p=0.00
Goods receipts using integrated of BI and ERP in flexible manufacturing system	4.62	4	0.952	D(37)=0.412, p=0.00
Goods issues using integrated of BI and ERP in flexible manufacturing system	4.82	4	0.877	D(37)=0.370, p=0.00
Accounts payable using integrated of BI and ERP in flexible manufacturing system	4.33	5	0.912	D(37)=0.439, p=0.00
General ledger using integrated of BI and ERP in flexible manufacturing system	3.73	4	0.708	D(37)=0.481, p=0.00

Table 3. Continued

	Average	Median	S.D.	D (sig.p.)
Order confirmations using integrated of BI and ERP in flexible manufacturing system	4.18	4	0.769	D(37)=0.373, p=0.00
Maintenance and repair using integrated of BI and ERP in flexible manufacturing system	4.72	5	1.049	D(37)=0.492, p=0.00
Staffing decisions using integrated of BI and ERP in flexible manufacturing system	4.49	5	0.970	D(37)=0.436, p=0.00
Total Average:	**4.11**		**0.88**	

The link between the benefits of implementing an ERP system and the Business Intelligence capabilities in flexible manufacturing systems is examined in Table 4. Furthermore, the correlations between ERP system implementation and their Business Intelligence capabilities, with the years of ERP usage are also investigated, using the Spearman coefficient in IranKhodro Company.

Table 4. Results of perceptions of managers concerning Business Intelligence capabilities of ERP systems in flexible manufacturing systems

Correlations	Spearman coefficient	Significance p.
The relationship between "process improvement of materials planning", and "using integrated of BI and ERP in flexible manufacturing system".	-0.023	0.892
The relationship between "process improvement of capacity planning", and "using integrated of BI and ERP in flexible manufacturing system".	-0.018	0.903
The relationship between "process improvement of materials management", and "using integrated of BI and ERP in flexible manufacturing system".	-0.021	0.901
The relationship between "process improvement of Shop-floor control", and "using integrated of BI and ERP in flexible manufacturing system".	-0.019	0.897

The values of the Spearman coefficient indicate that BI plays essential role on the creation of flexible manufacturing systems (FMS). BI can be used to utilize the decision process of ERP. These methods can increase accuracy, flexibility and sensitiveness of decision making information. Also, Business intelligence can help organizations predict the quality indicators for the future. In addition, using a combination of BI and ERP systems based on Tenhiala *et al*.' Model show that suggested model can improve flexible manufacturing systems (FMS).

8. Conclusions

In this paper, we have evaluated the impacts of BI in ERP systems based on Tenhiala et al.' Model (2015).This model suggests that successful implementation of ERP is dependent on the implementation of 4 levels, including: Materials planning, Capacity planning, Materials management, and Shop-floor control. Based on the descriptions of the critical success factors and the definitions of the Tenhiala et al. framework elements, the 15 critical success factors (CSFs) are classified into the Tenhiala et al. framework. Therefore, answer to this question is important "How can we use the potential data and intelligence of BI in ERP systems for the effective flexible manufacturing systems? The results have indicated that applying BI, as an enabler of ERP, will influence on flexible manufacturing systems (FMS). Note that this study was descriptive-cognition so statistical community of this study included the experts in 24 firms of Iran during August and September 2015. The majority of the firms (68.35%) are manufacturing sector, and 31.65% are commercial firms. More than one out of two firms (62.36%) employ more than 40 employees. In addition, we examine the results of model on IranKhodro Company (IKCO). Therefore, at present research the statistical society consists of the managers, supervisors, experts and sales and marketing staff of IranKhodro Company. The data collection method is using the questionnaires.

Managers and users of ERP systems were personally interviewed, with the use of a structured questionnaire divided in 4 sections: Materials planning, Capacity planning, Materials management, Shop-floor control. All questions were taken from relevant literature hypotheses, and were presented using the Likert scale from 1 (totally disagree) to 5 (totally agree). Results of the test the perceptions of managers concerning benefits of ERP implementation differ tow across sectors show that the value of the test is $\chi 2$ (3, N=24) = 8.277, $p = 0.033 < 0.05$ probability and $\chi 2$ (3, N=24) = 7.639, $p = 0.042 < 0.05$ probability. Also, the average value for the total of the 15 variables is 4.11 with a standard deviation of 0.88. Cronbach a value for the questions of Table 3 is 0.903 and the Kolmogorov-Smirnov test shows that answers do not follow normal distribution.

Furthermore, the values of the Spearman coefficient indicate that BI plays essential role on the creation of flexible manufacturing systems (FMS). In order to identify the relationship between the advantages yielded by the usage of business intelligence features as an enabler of ERP in FMS based on Tenhiala *et al*.' Model, various statistical tests were employed as the non-parametric test of Kruskal-Wallis, the Spearman correlation coefficient and the Kolmogorov–Smirnov non parametric test.

Therefore, this is the limitation of this research and we suggest to interested researchers to apply Tenhiala *et al*.' Model for various case studies in different organizations, separately.

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