Paper No: SE-05 **Systems Engineering**

A MILP model to optimize the proportion of production quantities considering the ANP composite performance index

N. T. H. Thalagahage*
Dept. of Industrial Management
Faculty of Science,
University of Kelaniya, Sri Lanka
Nayomi1013@gmail.com

A. N. Wijayanayake
Dept. of Industrial Management
Faculty of Science,
University of Kelaniya, Sri Lanka
anni@kln.ac.lk

D. H. H. Niwunhella
Dept. of Industrial Management
Faculty of Science,
University of Kelaniya, Sri Lanka
hirunin@kln.ac.lk

***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 to 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 their setting and due dates of production completion. The decisions that address line planning functions 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* - *Analytical Network Method (ANP), apparel production planning, linear programming, multi-criteria decision making (MCDM), production line planning

I. 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 for opponent firms standing by to challenge them. Even though the apparel and textile business may be buyer-focused to fulfill retail procedures and shopper needs, 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. As clothing organizations face the requests of things to come, capital speculations turn into a genuine budgetary issue.

[1] 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 the 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 are to be expected (target) from the line and when an order is to be completed. 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.
[2] A production line has the capability to produce a number of different product types. There exists a large number of process constraints from one production system to the other due to the 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-processes require sharing of special tools and machinery. Some products have constraints with regards to the precedence of operations that should be performed for the production 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 a reduction in efficiency and it wastes lots of machine and labor production hours of the manufacturing firm. Current practices on scheduling daily production in the production lines are based on the experience of the management. At present, scheduling daily production in the manufacturing process is subjectively based on the manager'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, decision-makers need 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 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. The main objectives of the research are to

RO1: Identify the production line selection criteria of an apparel manufacturing firm

RO2: Identify the most suitable MCDM method for the research

RO3: Develop a framework to select the most suitable production line in the apparel sector

II. 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.

A. Production planning approaches

This section reviewed the literature which mainly focused on capacity planning and scheduling function in different industries. Those results were used to identify the main criteria and sub-criteria in the ANP framework. [3] Discuss 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. [4] Also discusses how the operator's performance is affected in a production line and recommends that it should be taken into consideration in the line planning process. It also investigated flexible flow line problems with sequence-dependent setup times and different Project Management policies to minimize the make span in parallel machines. [5] 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, the lot sequencing approach can be used to verify the earliest available slot for a lot size and hence commit to the due date. Also, he discusses the fact that there's a priority level for different orders based on the logistic model. 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.

[4] Discusses 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 setups 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. [2] Discusses a solution to product family setup time, under Group Technology (GT) concept. In the GT approach, some parts of different products which involve similar manufacturing processes are combined 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. [6] Also, addresses the need for diminishing switch over methodology between production systems, which is a current administration concern. It is referenced that production run length (the number 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. [6] showed calculations to produce everyday 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 because 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 imply 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. Analysis of literature showed that there's a large set of criteria that needs to be considered. Therefore, when selecting the best production line for a given production order, proper balance between each criterion should be considered.

B. Multi criteria decision making 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 [7]. 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 [8] 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.

C. 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 [9]. 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.

[10] Did an exploration study to give decision support to supervisors concerning the determination issue. The cutting-machine determination rules were controlled by thinking about the related literature, and 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. [6] Utilized AHP for the arrangement of assembling techniques to client necessities. [11] 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 [12]

While the AHP represents a framework with a uni-directional hierarchical AHP relationship, the ANP allows for complex interrelationships among decision levels and attributes. [13] 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. [14] 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. [8] 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. [15] 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 [16] 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 [17] 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.

D. Linear programming for production planning

When making decisions using MCDM methods, the Decision Maker has to face problems relating to the use of limited resources considering how to decide on which resources would be allocated to obtain the best result, which may relate to profit or cost or both. MCDM methods are characterized by subjectivity, where the framework can be different from person to person and apparel firm to firm. Therefore, a Linear Programming model can be formulated and solutions can be derived to determine the best course of action within the constraints that exist.

Linear Programming is a method of allocating resources optimally. It is one of the most widely used operations research tools to determine optimal resource utilization. Therefore, this research develops a model which consists of the objective function and certain constraints. In past researches, Linear Programming is heavily used in microeconomics and company management such as planning, production, transportation, technology, and other issues.

[18] presents a model to be applied in the consumer goods industry consisting of multiple manufacturers, multiple production lines, and multiple distribution centers which integrates the production and distribution plans. Number of products, number of product groups, number of production lines, number of plants, number of production lines at plant, number of products that can be processed on a line, number of distribution centers, number of periods have been used as the constraints for the model while the capacity of the production line, external demand of the product, time consumed to produce a product, minor setup time of product group, the major setup time of product group, processing cost of the product, minor setup cost of the product, major setup cost of product group, inventory holding cost of the product are used to decide the optimum production methods and distribution means.

[[19] used equipment technology options, timing constraints, lot assignment constraints, the capacity of the equipment in the batch tasks, maximum campaign length in continuous tasks, changeover procedures, setup time, corresponding due dates, storage and shelf-life constraints, maintenance operations as the constraints in the planning optimization model for the biopharmaceutical industry.

[20] used the data collected from the industries like monthly held or available resources but a company procures resources like fabrics and threads as the production requirement. Monthly available time also can be variable because the number of workers may be increased or decreased as per the production plan. In this paper, the cost minimization along with increasing profit using the same resources used at present is proposed. Using a linear programming method, the optimal, or most efficient, way of using limited resources to achieve the objective of the situation was found out.

III. Methodology

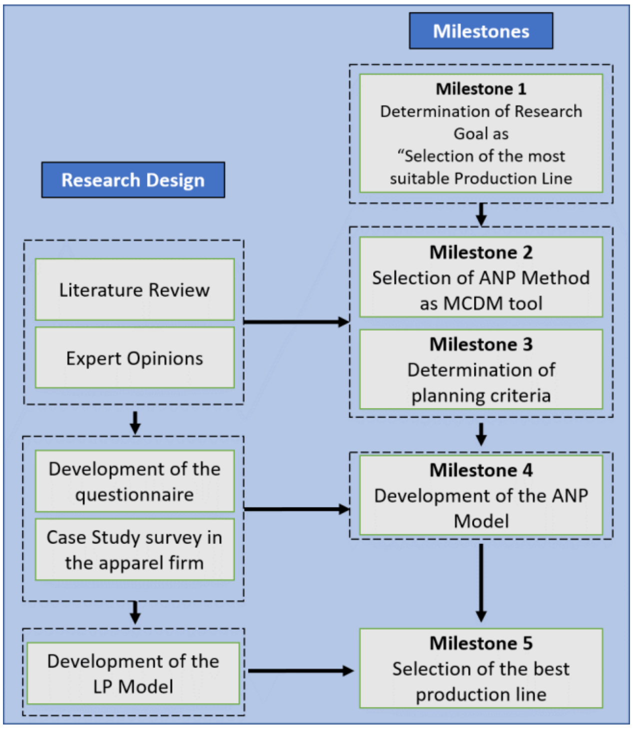

Fig. 1: Flow diagram of the methodology process

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 research. 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 a quantitative solution for the critical issue in production line selection. It mainly focuses on the optimization of machinery and human resource allocation for production orders. Here, the 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 to identify the line selection criteria and it was used in the ANP conceptual framework.

A. Criteria identification

Table I shows the 5 criteria, 19 sub-criteria which were identified for the production line selection decision. The table also shows the references used for the criteria identification. (LR- Literature Review/ EO- Expert Opinion)

TABLE I. CRITERIA AND SUB CRITERIA OF PRODUCTION LINE SELECTION

Goal: To select the most suitable production line under different criteria	
Criteria	**Sub Criteria**
(C1) Characteristics of the product	(C1.1.) Standard Minute Value (LR/EO)
	(C1.2.) Labor time (EO)
	(C1.3.) Style efficiency (EO)
	(C1.4.) Supervisory control (EO)
	(C1.5.) Throughput time (LR/EO)
	(C1.6.) Number of operations (LR)
(C2) Characteristics of the Production Order	(C2.1.) Delivery Date (LR/EO)
	(C2.2.) Order Quantity (LR)
	(C2.3.) Size Quantities (EO)
	(C2.4.) PCU Date (EO)
(C3) Characteristics of the Production Line	(C3.1.) Technical Infrastructure (LR)
	(C3.2.) Ability to adopt changeovers (LR)
	(C3.3.) Efficiency of the Production Line (EO)
	(C3.4.) Skills inventory of the Production Line (LR)
	(C3.5.) Availability of the Production Line (EO)
(C4) Technical support	(C4.1.) Infrastructure support by the technical team (EO)
	(C4.2.) Machine service requirements (EO)
(C5) Quality and IE concerns	(C5.1.) Expected quality parameters (EO)
	(C5.2.) Cadre (EO)
Alternatives: Potential production lines – 6 were selected	

■

B. Development of Linear Programming model

Next objective of this study is to optimize the resources required for the production of the order by considering the relevant constraints. Here, Linear Programming will be used to build the optimization model.

Constraints for the LP model were selected through the interviews conducted with the respondents of the case study organization. The business unit produces products with simple to mid-level complexity. The variety between product types are high, therefore, one of main objectives of the planning process is to minimize the number of changes done to a production line from one product to the other. Unless the objective is achieved, the machine idle time, operator idle time go high due to frequent switching between one product to the other.

- Decision variables

The planner's task is to set a production amount for each production line ranked through the ANP method. Therefore, the decision variables will be whether the production line is selected, and if selected, what is the amount of production order assigned for each production line.

- Objective function

To maximize the ANP weighted composite performance index through selection of production lines. In here calculated competency score values will be used as coefficient values of the objective function.

Assumptions:
In the formulation it is assumed that,

i. Production output is stored in one main warehouse, therefore there are no inventories per individual production line and the previous production output has been transferred to the warehouse at the beginning of the Production Order.
ii. Raw materials are supplied to all production lines without any delay and limit, as per the production plan and raw materials are consistently provided without any disruption.

<u>Constraints</u>
The following constraints were identified and will be used for the formulation of Linear Programming model.

1. Machine hours
2. Trimming labor hours
3. Sewing labor hours
4. Machine set up time
5. Machine set up cost
6. If xi is zero then no line is assigned for production If xi>0, then yi is assigned for production
7. Total number of production lines should be below the desired number of lines

Development of the model
Indices

i - ith Production Line
n - Number of Production lines
xi=qi/Qi - Proportion of Production allocated to the ith production line (this number is a fraction of the total production quantity of the order)
yi - Production Line i, if selected 1, otherwise 0, a binary variable

Parameters

$m_i c_i m_i$ - ANP Composite performance index of the i^{th}production line
M - Maximum number of machine hours allowed for order completion on Production End Date (PED)
m_i - Number of machine hours required for production completion in each i^{th} production line
T - Maximum number of trimming labor hours allowed for production completion on PED
t_i - Number of trimming labor hours required for production completion in each i^{th} production line
S - Maximum number of sewing labor hours allowed for production completion on PED
s_i - No of sewing labor hours required for product. completion in each i^{th} production line
Qi - Total production Order quantity
q_i - Production quantity allocated for i^{th} production line
N - Desired number of production lines
POS_i - POC_i - Maximum set up time allowed from each i^{th} production line for the Production Order to start production on Production Start Date (PSD)
POSi - Next order Production Start Date
POCi - Current order Completion Date
st_i - Setup time required for each i^{th} prod. line
SC - Maximum set up cost allowed for the Production Order to start production within the profitable range
sc_i - Set up cost required for each i^{th} production line

Objective Function:

$$\text{Max } Z = \sum_{i=1}^{n} c_i x_i$$

Subjected to

$$\sum_{i=1}^{n} m_i x_i \leq M \quad (1)$$

$$\sum_{i=1}^{n} t_i x_i \leq T \quad (2)$$

$$\sum_{i=1}^{n} s_i x_i \leq S \quad (3)$$

$$\sum_{i=1}^{n} sc_i \,.\, y_i \leq SC \quad (4)$$

$$st_i yi \leq POS_i - POC_i \quad i= 1\ldots..n \quad (5)$$

$$x_i \leq y_i \quad (6)$$

$$\sum_{i=1}^{n} y_i < N \sum_{i=1}^{n} y_k \leq N \quad (7)$$

x_i >=0 and yi = (0,1)

IV. DATA COLLECTION AND ANALYSIS

Data collection was done through a questionnaire which was designed to feed pairwise comparisons to the matrix form. The survey was conducted as a case study, therefore professionals from production planning department of an apparel manufacturing firm in Sri Lanka were involved.

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

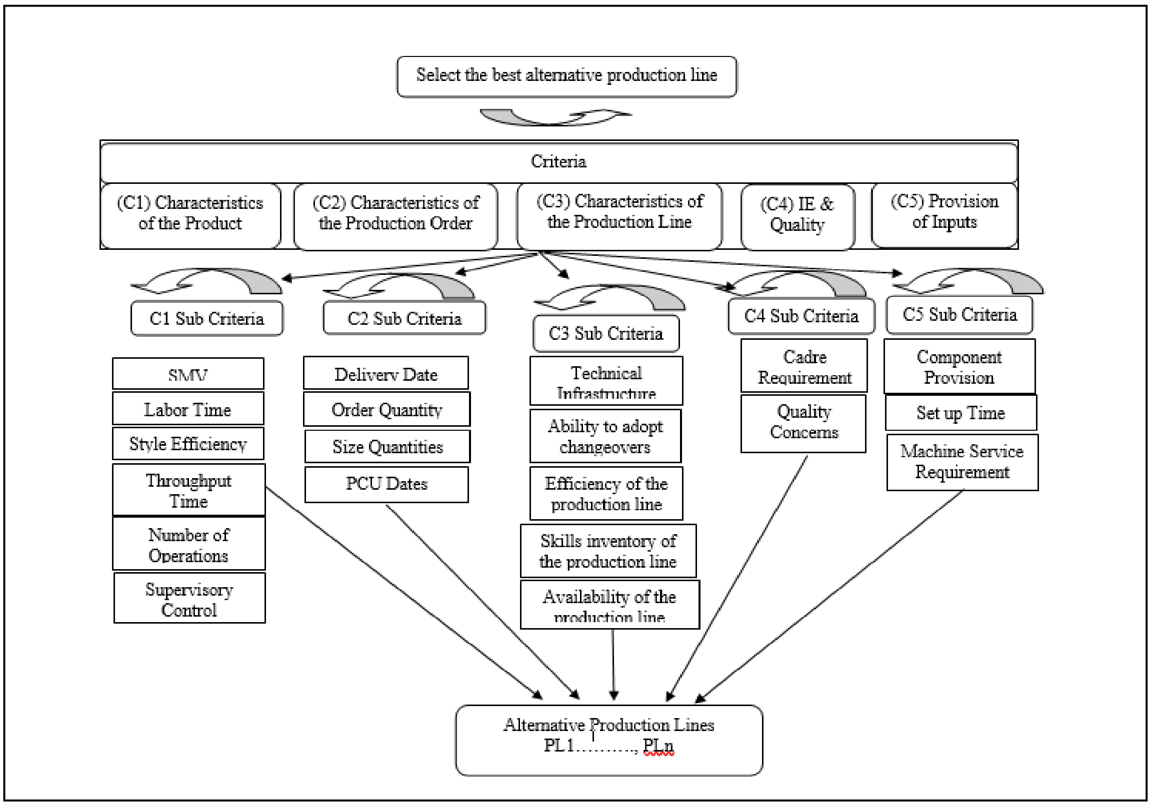

Fig 2: ANP framework

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.

V. Data Analysis and Discussion

After the case study was conducted, the ANP framework was developed using SuperDecisions Software. SuperDecisions is a free educational software that implements AHP and ANP methods and was developed by Thomas Saaty's team who created the method.

Compared to other software tools SuperDecisons is known as a simple, easy to use software package for constructing decision models with dependence and feedback. Moreover, it is an opensource software which was designed to run in many different environments from Windows to Macintosh to Unix systems as Linux.

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

The ANP framework calculates the priorities for each production line and the following result (Table II) was received for the case study.

Table II: ANP Ranking

Alternative	Normalized Priority Score	ANP Rank
Production Line 1	0.03587	6
Production Line 2	0.04856	5
Production Line 3	0.22997	2
Production Line 4	0.43481	1
Production Line 5	0.15413	3
Production Line 6	0.09666	4

■

Weights received from the ANP model were taken as the coefficients for the Mixed integer Linear Programming (MILP) model and it was simulated using MS Excel. Then the model was solved using solver. Result has been recorded in Table III.

Table III: Results of the MILP Model

Alternative	Quantity Assigned	Set up time (Mins)	Set up cost (Rs.)
PL 1	0	0	0
PL 2	0	0	0
PL 3	21877.5	540	120
PL 4	53122.5	720	200
PL 5	0	0	0
PL 6	0	0	0

VI. Conclusion

Ranks received can be used to prioritize the production lines for a particular production order. When implemented once, the same framework can be used for similar production orders. Most of the times, the case study organization receives orders from same client with same style and quantity specifications for repeating months. When such occasions arise, only the alternative comparison has to be performed because pairwise comparison of criteria and sub criteria are same. Then the ANP weights can be applied to the LP model and optimize the alternative production lines.

When totally new styles are received, the whole process should be carried out again along with the pairwise comparisons. However, all the criteria will be covered and visibility to every detail will be made sure, therefore the probability of re-planning is very low.

Addition of Mixed Integer Linear Programming model will help the planner to decide on the quantity that should be manufactured in each alternative production line. This way, the production line which consists of materials, machines and equipment, manpower can be optimized.

VII. Future Work

The framework was primarily developed for apparel sector industrial setting, but with the extensive study done under production planning in general, this framework covers most of the considerations of other industries as well. Therefore, with slight modifications, this methodology can be applied for any industry in production line selection function.

In order to have a more reliable result, it is suggested that in the future Fuzzy ANP be applied to guide decision making toward a more constructive and consolidated line allocation.

With the usage of Linear Programming, continuous planning model can be developed with product routing and line balancing implications. Furthermore, an algorithm can be developed to solve the ILP model using CPLEX which is much more efficient and accurate.

The model was implemented in only one organization as a case study. Therefore, more scenarios can be used under different contexts and the framework can be further validated.

References

[1] Figueira, G., Oliveira Santos, M., & Almada-Lobo, B. (2013). A hybrid VNS approach for the short-term production planning and scheduling: A case study in the pulp and paper industry. Computers and Operations Research, 40(7), 1804–1818. https://doi.org/10.1016/j.cor.2013.01.015

[2] Shin, H. & Leon, V. Jorge. (2004). Scheduling with product family set-up times: An application in TFT LCD manufacturing. int. j. prod. res. 15. 4235-4248. 10.1080/00207540410001708461.

[3] Mok, P. Y., Cheung, T. Y., Wong, W. K., Leung, S. Y. S., & Fan, J. T. (2013). Intelligent production planning for complex garment manufacturing. Journal of Intelligent Manufacturing, 24(1), 133–145. https://doi.org/10.1007/s10845-011-0548-y

[4] Song, B. & Wong, W. & Fan, J. & Chan, S.. (2006). A recursive operator allocation approach for assembly line-balancing optimization problem with the consideration of operator efficiency. Computers & Industrial Engineering. 51. 585-608. 10.1016/j.cie.2006.05.002.

[5] Figueira, G., Amorim, P., Guimarães, L., Amorim-Lopes, M., Neves-Moreira, F., & Almada-Lobo, B. (2015). A decision support system for the operational production planning and scheduling of an integrated pulp and paper mill. Computers and Chemical Engineering, 77, 85–104.

[6] https://doi.org/10.1016/j.compchemeng.2015.03.017

[7] Ben Hmida, J., Lee, J., Wang, X., & Boukadi, F. (2014). Production scheduling for continuous manufacturing systems with quality constraints. Production and Manufacturing Research, 2(1), 95–111. https://doi.org/10.1080/21693277.2014.892846

[8] Poh, K. L., & Liang, Y. (2017). Multiple-Criteria Decision Support for a Sustainable Supply Chain: Applications to the Fashion Industry. Informatics, 4(4), 36.

[9] https://doi.org/10.3390/informatics4040036

[10] Ggolcuka & Baykasoglu (2016). An Analysis of DEMATEL Approaches for Criteria Interaction Handling with ANP

[11] Expert Systems Application

[12] Hofmann, E., & Knébel, S. (2013). Alignment of manufacturing strategies to customer requirements using analytical hierarchy process. Production and Manufacturing Research, 1(1), 19–43.

[13] https://doi.org/10.1080/21693277.2013.846835

[14] Vatansever, K., and Kazançoğlu, Y., "Integrated usage of fuzzy multi criteria decision making techniques for machine selection problems and an application", International Journal of Business and Social Science, vol. 5, no. 9, pp. 12–24, 2014.

[15] Görener, A., (2012) Comparing AHP and ANP: An Application of Strategic Decisions Making in a Manufacturing Company

[16] International Journal of Business and Social Science

[17] https://www.researchgate.net/publication/267857709

[18] (Saaty and Özdemir, 2005), The Analytic Hierarchy and Analytic & Analytic Network Processes for the Measurement of Intangible Criteria and for Decision Making

[19] International Series in Operations Research & Management Science book series (ISOR, volume 78)

[20] Wei, Jin-Yu & Bi, Ran. (2008). Knowledge management performance evaluation based on ANP. Int Conf Mach Learn Cybernet. 1. 257 - 261. 10.1109/ICMLC.2008.4620414.

[21] Agarwal, Ashish & Tiwari, Manoj. (2006). Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach. European Journal of Operational Research. 173. 211-225. 10.1016/j.ejor.2004.12.005.

[22] Ivanov, Dmitry & Hosseini, Seyedmohsen & Dolgui, Alexandre. (2019). Review of quantitative methods for supply chain resilience analysis. Transportation Research Part E Logistics and Transportation Review. 125. 285-307. 10.1016/j.tre.2019.03.001.

[23] Navid, H. (2017). Evaluating Airline Quality Using Fuzzy DEMATEL and ANP. Strategic Public Management Journal. https://doi.org/10.25069/spmj.351296

[24] Liu, P. C. Y., Lo, H. W., & Liou, J. J. H. (2020). A combination of DEMATEL and BWM-based ANP methods for exploring the green building rating system in Taiwan. Sustainability (Switzerland), 12(8), 3216.

[25] https://doi.org/10.3390/SU12083216

[26] Bilgen, B. (2010). Application of fuzzy mathematical programming approach to the production allocation and distribution supply chain network problem. Expert Systems with Applications, 37(6), 4488–4495.

[27] https://doi.org/10.1016/j.eswa.2009.12.062

[28] Vieira, M., Pinto-Varela, T., & Barbosa-Póvoa, A. P. (2019). A model-based decision support framework for the optimisation of production planning in the biopharmaceutical industry. Computers and Industrial Engineering, 129(January), 354–367.

[29] https://doi.org/10.1016/j.cie.2019.01.045

[30] Woubante, Gera. (2017). The Optimization Problem of Product Mix and Linear Programming Applications: Case Study in the Apparel Industry. Open Science Journal. 2. 10.23954/osj.v2i2.853.

[31] Thalagahage N.T.H., A. Wijayanayake, and D. H. H. Niwunhella, Developing a Multi Criteria Decision Making Framework to Select the Most Suitable Production Line in Apparel Firms :Use of ANP Method *International Conference on Industrial Engineering and Operations Management Singapore, March 9-11*, 2021