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# DSC Index: Measuring the Digital Supply Chain Practice among the Higher Education Institutions Community in Least Developed Countries

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***Abstract* - The 4th Industrial Revolution, more commonly referred to as Industry 4.0, has brought about a wave of multifaceted changes across the industrial spectrum around the world, and it has triggered the digitalisation of supply chains and their management regardless of the type of organisation. With increasing interconnectivity through various sectors, digital supply chain (DSC) practices and intentions have also become integral to higher education institutions. As streamlined, automated administrative processes and virtual classes conducted through online platforms become the norm, digitalisation has been catalysed in the education sector. However, several sociocultural, economic, and psychographic factors influence the adaptation of new technologies, especially in developing countries such as Bangladesh. This study uses the composite index approach to determine the Index derived from the correlation between the factors and their impact on the DSC practices and intentions. The study indicates that Trust (T) is the primary influencer, along with Performance Expectancy (PE), closely followed by Facilitating Value (FV), Facilitating Conditions (FC), and Digital Literacy (DL).**

***Index Terms* – ICT practice, higher education institution, Index, digital literacy, supply chain**

## I. Introduction

Digitalisation is a crucial driver of the transformative changes brought about by the 4th Industrial Revolution, or Industry 4.0, evolving the practices of organisations through challenges and opportunities in both local and global contexts. Moreover, that no longer pertains to technologically dependent sectors like engineering or manufacturing. Digitalisation has networked itself onto even previously heavily manual sectors, from finance to retail to education. Today, whatever the type of organisation is, whether manufacturing or service, they need to connect all means of operations to enhance their productivity and interact in real-time to bring more accuracy to their decisions. The Digital Supply Chain (DSC) model introduces and combines new types of actors and roles, aligning with the essential elements and constructs of Industry 4.0. In their research work, [1] suggested that, in the upcoming days, research should concentrate more on investigating and exploring the impacts of Industry 4.0 on the operational structure and the organisations as a whole.

Even though the DSC is in its early stage and most of its potential is yet to be realised, it has undoubtedly brought rapid change and innovation in traditional supply chains [2]. The objective of the industrial revolution (i.e., Industry 4.0) is to develop and embed agile capabilities in organisations through digitalisation [3]. A company must realise that digitalising its core operations in the current era is mandatory for cost reduction and improved productivity. DSC mainly focuses on agility in service, automated, flexible and real-time data access, online communication, improved trust, and reduced service time [4]. The acceptance and adoption of digitalisation may vary from sector to sector, with distinct variances apparent between developed and developing countries. The temperament of these nations' sociocultural, economic, and psychographic aspects determines several factors influencing organisations' DSC practices.

Considering the entire blueprint of higher education institutions (HEIs) in the service sector as a DSC, it has come a long way from paperback books and chalkboards. Over the years, higher education has undergone significant changes, thanks to the accelerated triggers of technological advancements across sectors in developing countries. Nonetheless, the statistical analysis conducted by the International Telecommunications Union in the year 2020 in 104 countries revealed that among the Least Developed Countries (LDCs), only 38.3% of the youth population is online. Only 7.2% of LDC households have computers, and

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16.3% have Internet access [5]. Even though the mobile phone has reached 75% of the population in LDCs, only 33% subscribe to mobile broadband services. Affordability is one of the main challenges for LDCs [5]. It is evident that with such limited access to online platforms, HEIs in LDCs struggle to access digital tools and resources, eventually affecting the standard of education and their nations. According to UNESCO, about 30% of the illiterate population is concentrated in the LDCs [6]. They are not only suffering from low literacy but also digital literacy [7].

Therefore, this study has evaluated just that – the factors that influence the DSC practices in HEIs and their Index to determine which of them are the most to least influential in enabling the digitalisation of HEIs' supply chains. In detail, the paper examines the importance of factors that can be considered for general DSC practices for higher education in the LDCs. As the concept of a supply chain in academia, along with its digitalisation and practices, becomes more familiar, the emerging technologies that catalyse its changes only take effect upon their acceptance and adoption. Hence, factors like trust, performance, usability, infrastructure, and awareness are crucial to identifying the key to unlocking the full potential of digitalising supply chain in higher education so that it can map out the pathway to ensuring the advancement of academia through uncertain and disruptive phases of the global evolution.

### *A. Challenges of Practicing Digital Supply Chain in HEIs of Bangladesh*

While there have been notable advancements in recent years, affordability remains a significant hurdle for Least Developed Countries (LDCs) [8]. Many Higher Education Institutions (HEIs) in LDCs still grapple with limited access to online platforms, making it improbable that they possess the essential digital tools and resources. Consequently, there is a risk of delivering subpar education to their populations. The process of digital transformation does not occur in isolation; it necessitates substantial financial investment, the establishment of comprehensive national digital infrastructure, and fundamental physical resources such as electricity and internet connectivity. It is the collective effort of these essential digital components that promotes widespread adoption and innovation. However, the challenge is daunting, considering that nearly one billion people worldwide lack access to electricity, and less than a quarter of the population in lower-income countries lacks internet access [8]. In the context of LDCs, where remote and rural areas are predominant, traditional network infrastructure is often economically unviable due to the high costs. This cost disparity is primarily due to the absence of connectivity in these areas, which is roughly four times more expensive than in urban areas.

The hindrances to digitalization extend beyond academia and encompass the broader economy. Factors such as an unequal playing field for vendors, limited public sector involvement, costly internet connectivity, inadequate energy supply, logistical challenges, an underdeveloped financial technology industry, and weak regulatory and legal frameworks all contribute to the lag in digitalization, as emphasized by [8]. The development of a country's infrastructure, both physical and digital, is primarily shaped by government legislation and policies. Beyond legislative changes, development also demands significant investment in both "soft" and "hard" infrastructure, with a focus on areas such as trade facilitation, energy, information and communication technology (ICT), and transportation [9].

Bangladesh, being among the least developed nations, confronts a multitude of hurdles. These obstacles encompass a shortage of skilled workforce, an unstable economic climate, and inadequate infrastructure [8]. These circumstances present substantial barriers to the adoption of digital technology in Higher Education Institutions (HEIs). While digitalization has the potential to greatly improve the efficiency and effectiveness of HEIs, the precise measures required to facilitate this transformation are not yet comprehensively grasped or put into practice.

According to a recent census report, Bangladesh's population is 165,158,616 (165 million 58 thousand 616). Out of which, 10 (ten) per cent of the total population belongs to the 15-19 age group, 9 (nine) per cent are in the 20-24 group, and 8.71 per cent are in the 25-29 group. A significant chunk of the population is youth. On average, 2 million people annually join the workforce [10]. There are 157 universities in Bangladesh, where 12,30,198 students are enrolled [11]. Affordability, Poverty, Digital literacy, Physical infrastructure, insufficient logistical support, Infrastructure costs, and many other phenomena were identified as the drawbacks of digitisation in countries like Bangladesh, and eventually, they also impact higher education institutions [5][12][13][14]. Data presented in previous sections, like the Digital Adoption Index (DAI), ICT Development Index (IDI) and Digital Readiness Score 2019, also reflect this issue. Moreover, the recent crisis of the COVID-19 pandemic seemed to have an impact on the usage of ICT-related technologies [15][16]. Hence, the scope of this study is narrowed down to the higher education institutes of Bangladesh.

## II. Literature Review

The entire educational system, ranging from overall administration to educational management, and even the pedagogical systems, has undergone a comprehensive transformation. This transformation has evolved from manual to analog and, ultimately, to a digital format. All the essential functions needed for the operation of Higher Education Institutions (HEIs), such as human resource management, financial accounting, marketing, and customer service, as well as the academic aspects like handling student applications, registration, scheduling teaching assignments, and grading, have been converted into efficient digital processes. These processes are now easily accessible and operable through online platforms [17]. Research indicates that similar to manufacturing processes, the education system experiences inefficiencies, often referred to as 'wastes,' which can be eliminated by transitioning to a digital academic supply chain. This transition is based on the 'lean thinking model' pioneered by Taiichi Ohno,

the Chief Engineer of the Toyota Production System. When this underlying principle is applied in classrooms, it has been demonstrated as effective in creating what are known as 'agile classrooms.' This same approach holds significant promise for optimizing digital academic supply chain management as well [18]. Existing research on DSC practices in HEIs has predominantly focused on developed countries, offering models and frameworks that may not be entirely applicable or effective in the context of least-developed countries [16][18]. The differences in the economic, social, and infrastructural conditions between these countries suggest a more flexible and adaptable DSC model considering the unique circumstances and limitations of least-developed countries like Bangladesh. In their study, [19] found that Bangladesh's citizens struggle to avail themselves of ICT-aided services due to their low digital literacy. A similar observation was also found in other studies where digital literacy was identified as a crucial contributor to ICT-enabled services. Adequate digital literacy aids widespread access to e-health services [21][22][23]. The study by [24], in his exploratory research on the National ICT Policy of Bangladesh, published in 2015, identified that although the policy focuses mainly on infrastructural development across the country by making rapid ICT network expansion and services, it lacks sufficient detail on its realisation. There is hardly any action plan towards its goal of affordable accessibility of ICT infrastructure, particularly in rural areas of Bangladesh. It is essential to provide specific guidelines on how communities will overcome socio-economic challenges to access ICT resources and contribute to increasing digital literacy. Even though the Bangladesh government has established a task force for digitising education nationally, accessible guidelines and precise mechanisms are essential to ensure its actual impact. In Bangladesh, there is an awareness of digitisation and the need for augmenting education quality, equity, and efficiency at the national level. However, low digital literacy has constrained realising this awareness into reality [25]. Research also shows that in Bangladesh, digital literacy can contribute significantly to bridging the digital divide [26].

One of the most comprehensive theories related to technology acceptance is the Unified Theory of Acceptance and Use of Technology (UTAUT). The UTAUT was established initially by Viswanath Venkatesh, Michael G. Morris, Gordon B. Davis and Fred D. Davis [27], correlated user intentions and acceptance of information technology and the subsequent usage behaviour. The initial idea was built on four fundamental constructs: performance expectancy, effort expectancy, social influence, and facilitating conditions. Consolidated through a mix of previously established relevant theories of information technology and user behaviour, UTAUT quickly gained validation in multiple fields for its cohesive application across the spectrum, and another three additional buildings have been incorporated into UTAUT: hedonic encouragement, quality worth and habit [28][29]. The model is then known as UTAUT2, and the factors used in this study are selected based on the UTAUT2 Model.

Based on the literature review, the conceptual framework for this research is designed and illustrated in Fig. 1. This conceptual framework combines the underpinning theory – UTAUT2, in alignment with the extracted attributes, and it focuses on the stakeholders, as mentioned in the supply chain studies conducted on HEIs in Bangladesh. The framework also includes a new attribute called Digital Literacy that was identified as a critical element for the stakeholders of LDCs, as evident in the relevant literature.

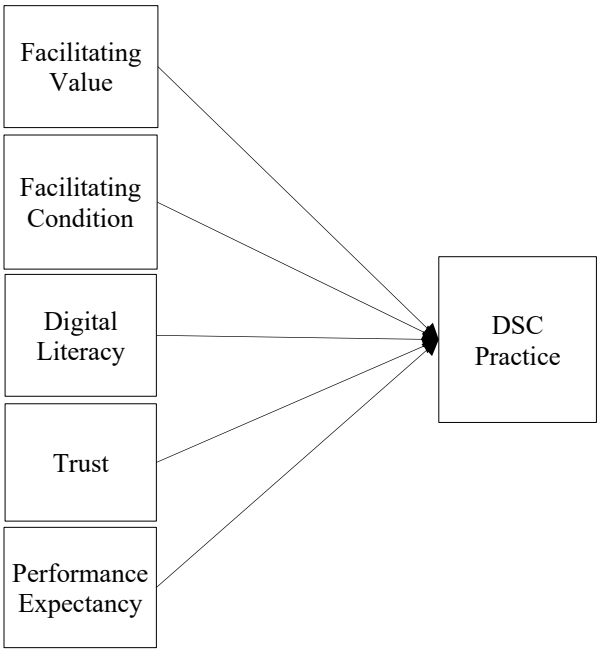


Fig. 1. Conceptual Framework

## III. METHODOLOGY

The Index has been developed based on the opinion of 241 stakeholders of HEIs community in Bangladesh (i.e., students, teachers and administrators) located in rural and urban areas via a questionnaire survey, which has been selected based on the simple random sampling technique. From the survey, they were asked to rate their level of agreement regarding their opinion about the influence of the five factors (i.e., Trust (T), Performance Expectancy (PE), Facilitating Value (FV), Facilitating Conditions (FC), and Digital Literacy (DL)) on their DSC practice with a seven-digit numerical scale ranging from 'strongly agree' to 'strongly disagree'. The items of questions asked in the questionnaire are provided in Appendix A. In this study, a composite index approach has been adopted where the five factors are considered as the variables to determine the Index derived from the correlation between these factors and their impact on stakeholders' DSC practices in Bangladesh's HEIs.

The development of an Index has three steps: data standardisation, weight determination, and index development. In this case, for step 1, the data was standardised by using the max-min data standardisation technique; for step 2, the

weightages for each factor were computed by using the standard deviation objective weighting technique, and for step 3, a composite index of multiple criteria was adopted to develop the Index [30]. A detailed explanation of the Index development is the following.

### A. Data Standardisation

Firstly, the data from the questionnaire survey has been standardised to alter the variance of the factors before the Index can be developed. To calculate the standardise values, this study used the maximum and minimum or min-max values approach where the standardised value is denoted by $z_{ij}$ and the formulation of the standardised data is given by

$$z_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \quad (1)$$

In this formula, $x_{ij}$ is generally a value of the performance of evaluating the elements for the alternative $i$ to factors $j$. This approach is suitable for the data collected in this study as compared to the other approaches (e.g., optimum value and normalisation value approaches) since it is capable of comparing the values that have been measured using different units of measurement [31], whereby both of the values (i.e., minimum and maximum) are taken into account, simultaneously.

### B. Weight Determination

Next, the weights of the factors are calculated by taking the correlation size into account, where the correlation size is vital in the weighting process when significant correlations exist between the factors [30]. The factors' weights are proportional to the correlation, corresponding to the mutual relevance of each factor's weight [32], whereby the correlation coefficient's value can affect the factors' value. If the value of the correlation coefficient is increased, then the value of the weight is also higher [30]. The formula used to compute the weight for the factor is the following:

$$w_j = \frac{r_j}{\sum r_l} \quad (2)$$

where $w_j$ is the weight of the $j$ factor and the standard value, $r_{ij}$ is the correlation coefficient between the $i$-th and $j$-th factors.

### C. Index Development

Finally, the Index is developed using the composite Index of multiple criteria approach. This approach is commonly used because it is simple, straightforward and accurate in examining the existence of multiple [30]. Besides, this approach is also able to integrate all the information of the criteria into a lucid format [33][34] (Singh, Murty, Gupta & Dikshit, 2007; Booysen, 2002), where a single comparable index is produced from the evaluation of multiple aspects [33]. It involves combining a set of values into a single value [35]. In this study, the linear combination method is used to determine the ranking of preferences. The composite score for option $i$ is equal to:

$$y_i = w_1 z_{i1} + w_2 z_{i2} + \cdots + w_k z_{ik} \quad (3)$$

From the given formula, $w_i$ is the weight of the factors produced as explained in the previous section, and $z_{ij}$ is the value of the factors after the standardisation process. From the score $y_i$, the ranking of preferences of the factors that can present the general practice for DSC for higher education in Bangladesh is determined. In other words, the Index measures whether the HEI community in Bangladesh has practised the digital supply chain or vice versa.

## IV. Results and Discussions

The discussion of findings includes the correlation test results, weights computation and indices.

### A. Correlation Test

The results of the correlation test among the five factors (i.e., Trust (T), Performance Expectancy (PE), Facilitating Value (FV), Facilitating Conditions (FC), and Digital Literacy (DL)) that can present in the Digital Supply Chain (DSC) practices for HEIs in Bangladesh are shown in TABLE I. From TABLE I, it shows that all factors are strongly correlated since the correlation values lie between 0.5 and 1.

TABLE I
The Correlation Values Among The Factors

| Variable | FV | FC | DL | T | PE |
|---|---|---|---|---|---|
| FV | 1.0000 | 0.6985 | 0.4948 | 0.6895 | 0.6371 |
| FC | 0.6985 | 1.0000 | 0.5243 | 0.6984 | 0.6214 |
| DL | 0.4948 | 0.5243 | 1.0000 | 0.5390 | 0.5271 |
| T | 0.6895 | 0.6984 | 0.5390 | 1.0000 | 0.7219 |
| PE | 0.6371 | 0.6214 | 0.5271 | 0.7219 | 1.0000 |

Since all the factors have a positive correlation, they have been included in the weighting process.

### B. Weight Values

The result of the weight for the factors is tabulated in TABLE II. The weighted values of the factors were ranked to identify the criteria that highly influence the DSC practices in Bangladesh HEIs. From TABLE II, Trust (T) is in the first rank with the weightage value, $w_j = 0.2153$, followed by Facilitating Condition (FC) ($w_j = 0.2066$), Facilitating Value (FV) ($w_j = 0.2048$), Performance Expectancy (PE) ($w_j = 0.2038$), and lastly is Digital Literacy (DL) ($w_j = 0.1695$). Based on the ranking of the factors, Trust is the most crucial factor affecting the digital supply chain practice among Bangladesh's HEIs community. Trust becomes especially relevant in digital technologies, where data security and privacy often emerge as significant concerns [36][37]. The facilities' condition and value then follow it. It implies that the number of Bangladesh HEI communities involved in digital supply chain practice would increase if facilities enable them to use digital technologies [38][39] and they understand the benefits of using the digital platform in daily activities [40][41].

TABLE II
THE WEIGHTAGE OF THE FACTORS

| Factors | Weight, *wj* | Rank |
|---|---|---|
| T | 0.2153 | 1 |
| FC | 0.2066 | 2 |
| FV | 0.2048 | 3 |
| PE | 0.2038 | 4 |
| DL | 0.1695 | 5 |

The weighted values of the factors were also ranked according to the location of the respondents, tabulated in TABLE III. Overall, the respondents from rural and urban areas perceived Trust as the most critical factor among the five factors. Prior research conducted by [42] and [43] revealed that trust is an influencing factor for adopting digitisation. However, the importance of factors related to the digital facility according to its condition, value and performance differ between urban and rural areas. Urban communities perceived that the benefits of using the digital facility were more important than the facility's condition, while rural communities perceived that the facility's condition was more important than the benefits of using the digital facility. It is well understood that urban areas are better facilitated than rural areas. Researchers also found that for rural communities, value [44], facilitating conditions [45][46], and performance expectations [47][48] significantly and positively impact users' adoption of technology.

TABLE III
THE WEIGHTAGE OF THE FACTORS IN INDIVIDUAL AREAS

| Factor/ Area | Weighted value, *wj* | Rank |
|---|---|---|
| | T | |
| Urban | 0.2188 | 1 |
| Rural | 0.2160 | 1 |
| | FV | |
| Urban | 0.2047 | 2 |
| Rural | 0.2043 | 3 |
| | PE | |
| Urban | 0.2061 | 3 |
| Rural | 0.2042 | 4 |
| | FC | |
| Urban | 0.1974 | 4 |
| Rural | 0.2118 | 2 |
| | DL | |
| Urban | 0.1702 | 5 |
| Rural | 0.1638 | 5 |

### *C. The Index*

With the weighted value, the Index of DSC practice was developed for each respondent using the index development formula. After calculation, the respondents were sorted with the Index's value from high to low. Fig. 2 compares respondents' strata between urban and rural areas of the first 50 respondents and the last 50 respondents according to the Index sequenced.

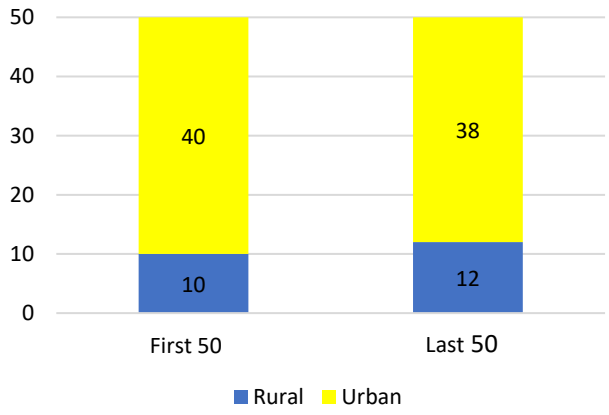


Fig. 2. Respondents' strata between urban and rural areas of the first 50 respondents and the last 50 respondents according to the Index sequenced

In the first-ranked 50 respondents' group, the urban community comprised the most considerable portion, with 40 respondents out of the two strata. It indicated that urban communities were more active in digital supply chain practice than rural communities. In the other group of the last-ranked 50 respondents, the urban community occupied the most prominent portion with 38 respondents. It implied that urban communities also have less practice in digital supply chains than rural communities [49]. A study on m-banking adoption in Indonesia revealed that the urban millennial generation had a more personal orientation while adopting digitalisation [50], revealing that the urban community has their own preference when adopting digital technology. In summary, the Index of digital supply chain practice has been successfully developed, whereby urban communities comprise the more significant portion of the HEIs' stakeholder's community in Bangladesh who are actively involved in using digital platforms in their daily activities.

## V. CONCLUSION

In conclusion, this study has delved into the intricate realm of digital supply chain (DSC) practices within the HEIs of least developed countries (LDCs), exemplified by Bangladesh. Amidst the surge of Industry 4.0, which has spurred the digitalisation of supply chains across various sectors, this research has spotlighted the critical role of trust, performance expectancy, facilitating value, facilitating conditions, and digital literacy in shaping DSC practices. The study's primary objective was to unravel the factors influencing DSC practices and their cumulative impact on the digital supply chain index. Among these, trust emerged as the linchpin, followed by performance expectancy, facilitating value, facilitating conditions, and digital literacy. These factors collectively drive the integration of DSC practices within HEIs. This research

holds significance in both practical and theoretical realms, offering insights for HEIs navigating the challenges of digital transformation. It underscores the crucial need to foster trust, enhance performance expectancy, bolster facilitating conditions, and promote digital literacy to harness DSC's potential in higher education effectively.

Furthermore, the findings reflect nuanced perceptions between urban and rural communities, emphasising the importance of benefits for urban areas and the condition of facilities for rural regions. These disparities underscore the imperative of equitable access and infrastructure development. As HEIs grapple with the evolving landscape of education, this study provides a strategic roadmap for leveraging DSC practices. By addressing the highlighted factors, HEIs can navigate the dynamic terrain of Industry 4.0, fostering innovation and propelling education into a digitally empowered future.

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**Appendix A: Factors and Items**

| | |
|---|---|
| **Facilitating Value (FV)** | |
| 1 | Digital tools, networking and ICT infrastructure in my University are reasonably priced. |
| 2 | At the current price, digital tools, networking and ICT infrastructure in my University provides excellent value. |
| 3 | Digital Supply Chain is capable to provide a better facility with a minimum cost incurring to the users in my University |
| 4 | The value of Digital Supply Chain in my University worth its price. |
| **Facilitating Condition (FC)** | |
| 1 | I have the necessary resources to use digital platform in my university |
| 2 | I have the necessary knowledge to use digital platform in my university |
| 3 | Digital tools, networking and ICT infrastructure in my University is compatible with other personal technologies I use. |
| 4 | I can get help from others when I have difficulties using digital tools, networking and ICT infrastructure in my University |
| 5 | My University always update or change its digital tools, networking and ICT infrastructure with the latest version. |
| **Digital Literacy (DL)** | |
| 1 | I know how to solve my own ICT related technical problem |
| 2 | I can learn new digital technologies easily |
| 3 | I have the technical skill I need to use digital tools, networking and ICT infrastructure in my University for working (e.g.: online teaching-learning) that demonstrate my understanding of what I have learnt |
| 4 | I am familiar with issues related to web-based activities (e.g.: plagiarism, cyber safety) |
| 5 | I frequently obtain help with tasks from my friends over the Internet (e.g., through Facebook, Skype, Blogs) |
| **Trust (T)** | |
| 1 | I trust the implementation of Digital Supply Chain in my University. |
| 2 | I feel assured that legal and technological structures are implemented adequately in my University to protect me from problems in Digital Supply Chain practices |
| 3 | I have doubt on the truthfulness of Digital Supply Chain in my university. |
| 4 | Even if not monitored, I would trust the implementation of Digital Supply Chain practice to do the job correctly in my university |
| 5 | The Digital Supply Chain can fulfill my required tasks relevant to University management. |
| **Performance Expectancy (PE)** | |
| 1 | Digital Supply Chain increases the completion of the work tasks that are important to me. |
| 2 | Digital Supply Chain helps me accomplish work tasks more quickly. |
| 3 | Digital Supply Chain increases my work productivity. |
| 4. | Digital Supply Chain information received from other parties to complete my work tasks is always fast, accurate and informative. |
| 5. | I find Digital Supply Chain useful to enhance my University's performance. |
| **Digital Supply Chain Practice (DSC Practice)** | |
| 1 | I find Digital Supply Chain useful in my job. |
| 2 | Digital Supply Chain enables me to accomplish my job tasks more quickly. |
| 3 | Digital Supply Chain increases my job productivity. |
| 4 | In my institution, Digital Supply Chain enables me to receive fast, accurate and informative instruction/information about my job. |
| 5 | Digital Supply Chain increases my creativity skills in doing my job |