Developing a Multi Criteria Decision Making Framework to Select the Most Suitable Production Line in Apparel Firms: Use of ANP Method

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Abstract

The apparel industry is considered as one of the most labor-intensive industries where Production Planning and Control (PPC) is considered as an important function, because of its involvement from scheduling each task in the process till the delivery of customer demand. Line planning is a sub process within PPC, through which the production orders are allocated to production lines according to its setting and due dates of production completion. The decisions that address line planning function still heavily rely on the expertise of the production planner. When production planners are required to select production lines for the production of a particular type of product, little emphasis has been placed on ways to apportion certain production orders to the most appropriate production system. In this research, a framework is developed using Analytical Network Process (ANP) which is a Multi Criteria Decision Making (MCDM) method, enabling the incorporation of all the planning criteria in the selection of a production line. The weighted scores obtained by the best alternative production lines are used in a Linear Programming model to optimize the resource allocation in an apparel firm.

Keywords

Apparel Production Planning, Production Line Planning, Multi Criteria Decision Making (MCDM), Analytical Network Method (ANP)

1. Introduction

Clothing is the quintessential worldwide industry wherein the world's biggest retailers, marked advertisers, and producers without processing plants are the dominant players. The clothing and material industry area is consistently under steady tension and where rivalry is fierce, there is an opportunity of opponent firms standing by to challenge them. Despite the fact that the apparel and textile business may buyer focused to fulfill retail procedures and shopper need, the clothing manufacturing system is at the core of any cut-and-sew activity. The production system, as the center of an assembling undertaking, shapes a huge capital venture for any organization (Jacobs, Chase, and Aquilano, 2008). As clothing organizations face the requests of things to come, capital speculations turns into a genuine budgetary issue (Cooper, 2010).

Figueira, G., (2013) Discusses capital intensity, energy intensity and competitive market as the three main factors which make production planning an essential activity in the quest for improvements in operational efficiency. In apparel industry, production line planning is the process of scheduling and allocating production orders to production lines according to product setting (product is being made in the line) and due dates of production completion. A line plan defines when a style is going to be loaded to the line, how many pieces to be expected (target) from the line and when order to be completed. (Syduzzaman, M., 2015). Production planning usually assumes a perfect environment in terms of resource availability and process quality. Resource unavailability during the production process will increase production costs and affect inventory levels needed to satisfy customer demand. Production planning is done as part of a hierarchical planning process, where the production plan is cascaded down to a more detailed production schedule. A production line has the capability to produce number of different product types. There exists a large number of process constraints from one production system to the other due to its varied capabilities and processing requirements of a given production order. Some of the production orders can be produced on more than one production line and some of the sub process require sharing of special tools and machineries. Some products have constraints with regards to the precedence while others have similar production conditions that should be scheduled for consecutive production. Switching from one production line to another for the same product style or switching in between different styles within the same production line leads to reduction in efficiency and it wastes lots of machine and labor production hours of the manufacturing firm. Hmida et al (2013), Shin, H., & Leon, V., (2004). Current practice on scheduling daily production in the production lines is based on the experience of the management. Currently, scheduling daily production in the system is subjectively based on the management's experience. With an increasing emphasis on the multiple objectives of on-time shipment, low inventory, and production quality; the management of the plant needs a scheduling tool to improve the production scheduling for better system performance.

To improve the process of line planning, it is important for decision makers to understand the impacts of the characteristics of apparel production systems and parameters in the manufacturing environment on production system performance which can thus provide insights into the selection decision. However, it is difficult to anticipate the impact of the parameters in the manufacturing environment on production system performance through observation or experimentation because it is costly and time-consuming. In such circumstances, Multi Criteria Decision Making framework frameworks can be used because of its ability to explicitly model multiple and possibly conflicting factors. In this research a Multi Criteria Decision Making (MCDM) framework is constructed with the objective of finding the best suitable production line to minimize the total costs, including the production costs, inventory holding costs, idle time costs and lateness costs. Therefore, this research will focus on finding the solution for on, how to select the best production line for a particular production order through a collaborative decision making framework and increase the production planning efficiency in the apparel sector in Sri Lanka.

1.1. Objectives

The main objectives of the research are to

1. Identify the production line selection criteria of an apparel manufacturing firm
2. Identify the most suitable MCDM method for the research
3. Develop a framework to select the most suitable production line in apparel sector

2. Literature Review

In this section, the existing achievements of the industry and work by academic scholars in the intersecting fields of the scope of the research are being reviewed. The literature review was done under the topics of capacity planning and line selection approaches, MCDM frameworks used for different research problems in different industries with their pros and cons comprehensive review on ANP method and applications of Linear Programming in production planning.

2.1. Production planning approaches

The literature reviewed under this section mainly brought results pertaining to the main considerations in capacity planning and scheduling function in different industries. Those results were used to identify the main criteria and sub criteria in ANP framework. Mak and Che (2016) discusses about 3 main parameters that are considered to have the most significant effect on the selection of production systems in real-life which are, product complexity, production order size and operator competence level. Song (2006) also discusses how operator's performance is affected in a production line and recommends that it should be taken into consideration in the line planning process. Naderie et al., (2009) investigated flexible flow line problems with sequence dependent setup times and different Project Management policies to minimize the make span in parallel machines. Figueira (2015) also mentions that, when scheduling orders in the paper and pulp industry managers have to use a base sequence of grades. Customers place orders for reels of different widths and grades therefore, lot sequencing approach can be used to verify the earliest available slot for a lot size and hence commit to a due date. Also he discusses about the fact that there's a priority level for different orders based on logistic mode. The maximum priority is given to those that travel by ship, since the company has to schedule containers in advance and commit to a given due date. Also, the important costs related to production stability, must be taken into account when defining production plans.
Shin, H., & Leon, V., (2004) discusses about the production family concept. Family set-up time reflects the need to change a tool for each class of styles and even sizes within the style. This set-up time is large compared to the average processing time of the production order. In general, therefore, large batches have the advantage of high machine utilization because the number of set ups is small. On the other hand, processing a large batch may delay the processing of an important job belonging to a different family, resulting in customer dissatisfaction due to tardy deliveries. Mok, P. et al. (2013) discusses about a solution to product family setup time, under Group Technology (GT) concept. In GT approach, some parts of different products which involve similar manufacturing processes are combined together in the production process. This method reduces inventories and work in progress (WIP). Since workers are producing similar products all the time, throughput time and setup time can be largely reduced. Hmida et al. (2013) also addresses the need of diminishing switch over methodology between production systems, which is a current administration concern. It is referenced that production run length (the quantity of days a handling line is booked to deliver a similar item type) should be long enough to deliver completed items with predictable quality. Regular item switchovers in the preparing line can bring about quality issues. Be that as it may, a run length bigger than should be expected can expand the stock level. Hmida et al. (2013) showed calculations to produce every day creation plans considering two different goals which are, to limit shipment delays and to limit normal stock levels. The administration fabricating frameworks faces the issue of meeting client conveyance dates while working the system productively. This includes clashing targets. The contention emerges in light of the fact that, improvement in one target can be made to the disservice of at least one of different goals. In addition, different creation and quality requirements should be fulfilled.
The literature showed that making a decision based on multi criteria is a considerably complex task. In general, scheduling problems implies that a set of rules should be evaluated and ranked according to different criteria which are conflicting to each other. These facts emphasize the need of a Multi Criteria Decision Making framework to be used in the production planning process. Given a client request, two practical heuristic or successive streamlining calculations are created to produce every day creation plans for two essential destinations: limit shipment delays (pull-in reverse strategy) and limit normal stock levels (push-forward technique). A third heuristic calculation (decrease switch-over method) which depends on the current administration practice is additionally evolved to fill in as a benchmark. Ben et al (2014). Analysis of literature showed that there's a large set up criteria that needs to be considered. Therefore, when selecting the best production line for a given production order, proper balance between each criteria should be considered.

2.2. Multi Criteria Decision Making (MCDM) methods

Many methodologies were discussed in the literature under the selection process, which involve building alternatives, identifying selection criteria, and evaluating alternatives against the criteria. This approach in selection is developed as MCDM, which has the ability to reveal the complexity of the problem with decisive attributes, to make appropriate trade-offs among conflicting factors, and to recommend well-balanced solutions to different stakeholders Poh and Liang (2017). When considering MCDM methods, the criteria interactivity should be concerned since there're several forms of interactions among criteria that might occur in real world problems. According to the classification done by Golcuka and Baykasoglu (2015) there're distinct philosophies under criteria interactivity. Alternative selection methods fall under the structural dependency which implies the dominance and dependency relations in the structure of the criteria. The structural dependency is prevalent in AHP, ANP, and hierarchical TOPSIS methods.

2.3. AHP and ANP Methods

AHP technique is one of the multi criteria decision making methodologies. The AHP is a typical methodology of numerous models dynamic in operations management (Beck and Hofmann, 2012). A primary preferred position of this technique is to beaten impromptu choices of supervisors which are regularly founded on encounters or emotions. Numerous dynamic issues can't be organized in a hierarchal manner as a result of the connections and conditions between standards. In such cases the structure of the issue ought to be inherent the type of an organization. ANP is the general type of the AHP, and can help in managing conditions and collaborations in complex dynamic issues. Throughout the most recent decade there have been many studies considers that were led utilizing ANP in various ventures for various purposes. This follows a review of such work to recognize the diverse emphasizing points of interest and weaknesses of AHP and ANP strategies. Since ANP is developed from AHP, the two techniques were examined and contrasted with the utilization of ANP strategy for the advancement of production line planning system. Vatansever, K., and Kazançoğlu, Y. (2014) did an exploration study to give decision support to supervisors with respect to the determination issue. The cutting-machine determination rules were controlled by thinking about the related literature, and furthermore by counseling the industrial experts. After that, selected criteria weights were determined by fuzzy AHP and ranking cutting machine alternatives by fuzzy MOORA method. The investigation recommended for the most appropriate cutting machine for the firm. Hofmann and Knébel (2013) utilized AHP for the arrangement of assembling techniques to client necessities. Görener, A., (2012) analyzes AHP and ANP through a use of key dynamic in an assembling organization. It specifies that numerous choice issues can't be organized progressively when they involve the interaction and dependence of higher level elements in a hierarchy on lower level elements (Saaty and Özdemir, 2005).

While the AHP represents a framework with a uni-directional hierarchical AHP relationship, the ANP allows for complex interrelationships among decision levels and attributes. Ran Bi & Jin-yu Wei (2008) used ANP method to develop an Evaluation Indices System for product line selection process for ERP. This framework was built to facilitate ERP system of the organization to make decisions on how to organize production rationally to achieve the highest profit and the lowest cost given limited resources. Agarwal et al. (2006) presented the ANP to explore the relationship among lead time, cost, quality, and service level in a supply chain to select one strategy among a lean, agile or leagile (i.e., combining lean and, agile) supply chain. Poh, K. L., & Liang, Y. (2017) also developed an MCDM support for a sustainable supply chain. They used sustainable dimensions of a supply chain and selected the best alternative practice using AHP method. The research then developed the framework to an ANP method and compared the results of each method. The change in final result of each method implies that the earlier AHP model had been an over-simplification of the problem and that the interdependencies of the elements had not been properly and adequately captured by the model. The addition of the network influence of alternatives on criteria in the model has made the model more comprehensive and realistic, reflecting the relationships among the elements.

Hosseini, L. et al (2013) utilized ANP technique to choose the best methodology for reducing risks in a supply chain. Supply risk, process risk, demand risk, and disturbance risks were considered as risk factors in this paper. The ANP is applied to represent the significance of the supply chain risk factor and to assess the appropriate arrangement out of the other options, Total quality administration, Lean, Alignment, Adaptability and Agility. A hybrid MCDM approach is developed by Navid Haghighat (2017) to assess aircraft administration quality in Iran. Fuzzy DEMATEL was applied to decide the level of impact one criteria has on one another and that helped in ranking criteria based on the relationship. ANP network map was developed dependent on the connection map created from Fuzzy DEMATEL examination. Fuzzy ANP approach helped with organizing criteria based on the requirement for development and enabled in a more exact estimation in decision making. In the research Liu, P. et al, (2020) ANP strategy was utilized to decide the relationship among the measures for investigating the green building rating framework in Taiwan. DEMATEL and best worst method (BWM) was utilized to build up the system

3. Methodology

The figure shows the methodology used by the researcher from the identification of the research problem till the ANP model was developed and the best production line was selected. The design of the research was developed through intensive study under different research methods in use. The research methods used in the study are in line with the type of the research problem, the characteristics of the industry and its experts. Throughout the research, there were milestones achieved by the researcher, which are shown in the figure.

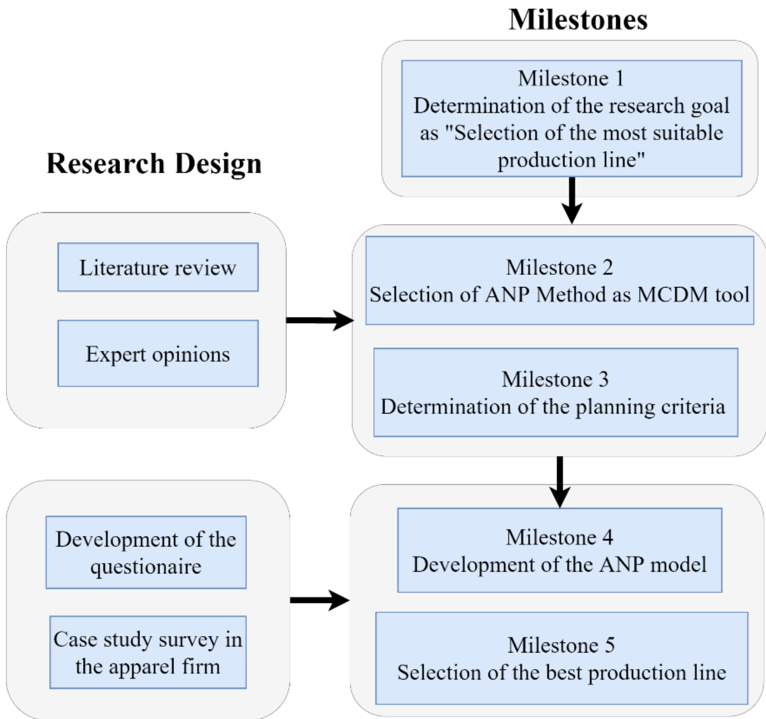

Figure 1: Research Methodology

The research was started with a literature review to find out the current situation in production planning function in apparel firms, the proposed approaches for the production line selection problem and to identify the gaps and limitations in the past researches. Identification of the research gap led to form the research objectives and then the research questions were formulated.

This study was carried out as a mixed approach study, which is a quantitative study together with qualitative features. This research study provides quantitative solution for critical issue in production line selection. It mainly focuses on optimization of machinery and human resource allocation for production orders. Here, ANP MCDM technique was used to build the production line selection framework and to select the best production line among the potential alternatives. Qualitative data (production line selection criteria and sub criteria) were gathered through literature review and interviews with the professionals in the planning function of the study apparel firm. Expert opinions were conducted with professionals from 5 different apparel firms in order to identify the line selection criteria and it was used in the ANP conceptual framework.

3.1. Criteria Identification

The table 1 shows the 5 criteria, 20 sub-criteria which were identified for the production line selection decision. The table also shows the references used for the criteria identification.

Table 1: Criteria and its references

Criteria	Sub criteria	Reference
(C1) Characteristics of the product	**(SC1.1)** Standard Minute Value	EO1, EO2,EO3,EO4
	(SC1.2) Labor time	EO1, EO3
	(SC1.3) Style efficiency	EO1, EO2,EO3
	(SC1.4) Throughput time	Mok, P. et al. (2013) , EO4
	(SC1.5) Number of operations	Mak and Che (2016) , EO1
(C2) Characteristics of the Production Order	**(SC2.1)** Delivery date	Hmida et al. (2013) , EO1,EO2,EO3,EO4
	(SC2.2) Order quantity	Mak and Che (2016), EO2
	(SC2.3) Size Quantities	Figueira (2015) EO1, EO3
	(SC2.4) PCU date	EO1, EO4
(C3) Characteristics of the production line	**(SC3.1)** Technical infrastructure	EO1,EO2,EO3,EO4
	(SC3.2) Ability to adopt changeovers	EO1,EO2,EO4
	(SC3.3) Efficiency of the line	EO1,EO2,EO3,EO4
	(SC3.4) Skills inventory of the line	Song (2006) Mak and Che (2016),EO1, EO2
(C4) Supply of inputs	**(SC4.1)** Continuation of inputs to the module	EO2
	(SC4.2) Infrastructure set up time	Shin, H., & Leon, V., (2004) EO1, EO2
	(SC4.3) Prioritization of machine service	EO1
(C5) Quality and IE parameters	**(SC5.1)** Quality concerns	EO1,EO2,EO3,EO4
	(SC5.2) Cadre requirement	EO1,EO2,EO3,EO4

Expert opinions are indicated as EO and the notation is given from apparel firm 1 to 4 using EO1, EO2, EO3 and EO4.

3.2. Development of ANP conceptual framework

AHP and ANP were introduced by prof. Thomas Saaty. In the AHP, a decision making problem has a hierarchical structure; at the top is the decision objective, and at the subsequent level are rules which can be divided into sub rules/components at a lower level. The objective, criteria and sub criteria make a tree. The tree is then upgraded with the alternatives at the most reduced level. The choices are associated with all (sub) criteria which are not decomposed into the lower level (the leaves of the tree). In the ANP, the hierarchal structure is moved up to network which permits interaction between components of the order (for example a specific leaf could impact different leaves). The organization in the ANP comprises of clusters and components. The organization structure of the figure below comprises clusters of objective, criteria, sub criteria and alternatives. The conditions between the rules are shown in arrows

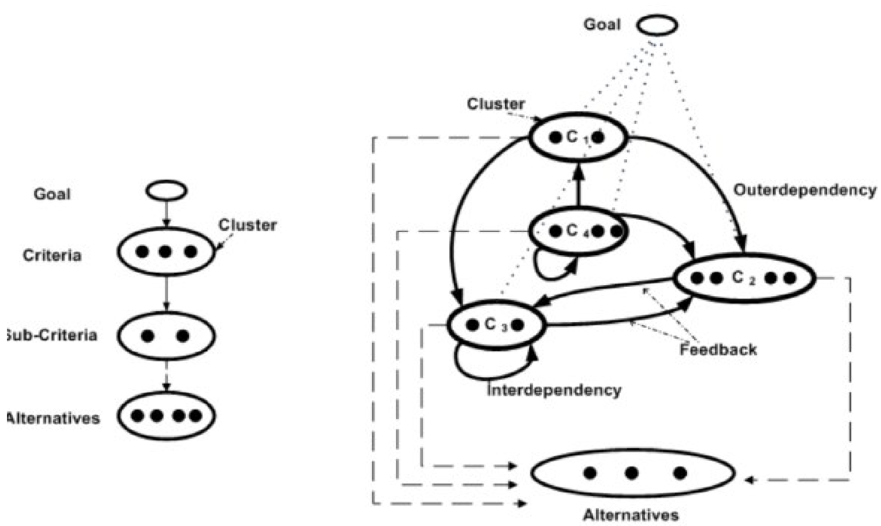

Figure 2: Görener, A., (2012) The structural difference between AHP and ANP

The 2nd part of figure 2 shows how the network is built in an ANP model. According to the research, the goal/ objective is to select the most suitable production line. While the sub criteria are clustered under main criterion and production lines are given as the alternatives. This conceptual framework will be converted to a framework through data collection and result will be obtained.

4. Data Collection

The proposed conceptual framework was applied to an apparel organization as a case study. An instance was created with one of the frequently manufactured styles in the organization. Questionnaires were given to 11 experts in the Planning Department of the organization to determine the relative importance of each sub criteria. The experts were selected based on the years of experience they have in the Planning Department and also based on the product type/style specialization. 1 Senior Manager, 2 Assistant Managers, 4 Senior Executives and 4 Executives were selected from the organization. They were instructed to relate the answers to the instance described prior to the questions. ANP model data were obtained from the questionnaire and they were fed to Super Decision software. Weights of each main criteria, sub criteria were calculated through pairwise comparisons considering interdependencies between each cluster in the ANP model.
The table 2 below consists of criteria weight and sub criteria weight calculated by ANP method. Multiplication of criteria weight and sub criteria weight were recorded as the final weight for each sub criteria. When calculating the weighted supermatrix in ANP, the pairwise comparisons at the node level must be done based on Saaty's scale. Comparisons should be done between,

i. The criteria and the goal
ii. Criteria with respect to other criteria
iii. Alternatives with respect to each criterion
iv. Each cluster

5. Results and discussion

ANP framework which is shown in figure 3, is the main outcome of the research.

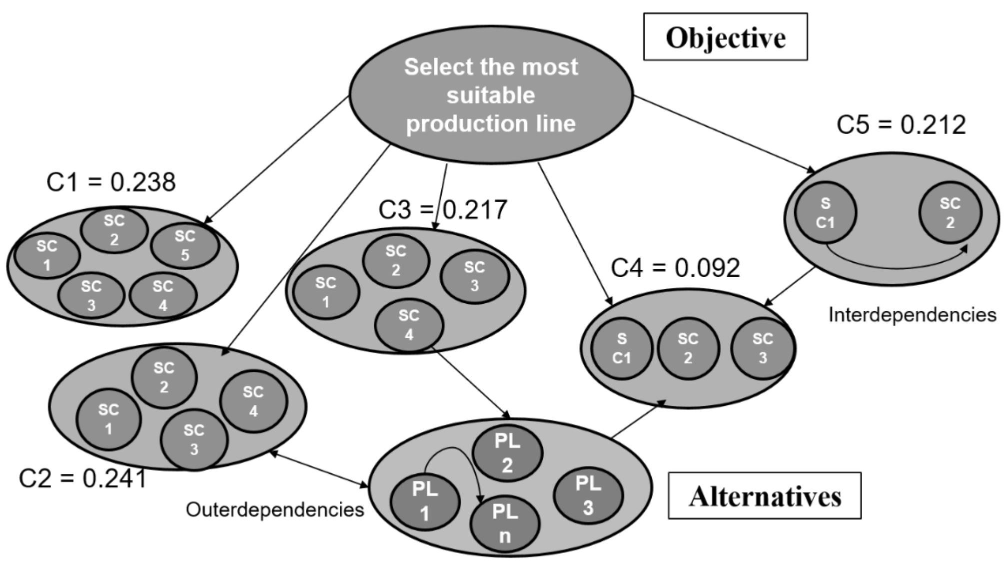

Figure 3: ANP Framework for the research

According to the framework, the organization gives 1st priority to Characteristics of Production Order, which is 0.241, and then to Characteristics of Product, Characteristics of Production Line, Quality and IE parameters and supply of inputs as the least prioritized with a weight of 0.092.
Table 2 shows weight received by sub criteria and final weight of each sub criteria. Considering the final weight sub criteria ranking has been done.

Table 2: Criteria weighting and ranking using ANP method

Criteria	Sub criteria	Criteria Weight	Sub Criteria Weight	Final Weight	Rank
(C1)	(SC1.1)	0.238	0.261	0.0621	6
	(SC1.2)		0.169	0.0402	11
	(SC1.3)		0.258	0.0614	7
	(SC1.4)		0.167	0.0397	12
	(SC1.5)		0.145	0.0345	13
(C2)	(SC2.1)	0.241	0.556	0.1340	1
	(SC2.2)		0.138	0.0333	14
	(SC2.3)		0.17	0.0410	10
	(SC2.4)		0.136	0.0328	15
(C3)	(SC3.1)	0.217	0.314	0.0681	4
	(SC3.2)		0.103	0.0224	17
	(SC3.3)		0.306	0.0664	5
	(SC3.4)		0.282	0.0612	8
(C4)	(SC4.1)	0.092	0.097	0.0089	18
	(SC4.2)		0.57	0.0524	9
	(SC4.3)		0.333	0.0306	16
(C5)	(SC5.1)	0.212	0.383	0.0812	3
	(SC5.2)		0.617	0.1308	2

3 production lines were selected by the respondents and each of the respondent were asked to rate the production line against sub criteria. Finally average rates given by the respondents were fed to the ANP model in Super Decision Software. Multiplication of final weight for each sub criteria and average received by each production line were recorded as the composite index in the table below.

Table 3: Alternative weighting and ranking using ANP method

			Composite Index			Score		
Criteria	Sub criteria	Final Weight	Production Line 1	Production Line 2	Production Line 3	Production Line 1	Production Line 2	Production Line 3
(C1)	(SC1.1)	0.0621	0.67	0.297	0.033	0.0416	0.0184	0.0020
	(SC1.2)	0.0402	0.48	0.427	0.093	0.0193	0.0172	0.0037
	(SC1.3)	0.0614	0.322	0.558	0.12	0.0198	0.0343	0.0074
	(SC1.4)	0.0397	0.363	0.54	0.097	0.0144	0.0215	0.0039
	(SC1.5)	0.0345	0.325	0.258	0.417	0.0112	0.0089	0.0144
(C2)	(SC2.1)	0.1340	0.717	0.105	0.178	0.0961	0.0141	0.0239
	(SC2.2)	0.0333	0.685	0.136	0.179	0.0228	0.0045	0.0060
	(SC2.3)	0.0410	0.317	0.54	0.143	0.0130	0.0221	0.0059
	(SC2.4)	0.0328	0.293	0.19	0.517	0.0096	0.0062	0.0169
(C3)	(SC3.1)	0.0681	0.297	0.333	0.37	0.0202	0.0227	0.0252
	(SC3.2)	0.0224	0.293	0.571	0.136	0.0065	0.0128	0.0030
	(SC3.3)	0.0664	0.323	0.19	0.487	0.0214	0.0126	0.0323
	(SC3.4)	0.0612	0.217	0.614	0.169	0.0133	0.0376	0.0103
(C4)	(SC4.1)	0.0089	0.593	0.297	0.11	0.0053	0.0027	0.0010
	(SC4.2)	0.0524	0.395	0.258	0.347	0.0207	0.0135	0.0182
	(SC4.3)	0.0306	0.682	0.109	0.209	0.0209	0.0033	0.0064
(C5)	(SC5.1)	0.0812	0.42	0.558	0.022	0.0341	0.0453	0.0018
	(SC5.2)	0.1308	0.628	0.228	0.144	0.0821	0.0298	0.0188
				Total score		0.4724	0.3275	0.2011

According to the results, Production Line 1 has received a total composite index of 0.4724 while Production Line 2 and 3 received total composite index of 0.3275 and 0.2011 respectively. Production Line 1 has received the highest among 3 Production Lines. For the case study organization, the 3 most important sub criteria for the production line selection are SC2.1, SC5.2 and SC5.1 in order. Production Line with high composite index for those prioritized sub criteria is considered the most suitable for the sample production order. However the total score is the combination of all the scores obtained for each sub criteria. SC2.1 resulted in as the most important factor because the organization considers Delivery Date as a key element when scheduling the production order. In order to meet the delivery date, the availability of the production line on the Production Start Date (PSD) is highly regarded. Also, the Cadre requirement calculated and recommended by the Industrial Engineering department is considered in the 1st phase of production line selection process. In the case study organization, there's a fixed number of cadre in each production line. Therefore, the number of cadre or individually the employees are not changed from production order to order. Therefore the planner has to choose the production line based on the cadre requirement as well. Also, the products manufactured in the firm are highly sensitive to colors of the fabrics, therefore the quality parameters recommended by Quality Department are highly regarded.

6. Conclusion

This research study proposes a Multi Criteria Decision Making framework to be used to in apparel firms, for the production line selection process. Line selection criteria was selected through an extensive literature review and expert opinions form different organizations covering a vast range of apparel products. ANP method was selected after carefully analyzing and comparing other MCDM methods based on the ability to consider dependence and feedback between the problem criteria. Data collection and analysis phase was conducted as a case study, therefore the criteria rankings received as the results are based on the case study organization's perspective. However, this framework can be applied to any apparel firm for any kind of production order. When using the framework for other apparel firms, the priority ranking can possibly be different based on the organizational setting and its policies. Even within the same organization, the result can be different from one person to the other, therefore composite index has to be used when achieving the final result.

As discussed earlier current practice on scheduling daily production in the production lines is based on the experience of the management. Therefore, the Managers could use this Multi Criteria Decision Making model as a scheduling tool to improve the production scheduling for better system performance. Further this Multi Criteria Decision Making framework enable the decision makers to understand the impacts of the characteristics of apparel production systems and parameters in the manufacturing environment on production system performance which can thus provide insights into the selection decision. This proposed model guides the decision makers to select the best production line for a particular production order through a collaborative decision making framework and increase the production planning efficiency in the apparel sector.

Further, this framework can be improved to be used in other manufacturing organizations with modifications through further criteria identification. Therefore, it is concluded that the main objective the research is attained. Research deliverables can be used to optimize resources of apparel firms, to improve planning and manufacturing efficiency and hence earn profits. Apparel industry, being one of the major contributors to Sri Lanka's economy through exports, can be further developed as a profitable sector and to achieve global excellence.

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