Exploring omnichannel and network design in omni environment

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Abstract: Modern day supply chain has gone through many changes in order to satisfy the ever increasing needs of customers. One of such change is origin of omnichannel in supply chain which believes in not only satisfying customer’s needs but also delighting them. Implementation of omnichannel in practice comes with lots of challenges. These challenges are summarized as major research areas in omnichannel and being explored in this paper through literature. Further, distribution system in omnichannel demands flexibility in distribution which results in restructuring and reconfiguring the practices of traditional supply chain. For this purpose, a mathematical model has been developed under omni environment which provides the facility of flexible distribution for customers. This proposed model is bi-objective in nature which considers sustainability along with minimization of total supply chain cost. To check the feasibility of the proposed model, numerical illustrations have been carried out for two different scenarios. In first scenario, the proposed model is solved for single product and single time period while in second scenario similar conditions are considered for conventional Supply Chain Network (SCN) and is being compared with proposed model. The proposed MILP model is coded in GAMS and solved using CPLEX solver. The results obtained indicate that proposed model possess superiority over conventional SCN in many aspects. The findings from the proposed model ensure that customers are free to avail product and services from their desired channel as per their choice.

Keywords: distribution network; future research calls; omnichannel; retailing; supply chain

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PUBLIC INTEREST STATEMENT
Due to ever increasing needs of customers, the traditional supply chain faces many problems. Customers wish to have information about products and services well in advance and get them as per their choice of channel, convenience and reach. This urge of customer is fulfilled by origin of omnichannel which believes in making customer shopping experience as seamless as possible. In this work we explore the major research areas in omnichannel to make its implementation possible. Further a mathematical model is developed in order to facilitate the flexible distribution under omnichannel environment.
1. Introduction

Today’s market is ruled by consumer’s wish since ever increasing competition has made the consumer a king. Consumer’s wish to get products and services in way they want with respect to their choice of channel, convenience, place and benefits which has led to the concept of omnichannel. Rigby (2011) was the person who coined this term in literature. In simple terms Omnichannel (OC) is the integration of all available channels for making customer shopping experience seamless (Brynjolfsson, Hu, & Rahman, 2013; Rigby, 2011). These channels could be physical stores, websites, kiosks, direct mail and catalogues, social media, call centers, mobile devices, televisions, gaming consoles, home services, networked appliances and more (Rigby, 2011). Broadly these channels can be categorized in Figure 1.

Omnichannel has revolutionized the way we do the business. Omnichannel is not about buying things online or offline, it’s about bringing customers back to the stores. Even now-a-days customer do share theirs information with retailers, which is helping the growth of omnichannel by learning customer shopping behaviour and providing customer what they wish. Happiest Mind (a US based firm) in 2015 reported that 47% of customers share their valuable information with the retailer if they get good offers from them. Bardwell (2012) stated that an omnichannel shopper eventually spends 3.5 times more on shopping than single channel shoppers due to easy access to mobiles, tablets and internet. Availability of useful information regarding products on dot com and convenience of getting them as per customer’s wish is the major factor responsible for growth of omnichannel. Also the use of Information Technology (IT) has emerged as key enabler for omnichannel implementation.

Many a times omnichannel is confused with multi-channel and cross channel and used interchangeably and not with clear distinction (Beck & Rygl, 2015). Each of these channels has certain advantage but no single channel is best suited in all situations. Chopra (2016) has given the strength and weakness of these channels and also talked about how these channel can be integrated so that omnichannel becomes the future of retailing. Further, Verhoef, Kannan, and Inman (2015) identified that industries as well as researchers are moving towards omnichannel retailing, where world will soon become showrooms without walls and boundaries between online and physical retailing will vanish (Boird & Kilcourse, 2011; Beck & Rygl, 2015; Brynjolfsson et al., 2013; Rigby, 2011). Moreover, omnichannel is more customer-oriented and customer-focused (Peltola, Vainio, & Nieminen, 2015).

Lazaris and Vrechopoulos (2014) reviewed the transformation of multi-channel retailing to OC retailing and came out with research gap to be analysed in OC retailing for its improvement. Tetteh and Xu (2014) talked about single, dual and omnichannel distribution network and stated the challenges faced by each of these channels. They also found out that having an efficient distribution
channel leads to product growth and add to organization’s profit. Hence efficient network design is must to leverage the benefits of omnichannel.

Network design is one of the key aspects for smooth functioning of any supply chain. Further Supply Chain Network (SCN) consists of upstream supply chain and downstream supply chain. Upstream supply chain starts with supplying raw material from suppliers to manufacturers. While downstream supply chain is concerned with design of distribution network to deliver products to end user. Lots of researches have been carried in the area of network design to solve different supply chain issues (Farahani, Rezapour, Drezner, & Fallah 2014; Melo, Nickel, & Saldanha-da-Gama 2009). Application of network design could be found to handle different supply chain issues like risk mitigation (see Singh, Mishra, Jain, & Khurana, 2012), uncertainty in supply chain (see Pishvaee, Rabbani, & Torabi, 2011; Singh, Jain, & Mishra, 2013) etc. Further with overwhelming response to implement omnichannel in real practice, new issues have arisen. This is due to fact that omnichannel customer is believed to enjoy flexible distribution which tends to alter downstream distribution network design. Due to flexibility in distribution, the level of complexity increases in designing distribution network. Different morphology of distribution can be found in Chopra et al. (2007).

The goal of omnichannel would not be possible in real practice without having an efficient and flexible distribution network. Thus there is a need to design flexible distribution network for successful implementation of omnichannel strategies. The purpose of this study has two main objectives. Firstly omnichannel need to be explored to make the concept of omnichannel possible in real practice. For this purpose an effort has been made to summarize research areas into different domain through this article. The second objective is to design a flexible distribution network so as to fulfil the requirement of omnichannel distribution. Through the proposed model, customers are free to access the products with respect to their desired channel.

This section deals with introduction about omnichannel and need to develop network design for omni environment. Section 2 explores the major research areas in omnichannel. A mathematical model is developed for designing flexible distribution in Section 3. Section 4 illustrates numerical cases to validate the proposed network model under omni environment. Finally Section 5 gives the concluding remarks of this study.

2. Exploring omnichannel

The omnichannel not only comes with adding extra-ordinary value, profit, reputation to organization but with many problems involving risk too, which should be tackled well in advance. The famous firm Deloitte released a document in 2015 concerning these issues and suggested that organizations should have Supply Chain Management (SCM) risk program to tackle these concerns. Many a time, omnichannel is having so strong impact that even it changes the whole supply chain network design of the organizations. For this purpose out of five retailers, four think that their SC does not suit to the requirement of OC retailing and thus needs re-engineering to structure their physical flows of products (EY, 2015). Though omnichannel has so much advantage and have potential to become future of retailing. But implementation of omnichannel in supply chain is big challenge which is current major research area in OC. Further, a summary of challenges and opportunities in the area of omnichannel is categorized as follows:

- Design of flexible distribution network.
- Harnessing the power of information technology.
- Developing omnichannel strategies for rural areas.

2.1. Design of flexible distribution network

Omnichannel distribution network not only delivers products to the customers but also take care of returned products giving rise to the concept of forward and backward omnichannel distribution network (Hubner, 2016). So this can be summarized as following:
(1) Forward distribution network consisting of location from where the product is dispatched up to where it is received i.e. end user place.

(2) Backward distribution network is consisting of collecting products from customers and back to retailer again.

Designing omnichannel distribution with forward as well as backward comes with many challenges since a customer in omnichannel believes to enjoy a convenient way to return the product to retailer in spite any volume of returns (Handfield, Straube, Pfohl, & Wieland, 2014). For this reason, organization must have facility to return the product in store as well as pick from home involving least paper work and convenience for customer. This will need a proper integration of different channels which is a challenging task having a lot of factors having probabilistic nature (Bell, Gallino, & Moreno, 2013; Frazer & Stiehler, 2014; Gallino & Moreno, 2014; Gallino, Moreno, & Stamatopoulos, 2017). However, leverage of Information Technology has helped much in integrating these channels and moving to a new era of OC retailing (Piotrowicz & Cuthbertson, 2014). One of the important outcomes of this integration is concept of “Buying online and picking up in-store” (BOPS) which is gaining much of sales now-a-days (Gallino & Moreno, 2014). BOPS is becoming win-win situation for both customer as well as organization since supply chain cost is reduced due to reduced cost of transportation. Neslin et al. (2014) proposed a framework for consumer decision for what to buy and where based on channel brand and choice of channel. This framework can be helpful in developing omnichannel strategy for OC retailing. Kuźmicz (2015) has talked about how to do benchmarking in omnichannel logistics and has used flexible delivery as a proxy for benchmarking in OC.

Xie, Jiang, Zhao, and Hong (2014) made the earliest contribution in the field of planning and allocating the product in multichannel distribution which has strong connection in developing omnichannel distribution network. They developed a two stage mathematical model for capacity planning and allocating a manufacture in SC who delivers products to customer independently as well as via service provider. Zhang, Lee, Wu, and Choy (2016) designed a multiple distribution channel considering the sustainability scenario, reducing SC cost over all and showed that omnichannel emergence has led to better benefits for customer by making available the products and services directly to them. The proposed model was solved using Ant Bee Colony (ABC) algorithm and compared its results with solution by GA. They found out that ABC results in better solution than GA for this problem.

Other prominent issues which could be raised while designing flexible distribution system for omnichannel environment could be (a) type of distribution network configuration is to be used for fulfilment (b) location and capacities of new facilities (c) design of responsive backward distribution network for returned products (d) incorporation of sustainability in designing multiple distribution channels supply chain network (MDCSCN) (e) which facilities should be used to fulfil orders from which customers? (f) how many lockers need to establish for a particular distribution network? (g) should these lockers is to be shared or not? If lockers to be shared, what kind of game theory (Nash or Stackelberg games) to be considered for cooperation? whether this will affect organization’s competitive strategy? If yes, what is solution? (h) right strategy for BOPS for e.g. pricing, profit trade-off, return etc.? (i) decisions regarding addition and deletion of different channels and right mode of product and services mix for retailers. (j) decisions regarding the inventory balancing, pooling and promotions in omnichannel retailing and new transportation strategy effective in terms of cost, time, capacity and delivery parameters.

2.2. Harnessing the power of Information Technology

Implementation of omnichannel strategies needs availability of real time information to all stakeholders of supply chain. This helps in proper integration and coordination between different channel for e.g. use of big data analytics etc. Further these kinds of applications for successful implementation of omnichannel strategies can be found in (Gallino et al., 2017). Ericsson, Farah, Vermeiren, and Buckalew (2012) from Cisco ISBG applied concept of omnichannel in banking sector and found to be
win-win situation for both organization as well as customer since customer were offered real time information and can use the desired channel as per their wish. They also stated it to be future of banking too which is clear indication that the world will be moving to virtual banking soon. Consumer shopping experience has also been improved a lot with the use of Application program interfaces (APIs). APIs help in making the activities of shopping more convenient and thus attract more masses to avail the services. However use of IT could be further harnessed for more benefits in form of following research opportunities: (a) use of Application program interfaces (APIs) to enhance omnichannel retail atmosphere (b) data mining technique to harness maximum valuable data (c) capturing real time useful information to retailers as well as consumers (d) designing advanced security layer free from all kind of threats i.e. internal as well as external threats (e) scenarios management i.e. possibility of cloud solving and implementation (f) strategy for order management in omnichannel environment (g) customer relationship management (CRM) by managing customer database to serve customer effectively, protecting customer data and ethical use for customer data for marketing (h) user friendly apps to navigate and track the desired product (i) seamless integration of different aspects (For e.g. Social media, CRM, call center, websites, mobile applications and instore technologies) (j) use of data analytics and data science to unify data both offline and online (k) strategy to be used in the case of dot com failure.

2.3. Developing the omnichannel strategies for rural areas

The concept of omnichannel would be more successful if it benefits more masses including rural people. Since basic infrastructure is not adequate in rural areas which makes it difficult to implement at remote places. Hence omnichannel strategies need to be altered in order to implement. For e.g. setting up a kiosk where people could visit and place their orders, while provision of delivery points for receiving products. Providing omnichannel experience to rural consumers not only benefit rural consumer but also to retailers since government in most of the countries are very keen to uplifting the life standard of rural people and provides incentives to companies helping in developing rural areas. Digital India is one of such initiatives by Government of India which would definitely help in successful implementation of omnichannel strategies. Rey-Moreno and Medina-Molina (2016) studied the current scenarios of e-government development of public services in Spain. They stated that use of omnichannel strategies can increase the citizen’s rate for the use of public services in Spain through e-government. Some of research opportunities to develop omnichannel strategies includes: (a) developing omnichannel framework for rural areas (b) establishing suitable cooperation policy among retailers to integrate different channels (c) provision of different financing schemes for rural customers (d) use of government subsidies to develop omnichannel approach in rural areas (e) developing information system through networking in rural areas.

In this section possible areas of research in omnichannel have been explored. Basically, omnichannel has brought revolution due to increased customer satisfaction through flexible distribution. So there is need to incorporate flexibility in distribution systems in existing conventional distribution network. This would result in restructuring and reconfiguring the existing conventional distribution network. Further, incorporation of such changes in existing conventional distribution network is a challenging task due complexity in solving and difficulty in handling the different constraints associated with these models. To encounter these challenges, a mathematical model is proposed for flexible distribution under omnichannel environment in the next section.

3. Mathematical formulation

In this section a mathematical MILP model is formulated for flexible distribution under omnichannel environment, which take care determining facilities location and optimum flow of product between these facilities. Figure 2 shows the detail insight of the proposed Multiple Channel Distribution Supply Chain Network (MCDSCN) model, in which manufacturers, Central DCs and Regional DCs are directly serving to the customers. The proposed model is flexible in nature since any of these facilities could entertain customer as per their wish for choice of channels. Information Technology could play as key pillar for this model as it can integrate all channels and provide the perfect information at right
place for necessary action. Supplier in this work is not considered since they don't supply goods and services directly to the customer. However, cost of transportation is considered between suppliers and manufacturers. The assumptions considered for designing our MCDSCN problem are as follows:

1. Demands of each customer have to be met.
2. Each customer can get their product and services from any facility.
3. The capacity and location of suppliers, manufacturers, central & regional DC is known well in advance.
4. There is no intra-echelons flow of products between facilities.
5. The model is designed only for a single product.

The notations and symbols used in designing MCDSCN are as follows:

| Notations | Description |
|-----------|-------------|
| $a, a_i$ | Set corresponding suppliers, set of manufacturers, set of central & regional DCs and set of customers |
| $b, b_i$ | The indexing of supplier and their capacity |
| $b, b_i$ | Manufacturer's index, capacity, environmental influences and fixed cost |
| $c, c_i$ | Central DC's index, capacity, environmental influences and fixed cost |
| $c, c_i$ | Regional DC's index, capacity, environmental influences and fixed cost |
| $g, g_i$ | Customer index and demands |
| $h, h_i$ | Corresponding distance between two facilities |
| $c, c_i$ | Unit cost of transportation between two facilities |
| $e, e_i$ | Unit environment influence produced between two facilities |
3.1. Decision variables

| Decision Variables | Their description |
|--------------------|-------------------|
| $y_b, y_c, y_g$    | Binary variables used for showing open/close status of manufacturer, central and regional DCs |
| $z_{ab}, z_{bc}, z_{cg}, z_{gh}$ | Integer variables used for showing quantity of product flow from supplier to manufacturer, manufacturer to central DC, central to regional DC and finally from regional DC to customer |
| $z_{bh}, z_{ch}$ | Integer Variables showing quantity of product flow to customer directly from manufacturers and central DCs respectively |

In this research work sustainable objective i.e. minimizing total supply chain cost and reducing carbon content is introduced in the proposed MCDSCN model. The first objective is minimizing supply chain cost which comprises fixed cost of the facility and transportation cost between the concerned facilities. All the other related cost like production cost, procurement cost etc. has been not considered here since they are more or somewhat remains constant. Mathematically supply chain cost can be written as follows:

$$
\text{Min } f_1 = \sum_{b \in B} b_{ye} y_b + \sum_{c \in C} c_{ye} y_c + \sum_{g \in G} g_{ye} y_g + \sum_{a \in A} \sum_{b \in B} c_{ab} z_{ab} + \sum_{c \in C} \sum_{g \in G} c_{bc} z_{bc} + \sum_{c \in C} \sum_{g \in G} c_{cg} z_{cg} + \sum_{g \in G} c_{gh} z_{gh} + \sum_{b \in B} \sum_{h \in H} c_{bh} z_{bh} + \sum_{c \in C} \sum_{h \in H} c_{ch} z_{ch}$$  \hspace{1cm} (1)

The second objective is for minimizing carbon content. The carbon content is produced from operating facilities and corresponding vehicle transportation between facilities for the purpose of product flow.

$$
\text{Min } f_2 = \sum_{b \in B} e_{ye} y_b + \sum_{c \in C} e_{ye} y_c + \sum_{g \in G} e_{ye} y_g + \sum_{a \in A} \sum_{b \in B} e_{ab} z_{ab} + \sum_{c \in C} \sum_{g \in G} e_{bc} z_{bc} + \sum_{c \in C} \sum_{g \in G} e_{cg} z_{cg} + \sum_{g \in G} e_{gh} z_{gh} + \sum_{b \in B} \sum_{h \in H} e_{bh} z_{bh} + \sum_{c \in C} \sum_{h \in H} e_{ch} z_{ch}$$  \hspace{1cm} (2)

These objectives are not free or unbounded rather they come with certain real world constraints. The constraint associated with this are as follows:

$$
\sum_{b \in B} z_{bh} + \sum_{c \in C} z_{bh} + \sum_{g \in G} z_{bh} = h_d$$  \hspace{1cm} (3)

$$
\sum_{h \in H} z_{gh} \times y_g < g_c$$  \hspace{1cm} (4)

$$
\sum_{h \in H} z_{ch} \times y_c + \sum_{g \in G} z_{cg} \times y_c < c_c$$  \hspace{1cm} (5)

$$
\sum_{h \in H} z_{bh} \times y_b + \sum_{c \in C} z_{bc} \times y_b + \sum_{g \in G} z_{bg} \times y_b < b_c$$  \hspace{1cm} (6)

$$
\sum_{b \in B} z_{ab} < a_c$$  \hspace{1cm} (7)

Constraint (3) ensures that customer demands are met. Different channel could have different demands. Constraints (4)–(7) make sure that product flow from any facility i.e. regional DCs, central DCs, manufacturer and suppliers do not exceed their respective capacities and flow constraint are logically followed. From above it is quite clear that this turns out to be MILP model. Further, commercial package GAMS using CPLEX solver was found suitable to handle such problem.
4. Numerical illustration

In this section a numerical is illustrated with a purpose of showing superiority of proposed MCDSCN model over conventional SCN. The location of suppliers, manufacturers, central DCs, regional DCs and customers is considered within a $200 \times 200$ in a coordinate scheme. For the problem considered, four suppliers, three manufacturer, four central DCs, four regional DCs and six customer zones are taken into account. Further the Euclidian Distance (ED) is considered between two points $(x, y)$ and $(x_1, y_1)$ as follows:

\[
\text{Euclidian Distance} = \sqrt{(x - x_1)^2 + (y - y_1)^2}
\]

The unit transportation cost is based on these distance, higher the distance higher will be unit transportation cost and vice versa. For our case study the unit transportation cost is taken as $0.1 \times \text{ED}$. However environmental effluents considered with transportation is directly proportional to distance travelled for product/services delivery to the customers and is denoted by $e_{ij} = \alpha x_d$ and here $\alpha$ is considered as 0.014. The unit transportation cost, unit environment effluents cost, and operating cost of facilities is given in Tables 1–6. The demand for various channels is also given in corresponding cost matrix table (Refer Tables 4–6). The capacities of different facilities are arranged in descending order from supplier to customer demands as mention in inequality 9.

\[
\sum_{a \in A} q_a > \sum_{b \in B} b_c > \sum_{c \in C} c_y > \sum_{g \in G} g_c > h_d
\]

Table 1. Unit transportation cost (TC) & environment effluents cost (EEC) from Supplier (S) to Manufacturer (M) and capacity of supplier

| Supplier | TC/EEC (M1) | TC/EEC (M2) | TC/EEC (M3) | Capacity |
|----------|-------------|-------------|-------------|----------|
| S1       | 14.84/2.07  | 20.08/2.81  | 12.84/1.79  | 4,000    |
| S2       | 5.78/0.8    | 16.33/2.28  | 15.54/2.17  | 5,000    |
| S3       | 10.68/1.5   | 3.84/0.53   | 11.2/1.56   | 4,500    |
| S4       | 5.82/0.81   | 16.35/2.28  | 13.92/1.95  | 6,000    |

Table 2. Unit transportation cost (TC) & environment effluents cost (EEC) from Manufacturer to central DC (CDC) and capacity of manufacturer

| Manufacturer | CDC 1 TC/EEC | CDC 2 TC/EEC | CDC 3 TC/EEC | CDC 4 TC/EEC | Capacity | FC1/FC2 |
|--------------|--------------|--------------|--------------|--------------|----------|---------|
| M1           | 2.62/0.36    | 13.38/1.87   | 6.67/0.93    | 17.33/2.42   | 5,000    | 5,400/600 |
| M2           | 9.15/1.28    | 20.63/2.88   | 17.31/2.43   | 14.25/2      | 4,000    | 5,000/400 |
| M3           | 7.56/1.05    | 14.29/2      | 15.07/2.1    | 7.58/1.06    | 6,000    | 5,800/700 |

Notes: FC1 = Fixed cost occurred due to operation of facility and FC2 = Fixed cost occurred due to incorporation of environment sustainability.

Table 3. Unit transportation cost (TC) & environment effluents cost (EEC) from central DC to regional DC (RDC) and capacity of central DC

| Central DC | RDC 1 TC/EEC | RDC 2 TC/EEC | RDC 3 TC/EEC | RDC 4 TC/EEC | Capacity | FC1/FC2 |
|------------|--------------|--------------|--------------|--------------|----------|---------|
| CDC 1      | 11.4/1.6     | 14.69/2.05   | 11.26/1.57   | 6.07/0.85    | 4,000    | 4,000/300 |
| CDC 2      | 2.12/0.29    | 2.3/0.35     | 9.51/1.33    | 13.36/1.87   | 3,000    | 3,500/200 |
| CDC 3      | 8.61/2       | 13.2/1.84    | 15.46/2.1    | 3.94/0.55    | 3,500    | 3,750/250 |
| CDC 4      | 17.02/2.38   | 16/2.24      | 6.72/0.94    | 20.39/2.85   | 3,500    | 3,750/250 |

Notes: FC1 = Fixed cost occurred due to operation of facility and FC2 = Fixed cost occurred due to incorporation of environment sustainability.
To solve this bi-objective, it is first converted into single objective by correspondingly adding unit transportation cost and unit environment effluents cost and similarly for the operating cost. Now this MCDSCN MILP model was programmed in GAMS using CPLEX solver running on a PC having a 2.5 GHz i5 processor with 3.78 usable RAM in a 64 bit Windows 10 platform. Two different scenarios were considered to show the utility of the proposed MCDSCN model in real world. In the first scenario, the MCDSCN model was solved for single product and single period while in second scenario, similar problem environment was considered for conventional SCN and results were compared.

### 4.1. Scenario 1: Analysis of proposed MCDSCN model for single period and single product

In this case the proposed MCDSCN model was solved for single product and single period. The total SC cost (i.e. objective 1) turns out to be 196,699 rupees while environment effluents cost (i.e. objective 2) was found to be 26,048.86 rupees (Refer Table 7). Also for this scenario only manufacturer 1 and manufacturer 2 were open while manufacturer 3 was closed (Refer Table 9). Similarly for Central DCs only CDC 1 and CDC 2 were open and rest were close while in the case of Regional DCs only RDC 3 and RDC 4 were open and other were closed (Refer Tables 10 and 11). Optimal flow of product between different facilities is shown in Tables 8–13.
4.2. Scenario 2: Analysis of conventional SCN and comparison of conventional SCN with proposed MCDSCN model

A similar scenario is considered for conventional SCN and results obtained are being compared with the proposed MCDSCN. In conventional SCN supplier supplies raw material to manufacturer where product are manufactured and sent to central DCs and then to regional DCs and finally reaches to customers from regional DCs. The schematic of conventional SCN is depicted in Figure 3.

With reference to Table 18, it is quite clear that MCDSCN possess superiority over conventional SCN in terms both sustainable objective i.e. minimizing total supply chain cost and reducing carbon content. For conventional SCN, the total SC cost (objective 1) incurred is 236,519 rupees while in the case of environment effluents it was 31,158.66 rupees. Similarly in the case of proposed MCDSCN model the total SC cost (objective 1) incurred is 196,699 rupees while in the case of environment effluents it was 26,048.86 rupees which is much lesser than cost incurred in conventional SCN. Also in the case of conventional SCN three Central DCs (1, 3 and 4) are open whereas in proposed MCDSCN only Central DCs (1 and 4) are able to handle all the product flow. Similarly in the case of Regional DCs for conventional SCN, Regional DCs (1, 3 and 4) are open whereas in proposed MCDSCN only Regional DCs (3 and 4) are able to handle the product flow. This shows that in the proposed MCDSCN, fewer numbers of DCs are required and these DCs need to carry lesser inventory as compared to that of conventional SCN. This not only saves the cost but also provide opportunities for organization to expand their

| Table 8. Optimal product flow between supplier and manufacturer for MCDSCN |
|-----------------|-----|-----|
|                | M1  | M2  | M3  |
| S1             |     |     |     |
| S2             |     | 5,000|     |
| S3             | 2,800|     |     |
| S4             |     |     |     |

| Table 9. Optimal product flow between manufacturer and central DC for MCDSCN |
|-----------------|-----|-----|-----|-----|
|                 | CDC 1| CDC 2| CDC 3| CDC 4|
| M1              | 4,000|     |     |     |
| M2              |     |     |     | 2,200|
| M3              |     |     |     |     |

| Table 10. Optimal product flow between central DC and regional DC for MCDSCN |
|-----------------|-----|-----|-----|-----|
|                 | RDC 1| RDC 2| RDC 3| RDC 4|
| CDC 1           |     |     | 300  | 2,500|
| CDC 2           |     |     |     |     |
| CDC 3           |     |     |     |     |
| CDC 4           |     |     |     | 2,200|

| Table 11. Optimal product flow between regional DC and demand points for MCDSCN |
|-----------------|-----|-----|-----|-----|-----|-----|
|                 | K1  | K2  | K3  | K4  | K5  | K6  |
| RDC 1           |     |     |     |     |     |     |
| RDC 2           |     |     |     |     |     |     |
| RDC 3           |     | 1,200|     | 800 |     | 500 |
| RDC 4           | 1,000| 1,000|     |     |     |     |
business. Further optimal flow of product between different facilities for conventional SCN is shown in Tables 14–17.

As shown in Table 18 it is clear that the proposed MCDSCN model has achieved significant saving than conventional SCN for both objectives. Further the customers have better convenience and reach to avail the product and services which increases customer satisfaction. Through this proposed model online giants can target more customers by providing products and services to customers as per customer’s choice of desired channel. The level of complexity in designing MCDSCN is much more than conventional SCN which could be seen from Figures 4 and 5.

**Table 12. Optimal product flow between manufacturer and demand points for MCDSCN**

|      | K1 | K2 | K3 | K4 | K5 | K6 |
|------|----|----|----|----|----|----|
| M1   |    |    | 500| 150| 250| 100|
| M2   | 300| 300|    |    |    |    |
| M3   |    |    |    |    |    |    |

**Table 13. Optimal product flow between central DC and demand points for MCDSCN**

|      | K1 | K2 | K3 | K4 | K5 | K6 |
|------|----|----|----|----|----|----|
| CDC 1| 100| 200| 200| 150| 150| 400|
| CDC 2|    |    |    |    |    |    |
| CDC 3|    |    |    |    |    |    |
| CDC 4|    |    |    |    |    |    |

**Table 14. Optimal product flow between supplier and manufacturer for SCN**

|      | M1 | M2 | M3 |
|------|----|----|----|
| S1   |    |    |    |
| S2   |    | 5,000|    |
| S3   |    | 2,800|    |
| S4   |    |    |    |

**Table 15. Optimal product flow between manufacturer and central DC for SCN**

|      | CDC 1 | CDC 2 | CDC 3 | CDC 4 |
|------|-------|-------|-------|-------|
| M1   | 4,000 |       | 1,000 |       |
| M2   | 2,800 |       |       |       |
| M3   |       |       |       |       |

**Table 16. Optimal product flow between central DC and regional DC for SCN**

|      | RDC 1 | RDC 2 | RDC 3 | RDC 4 |
|------|-------|-------|-------|-------|
| CDC 1| 1,300 | 200   | 2,500 |
| CDC 2| 1,000 |       |       |
| CDC 3| 2,800 |       |       |
| CDC 4|       |       |       |
Table 17. Optimal product flow between regional DC and demand points for SCN

|       | K1   | K2   | K3   | K4   | K5   | K6   |
|-------|------|------|------|------|------|------|
| RDC 1 |      |      |      | 1,200| 900  | 200  |
| RDC 2 |      |      |      |      |      |      |
| RDC 3 | 600  | 1,600|      |      | 800  |      |
| RDC 4 | 800  | 1,700|      |      |      |      |

Table 18. Comparison of saving between MCDSCN and SCN

| Network structure | Parameters | MCDSCN | Conventional SCN | Saving |
|-------------------|------------|--------|-----------------|--------|
|                   |            | Obj. 1 | Obj. 2          | Obj. 1 | Obj. 2 | Obj. 1 | Obj. 2 |        |
| 4 Supplier        | Data: Refer Tables 1–6 | 196,699 | 26,048.86       | 16.84  | 16.4% |
| 3 Manufacturer    | Results: Refer Tables 7–12 | 236,519 | 31,158.66       |        |        |
| 4 Central DCs     |            |        |                 |        |        |
| 4 Regional DCs and 6 Customers zones | Data: Refer Tables 1–4 | 196,699 | 26,048.86       | 16.84  | 16.4% |
|                   | Results: Refer Tables 13–16 | 236,519 | 31,158.66       |        |        |

Figure 3. A schematic of conventional SCN.
5. Conclusion
This paper focuses on two different objectives, first is to explore the major research areas under omnichannel while second is to develop a mathematical model for flexible distribution under omnichannel environment. The different domains of research areas explored and summarized into three different categories. These categories include designing flexible distribution system for omnichannel environment, harnessing the power of information technology and developing omnichannel strategy for rural areas.
Designing flexible distribution is a challenging task due to large complexity in solving and handling the different constraints associated with these models. Harnessing the power of information technology includes leveraging the use of IT to provide real-time information to all stakeholders of supply chain and to integrate the different echelons of supply chain. Developing omnichannel strategies for rural areas are also discussed in this article. There is lack of infrastructure and networking in rural areas. This is one of the main issues while developing omnichannel strategies for rural areas. Further, omnichannel has the potential to become future of retailing if above issues are considered while designing OC strategies of the organizations.

This article also proposes a mathematical model through which customers are free to access product and services as per their choice of channels i.e. either from manufacturers, central DCs or regional DCs. The proposed model is also useful for online giants to attract more customers and gain market share thus increasing the profit of the organizations by proper integration of different channels. Sustainable objectives i.e. minimizing SC cost and incorporating sustainability through reducing the carbon content by minimizing the travel distance of the product has been considered in the proposed MCDS SCN model. For showing the adoptability of proposed MCDS SCN model, two different scenarios have been considered. In the first scenario, the proposed MCDS SCN model is solved for single product and period while in second scenario, a conventional SCN is designed for the same problem environment and results are being compared. Further it was found that the proposed MCDS SCN model has superiority over conventional SCN in terms of cost saving, sustainable objectives and better customer service i.e. customer convenience by flexible distribution. Due to flexibility in distribution and easy access to different channel in the proposed model, uncertainty in demand may arise. Uncertainty at any point in MCDS SCN model will have lesser overall effect since it is being divided into different channel. Further different type of risk could also be embedded to make model more realistic. This would make the model more complex and could be solved using non-traditional optimization techniques like Multi-objective Particle Swarm Optimization (MOPSO), Multi-objective Genetic Algorithm (MOGA) and simulated annealing (SA) etc. The limitation of this work includes testing the proposed model on real-world field data though the numerical illustration is a good move in this regards.

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Notes
1. Multi-channel is concerned with delivering product through more than one channel but all working separately.
2. While cross channel is concerned with performing some of activities with one channel and other with different channel in same transactions or purchasing.

References
Baird, N., & Kilcourse, B. (2011, March). Omni-channel fulfillment and the future of the retail supply chain. Benchmark Report.
Bardwell, C. (2012). John Lewis: Multichannel shoppers spend 3.5 times more - IDC Community. IDC Retail Insights. Retrieved from https://idlcommunity.com/retail/retailomnichannelstrategies/john-lewis-multichannel-shoppers-spend-35-times-mo.
Beck, N., & Rygl, D. (2015). Categorization of multiple channel retailing in Multi-, Cross-, and Omni-Channel Retailing for retailers and retailing. Journal of Retailing and Consumer Services, 27, 170–178. https://doi.org/10.1016/j.jretconser.2015.08.001
Bell, D. R., Gallino, S., & Moreno, A. (2013). Inventory showrooms and customer migration in omni-channel retail: The effect of product information. Retrieved from SSRN, 2370535.
Brynjolfsson, E., Hu, Y. J., & Rahman, M. S. (2013). Competing in the age of omnichannel retailing. MIT Sloan Management Review, 54(4), 23.
Chopra, S. (2016). How omni-channel can be the future of retailing. Decision, 43, 135–144. https://doi.org/10.1007/s40622-015-0118-9
Chopra, S., & Meindl, P. (2007). Supply chain management. Strategy, planning & operation. Das summa summarum des management, 265–275.
Ericsson, J., Farah, P., Vermeiren, A., & Buckalew, L. (2012). Winning strategies for omnichannel banking. San Jose, CA: Cisco Systems Consulting Services Group.
EY. (2015). Re-engineering the supply chain for the omni-channel of tomorrow: Global consumer goods and retail omni-channel supply chain survey. Retrieved July 1, 2016, from https://www.ey.com/Publication/vwLUAssets/EY-re-engineering-the-supply-chain-for-the-omni-channel-of-tomorrow/$FILE/EY-re-engineering-the-supply-chain-for-the-omni-channel-of-tomorrow.pdf

Farahani, R. Z., Rezapour, S., Dreznier, T., & Fallah, S. (2014). Competitive supply chain network design: An overview of classifications, models, solution techniques and applications. Omega, 45, 92–118. https://doi.org/10.1016/j.omega.2013.08.006

Froher, M., & Stiehler, B. E. (2014, January). Omnichannel retailing: The merging of the online and offline environment. Proceedings of the Global Conference on Business and Finance, 9, 655–657.

Gallino, S., & Moreno, A. (2014). Integration of online and offline channels in retail: The impact of sharing reliable inventory availability information. Management Science, 60, 1434–1451. https://doi.org/10.1287/mnsc.2014.1951

Gallino, S., Moreno, A., & Stamatopoulos, I. (2017). Channel Integration, Sales Dispersion, and Inventory Management. Management Science, 63(9), 2813–2831. https://doi.org/10.1287/mnsc.2016.2479

Handfield, R., Straube, F., Pfohl, H. C., & Wieland, A. (2014). Key trends shaping the global logistics environment. Hübner, A., Holzapfel, A., & Kuhn, H. (2016). Distribution systems in omni-channel retailing. Business Research, 9, 255–296. https://doi.org/10.1007/s40885-016-0034-7

Kuzmicz, K. A. (2015). Benchmarking in Omni-Channel Logistics. Research in Logistics & Production, 5, 491–505.

Lazaris, C., & Vrechopoulos, A. (2014, June). Human-computer vs. consumer-store interaction in a multichannel retail environment: Some multidisciplinary research directions. In International Conference on HCI in Business (pp. 339–349). Springer International Publishing.

Melo, M. T., Nickel, S., & Saldanha-da-Gama, F. (2009). Facility location and supply chain management: A review. European Journal of Operational Research, 196, 401–412. https://doi.org/10.1016/j.ejor.2008.05.007

Neslin, S. A., Jeroth, K., Bodapati, A., Bradlow, E. T., Deighton, J., Gensler, S., ... Verhoef, P. C. (2014). The interrelationships between brand and channel choice. Marketing Letters, 25, 319–330. https://doi.org/10.1007/s11002-014-9305-2

Peltola, S., Vainio, H., & Nieminen, M. (2015, August). Key factors in developing omnichannel customer experience with Finnish retailers. In International Conference on HCI in Business (pp. 335–346). Springer International Publishing. https://doi.org/10.1007/978-3-319-20895-4

Piotrowsicz, W., & Cuthbertson, R. (2014). Introduction to the special issue information technology in retail: Toward omnichannel retailing. International Journal of Electronic Commerce, 18, 5–16. https://doi.org/10.2753/JEC1086-4415180400

Pishvaa, M. S., Rabban, M., & Torabi, S. A. (2011). A robust optimization approach to closed-loop supply chain network design under uncertainty. Applied Mathematical Modelling, 35, 637–649. https://doi.org/10.1016/j.apm.2010.07.013

Rey-Moreno, M., & Medina-Molina, C. (2016). Omnichannel strategy and the distribution of public services in Spain. Journal of Innovation & Knowledge, 1, 36–43. https://doi.org/10.1007/jik.2016.01.009

Rigby, D. (2011). The future of shopping. Harvard Business Review, 89, 65–76.

Singh, A. R., Jain, R., & Mishra, P. K. (2013). Capacities-based supply chain network design considering demand uncertainty using two-stage stochastic programming. The International Journal of Advanced Manufacturing Technology, 69, 555–562. https://doi.org/10.1007/s00170-013-5054-2

Singh, A. R., Mishra, P. K., Jain, R., & Khurana, M. K. (2012). Design of global supply chain network with operational risks. The International Journal of Advanced Manufacturing Technology, 60, 273–290. https://doi.org/10.1007/s00170-011-3615-9

Tetteh, A., & Xu, Q. (2014). Supply chain distribution networks: Single-, dual- & omnichannel. Interdisciplinary Journal of Research in Business, 3, 63–73.

Verhoef, P. C., Kannan, P. K., & Inman, J. J. (2015). From multi-channel retailing to omni-channel retailing: Introduction to the special issue on multi-channel retailing. Journal of Retailing, 91, 174–181. https://doi.org/10.1016/j.jretet.2015.02.005

Xie, W., Jiang, Z., Yao, Z., & Hong, J. (2014). Capacity planning and allocation with multi-channel distribution. International Journal of Production Economics, 147, 108–116. https://doi.org/10.1016/j.ijpe.2013.08.005

Zhang, S., Lee, C. K. M., Wu, K., & Choy, K. L. (2016). Multi-objective optimization for sustainable supply chain network design considering multiple distribution channels. Expert Systems with Applications, 65, 87–99. https://doi.org/10.1016/j.eswa.2016.08.037